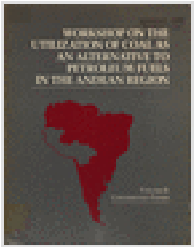

Workshop on the Utilization of Coal as an Alternative to Petroleum Fuels in the Andean Region: Volume II: Contributed Papers (1985)

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CONTENTS

PREFACE

In 1960, the contribution made by coal to meeting the world's primary energy requirements was 49 percent; by 1973 it had dropped to 29 percent. Since the advent of the petroleum crisis in the mid-seventies, with its escalating fuel oil prices, coal production has shown a substantial increase. Worldwide coal reserves are large, and the technology exists to exploit these reserves. Further efforts are needed, however, to encourage coal use. Andean countries, especially Peru, are known to have significant underutilized coal reserves, which could prove socially and economically attractive for energy policy and planning and for long-term self-sufficiency.

At present, many industrial operations and electric-generating facilities in Bolivia, Ecuador, and Peru are dependent on fuel oil from diminishing domestic reserves or from imports. With current prices of coal generally about half those for residual petroleum fuels (based on energy content), the potential exists for exploitation of Andean coal as an alternative to petroleum fuels. Greater use of coal resources would help meet the demand for increased energy needed to improve living standards and for increased industrialization in the area. Moreover, in addition to creating employment in mining, transporting, and marketing of coal, development of a domestic market for coal would release sizeable quantities of petroleum products for export, thereby earning needed foreign exchange.

During 1985, the world market price for petroleum continued to weaken, but this does not justify a long-term policy of artificially subsidized prices for domestic kerosene, gasoline, and petroleum fuels in Bolivia, Ecuador, and Peru. Greater use of coal, therefore, is still an attractive alternative. In an effort to promote awareness of the major technological and economic issues in Andean coal development, the U.S. Agency for International Development (AID)) sponsored a workshop on The Utilization of Coal as an Alternative to Petroleum Fuels in the Andean Region, held in Lima, Peru, June 24-28, 1985. Responsibility for planning, organizing, and conducting the workshop was shared by Empresa Promotora del Carbon, S.A. (PROCARBON), Lima, Peru; the Ministerio de Energia y Minas, Lima, Peru; and the U.S. National Academy of Sciences/National Research Council (NAS/NRC), Washington, D.C. The purpose of the workshop was to bring together a group of experts from the Andean region and the United States to examine the opportunities for a switch from oil to coal in thermal electric generation, industrial process heating, and other applications. Both technical and socioeconomic factors that can promote or impede the substitution were discussed. Such an examination is a necessary prelude to the development of policy measures that would stimulate the production and utilization of coal for economic development in the Andean region.

Ing. Luis Moran, president of PROCARBON, served as general chairman of the workshop. An inter-American panel of experts in coal production technologies, coal utilization, and energy economics presented technical papers and led the discussions on coal mining, transport, use, and marketing. More than fifty participants from Bolivia, Ecuador, and Peru attended, including industrial energy users, coal producers, coal processors, development planners, and energy policymakers, as well as representatives from universities and other technical groups working in solid fuels.

This document contains the technical papers presented at the workshop. The papers are arranged according to the agenda topics on energy policy, social impacts of coal, coal research, coal preparation and transport, coal utilization, and coal marketing. In an effort to bring the papers in a timely manner to an audience of persons concerned with these topics, there has been no systematic attempt to edit the papers or to produce a proceedings of the workshop. The papers are the responsibility of individual authors and do not necessarily reflect the views of the sponsors or workshop organizers. Persons interested in additional copies of the papers should contact individual authors.

Volume I, a summary report of the workshop with conclusions and recommendations, may be obtained either from:

PROCARBON
Juan del Carpio 282
San Isidro, Lima, Peru

or:

Board on Science and Technology for International Development
National Research Council
2101 Constitution Avenue N.W., Room JH 219
Washiington, D.C. 20418

ACKNOWLEDGMENTS

The success of the Andean Coal Workshop reflects the dedicated efforts and generous cooperation of individuals from many countries of the Americas. The financial support of the U.S. Agency for International Development (AID) is gratefully acknowledged. Special recognition is due Alberto Sabadell, Office of Energy, Bureau for Science and Technology, AID/Washington, who originated the idea of an Andean regional workshop and served as technical liaison between Washington and Lima during the entire planning period. He was also instrumental in obtaining assistance from the U.S. AID missions in Bolivia and Ecuador to ensure that energy officials in those countries were aware of the opportunities for participation.

Special acknowledgment is given to Luis F. Moran, Victor Sanchez Aizcorbe, and Carlos Soldi of the PROCARBON organization for their impressive contribution of time and effort in planning and organizing the program and providing so well for the conduct of the activities in Lima. The chairman of the panel, Ulrich Petersen, Professor of Geology, Harvard University, gave many hours of his time, working closely with the organizing staff. His ability to summarize key issues proved invaluable during the preparation, realization, and postworkshop periods. Thanks are also due the members of the panel of experts whose names are listed at the end of this document. They prepared technical papers, devoted many hours to formal and informal sessions during the week of June 24-28, 1985, and, overall, were an important resource for advice and suggestions on all workshop matters.

Appreciation is expressed to PETROPERU, the national petroleum company, for the use of its excellent conference facilities in the San Isidro section of Lima. Thanks are also due the Peruvian Ministry of Energy and Mines for its support and encouragement.

The National Research Council staff officer for the workshop, Jay Davenport, extends appreciation to his colleagues Jack Fritz, Maryalice Risdon, and F. R. Ruskin for their assistance.

Finally, recognition and thanks are given to the administrative secretaries, Eileen V. Payne, of the National Research Council in Washington, and Cecilia Vassallo Pastor and Yolanda Rojas, PROCARBON in Lima, whose efforts were so essential to bringing plans into reality.

COAL AND OIL POLICY IMPLICATIONS

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June 12, 1985

COAL AND OIL POLICY IMPLICATIONS

by

Nathaniel Arbiter
(Paper presented by Eugene Thiers, SRI International)

In the two centuries since the beginning of the Industrial Revolution a vast multiplication of the energy available to man has occurred. Before the XVIII century, the sources of energy were few: man's own muscles and those of the animals he domesticated; the energy in the wind for sailing vessels, initially, and after in the middle ages for windmills; and finally, the potential energy in rivers descending to the seas for conversion to mechanical energy, used from Roman times.

Wood, the dominant fuel up to the XIX century, was used in prehistoric times for domestic purposes and as early as several millenia before Christ; then in furnaces to smelt copper and iron and to produce glass and ceramics, well before the Christian Era.

By the XVIII century, the growing industrial use of wood produced the first energy crisis; in England and Western Europe there was a threat of a fuel shortage. This, in turn, even before the steam engine led to the increased use of coal for thermal energy, and to the preparation of coke and its use for iron smelting. With the growth in use of the steam engine for stationary sources of power in the XVIII century, and for the steamboat and the railroad in the XIX, and with the growth of chemical industries, coal use grew exponentially.

In Great Britain, in the 100 years from 1700 to 1800, coal consumption increased from 3 million to 6 million tons per year; but by 1850 there was a ten-fold further increase to 60 million tons per year. Industrial growth was initially slower in the U. S., coal consumption reaching 17 million tons annually by 1871; but it increased 30-fold to 550 million tons by 1970

After 1870 during the second century of the Industrial Revolution which might more appropriately be called the Energy Revolution, another critical change in energy availability occurred--the discovery of large resources of petroleum and natural gas and their rapid exploitation. Stimulated by these new energy sources and later, stimulating their ever-widening use, came the development of two major consumers of combustibles: internal combustion engines fired by petroleum fractions and used eventually for land, air, sea and undersea vehicles; and electricity generation. Although developments in understanding and use of electricity began only in the early XIX century, the first electric power station was already in use in London by 1882, with world-wide application spreading rapidly. In less than a century (1970) world consumption of electric energy had reached 8×10^{12} KWH annually, or 1800 KWH per capita.

We are now in the third century of the Energy Revolution and other major changes are foreseeable. Although precise forecasting here is neither necessary nor possible, it seems clear that both petroleum and natural gas production must eventually decrease. U. S. production peaked in 1973 and has been relatively flat since then, with imports increasing. World production may have peaked temporarily in 1979, but it is possible that the decreased production has been due to the economic slowdown. Regardless of these short term effects, there is agreement, although it is not complete, that petroleum and natural gas reserves are finite; and that in the long term they cannot continue to provide a major proportion of the world's energy supply. This has been the subject of concern for the past several decades, with a search for alternative energy sources widespread.

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World-wide in 1983, solid fuels were 1/3 of the energy supply, and the liquid/gaseous fuels, 2/3, with petroleum consumption twice that of natural gas in comparable units. World-wide petroleum use exceeded that of coal in the 1960's, particularly as the U. S. S. R. and China shifted rapidly away from coal toward newly developed oil reserves. The reasons for the shift are clear:

1] much simpler recovery, processing and handling
2] simpler combustion and lack of ash disposal.

In addition the liquid/gaseous fuels had relatively minor environmental problems compared with the SO_2 problems with coals. The resulting lower costs both for operating and capital with petroleum and natural gas, together with the rapid development of major oil and gas fields were the impetus for the shift away from coal. However, the introduction of political factors with with the Arab embargo in 1973 and the subsequent order of magnitude price increase for petroleum as well as the increasing political instability in the Middle East completely changed the outlook.

World use of all hydrocarbons has been stagnant since 1979. Whether pre-1979 growth trends resume or not, it appears probable that coal must eventually return to its earlier dominant position among the three hydro carbon combustibles. This follows because its reserves and resources are far greater currently than those of the liquid/gas hydrocarbons, with the obvious corollary that at current use rates, coal's life expectancy is far greater. While this is reassuring to a degree, it also provokes an important question: to what extent can the disadvantages which led to coal's displacement by petroleum and natural gas in the first place be overcome?

This is best answered by consideration of the functions for which major energy sources are used (Fig. 1). Although the

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the information in the table refers to the U. S., a highly-developed countty,: the following qualitative general conclusions can be drawn from the distributions shown:

1] Coal as such has no application to transportation (car, truck, railroad, boat, airplane) for which only liquid fuels are now suitable and for which 24% of the total energy was required.

2] For industrial usage, coal competes: favorably with both oil and gas, and would require mainly modification of combustion devices for existing plants or suitable similar devices for new plants.

3] For electricity generation coal is already dominant and could replace oil/gas without difficulty.

4] For the U. S., household and commercial usage--essentially heating, representing 21% of total energy consumption, is dominated by gas and oil with coal supplying a negligible proportion. For coal in lump or briquet form to substitute in the area would require an available and attractively priced upply of modern stoves and furnaces quipped to handle the solid fuel.

From the foregoing, it is evident that coal in a developed country can already provide energy for 55% of the applications; that it is excluded as such from the transportation field; and that with simple supporting technology it might easily penetrate the household and commercial market, representing 21% of the applications.

<u>Developing Technology for Direct Coal Use</u>

In this area, the goals are to increase the efficiency of coal combustion, to extend the range of coal types than can be used, and to decrease environmental impacts.

<u>Fluidized Bed Combustion</u>

Atmospheric pressure units for industrial scale boilers are already available under performance guarantees. It is also expected that these will be in use shortly for centralized power generation. The units are smaller than conventional boilers and can be used with lower quality coals, with easy elimination of SO_2 and reduced formation of nitrogen oxides.

Coal-oil mexture technology using pulverized coal dispersed in fuel oil is being developed to substitute in larger measure for oil in existing power plants. However, this is of little use where oil is in short supply or available only at long distances from the coal supply.

Conversion of Coal to Liquid and Gaseous Fuels

With the foregoing analysis in view, the major interest in a country with coal resources in the face of diminishing world supplies of petroleum, and with the almost complete inability of a solid fuel to penetrate the transportation field, would be in the potential for providing liquid fuels from coal. This has been under investigation for a half century with liquefaction plants technically successful during World War II in Germany and other countries.

A similar plant (SASOC) has been operated in South Africa since 1955. The processes require thermal decomposition of coal to produce a hydrocarbon gas and hydrogen, with further reaction to produce liquid hydrocarbons. The SASOC plant has been planned to expand production and eventually make South Africa self-sufficient in gasoline and diesel oil. It is an important model for other countries lacking in petroleum but with coal resources.

Summary and Policy Consideration

1] The dominant consideration for fuel policy, particularly for developing economies, is the possibility that coal could become the dominant form of fuel in the long range, if not the short. This is related to the much greater reserves of coal world-wide.

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2] For countries with no fuel reserves, three of the four major categories of use can be adapted to coal burning, but imports of liquid fuels for transportation must continue until coal to liquid fuel conversion becomes locally competitive.

3] For countries with petroleum/gas reserves only, adaptation of the three fuel consumption categories to imported coal burning in order to conserve petroleum for export should be considered. Relative economics of oil export versus coal import must of course be analyzed.

4] For countries with coal reserves only, adaptation of the three fuel consumption categories to domestic coal should also be considered to reduce petroleum imports to the minimum essential to transportation. At the same time these countries should keep abreast of developing coal to liquid fuel conversion technology for adaptation if and when it becomes overall competitive.

5] Changing use patterns for energy sources has been a feature of the energy revolution. Further changes are inevitable and will require mainly innovative technology and forward-looking leadership.

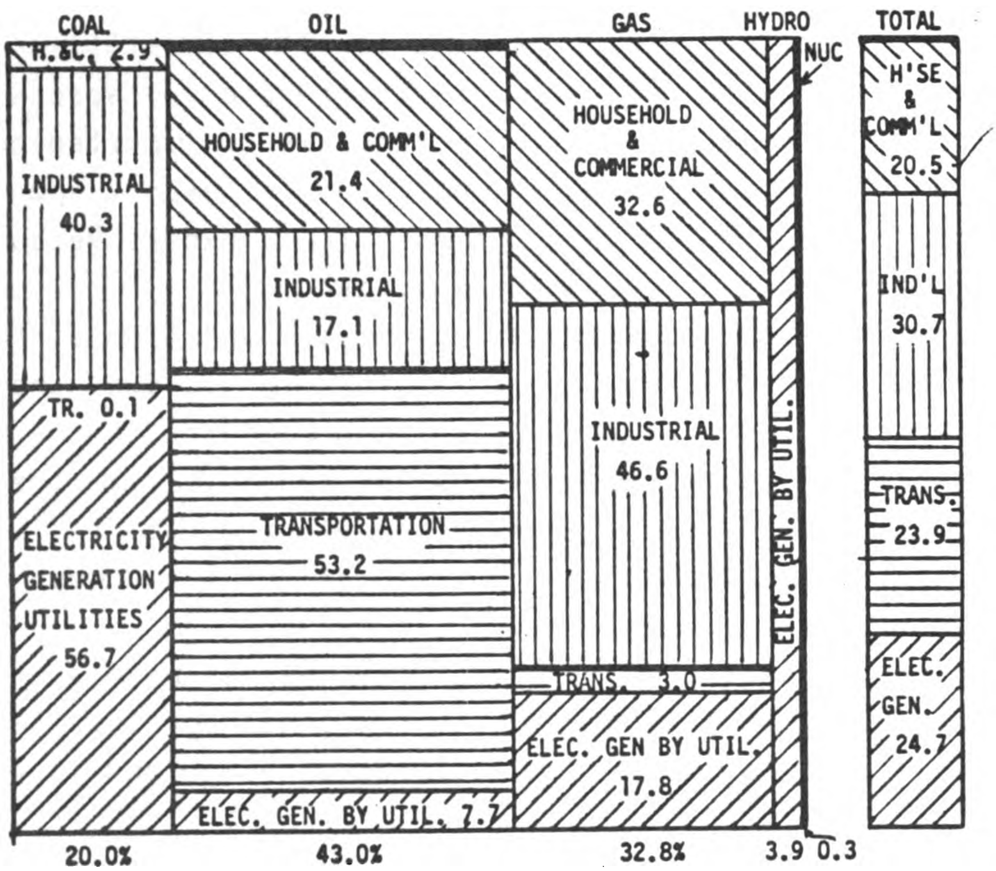

Figure 1-3. Distribution of U.S. Energy Consumption, 1970 (Preliminary Estimates by U.S. Department of the Interior)

DESARROLLO CARBONERO EN COLOMBIA

Carlos de Greiff Moreno
Bogota, Colombia

COLOMBIA

DESARROLLO CARBONERO

CARLOS DE GREIFF MORENO

Resumen

Las fuentes tradicionales de energía primaria comercial en Colombia han sido el petróleo, el gas natural, la hidroelectricidad y el carbón. La inestabilidad de las políticas de exploración y producción de hidrocarburos afectó en años pasados el volúmen de los suministros y tuvo como efecto el que Colombia perdiera su autosuficiencia en materia de energía y tuviera que importar petróleo y derivados a partir de 1974.

Sin embargo, el análisis previsivo y oportuno de los pronóstcos de demanda y suministro de energía primaria permitió evaluar la magnitud de los faltantes y estimuló el replanteamiento de los objetivos y políticas del sector. La reforma de 1974 a la legislación de hidrocarburos abrió el camino a los contratos de asociación y aportó una valiosa herramienta para aprovechar disposiciones de la Ley 20 de 1969, encaminadas a agilizar la extracción de los recursos mineros.

Estos instrumentos legales se tradujeron en la práctica en los términos del contrato de asociación acordado entre la entidad estatal Carbocol e Intercor, filial de Exxon Corporation, para el desarrollo de los depósitos de carbón de El Cerrejón-Zona Norte.

Este complejo ya ha realizado exportaciones anticipadas a las que habrán de determinar la iniciación de la etapa de producción a finales de 1985.

Las divisas provenientes de las exportaciones de carbón (de El Cerrejón y otros proyectos en vías de ejecución), sumadas a las previstas de crudo y derivados del petróleo, permitirán que Colombia recupere su calidad de país autosuficiente en materia de energía, asegurarán el autofinanciamiento de su sector de la energía (incluído el sector de la electricidad) y, eventualmente, podrían generar algunos saldos para contribuir al financiamiento global de su economía.

Antecedentes

Hasta ahora, las fuentes tradicionales de energía primaria comercial en Colombia han sido el petróleo (42%), el gas natural (17%), la hidroelectricidad (25%) y el carbón (15%). Los porcentajes entre paréntesis denotan las respectivas participaciones en 1984.

El Decreto 2140 de 1955 estimuló la exploración y producción de petróleo con resultados muy satisfactorios que redundaron en el descubrimiento de nuevas reservas y en el crecimiento de la producción, la cual alcanzó un nivel máximo de 219 kBD en 1970. Sinembargo, la Ley 10 de 1961 estableció medidas restrictivas a la acción de las compañías petroleras, lo cual se tradujo en declinación sostenida de la actividad de la industria hasta la reforma de 1974, la cual estableció reglas de juego e incentivos más acordes con la realidad.

No cabe la menor duda de que la desestimulante legislación de 1961 fue el motivo principal por el cual Colombia perdió su autosuficiencia en materia de energía y debió afrontar onerosas erogaciones para importar crudo y productos, a partir de 1974, a niveles de precios jamás imaginados cuando se sancionó la Ley 10 de 1961.

Pero ya, desde finales de 1970, los balances de energía elaborados por entidades del sector privado habían previsto los faltantes que habrían de registarse en la producción local de petróleo y las restricciones que en materia de suministros habrían de configurar lo que, a partir de 1971, comenzaba a vislumbrarse a nivel mundial como la "crisis de la energía".

Fué así como los pronósticos del balance de 1970, elaborados con base en horizontes a corto (uno a dos años), mediano (5 años) y largo (25 años) plazos, sugirieron un agotamiento paulatino y eventual del petróleo y el imperativo de buscar nuevas fuentes y/o de desarrollar a fondo las ya disponibles. Para Colombia, las posibilidades más atractivas indicaban la conveniencia y oportunidad de aprovechar las reservas carboneras de los depósitos de El Cerrejón, en la península de la Guajira.

Tal iniciativa afloró en los planteamientos que al respecto se hicieron ante la Comisión Nacional de Recursos de Energía (CNRE), la cual había sido creada por el Gobierno Nacional para examinar la situación, emitir un diagnóstico y recomendar lo pertinente.

La emergencia se hizo pública en el Seminario de Energía de Medellín, (Febrero de 1972), auspiciado por el Ministerio de Minas y Energía, la CNRE y las entidades privadas vinculadas al sector.

Las opciones del carbón permitirían obviar los faltantes previstos, diversificar la estructura del suministro, optimizar la eficiencia del uso y aplicaciones de la energía a todo nivel, y abrir estimulantes perspectivas para la recuperación de la balanza cambiaria del sector, para la generación de empleo y para el desarrollo de la economía del país.

Tales expectativas fueron prolijamente examinadas y comprobadas factibles en ocasión del I Seminario Internacional para la Utilización Integral del Carbón, promovido al efecto y celebrado en Bogotá en Marzo de 1974.

La Nueva Legislación

A partir de los balances de energía que año tras año actualizaban los diagnósticos, así como del exámen sostenido de los factores constitutivos del problema y de sus posibles soluciones, adelantado en múltiples foros, seminarios y simposios, y, en particular, como consecuencia de los resultados y recomendaciones del simposio internacional sobre el carbón y del minucioso análisis emprendido por la CNRE, el Gobierno Nacional introdujo la reforma de 1974, la cual se protocolizó y sancionó en los términos del Decreto 2310 de ese mismo año.

El Decreto 2310 consignó nuevas condiciones e incentivos en materia de hidrocarburos, finiquitó el regimen de concesiones e introdujo la modalidad de los contratos de asociación. Tal providencia, aunada a las disposiciones que en el campo de la minería había consagrado la Ley 20, de 1969, abrió el camino para el desarrollo racional, efectivo y oportuno de las reservas carboneras del país. El mecanismo de los contratos de asociación, en combinación con el de las áreas de aporte que introdujo la Ley 20 por razón del cual se facultaba a las empresas industriales y comerciales del Estado para acometer la explotación de recursos mineros por su cuenta o en asocio de compañías privadas, consolidaron la factibilidad de varios proyectos mineros, entre los cuales se destaca el de El Cerrejón-Zona Norte, y aportaron las bases para la definición de políticas actuantes y dinámicas para el sector.

La Gestión Institucional

La provisión legal de las áreas de aporte permitió conciliar la urgencia de acometer el estudio y evaluación de proyectos específicos de desarrollo carbonero con la carencia coyuntural de recursos institucionales específicos que facilitaran las gestiones pertinentes por parte del estado.

En tal virtud, la Empresa Colombiana de Petróleos (Ecopetrol), recibió en calidad de aporte el área de El Cerrejón, exceptuado el sector central, el cual venía siendo explorado por el Instituto de Fomento Industrial, en asocio de una entidad extranjera, desde hacía ya algún tiempo, pero con limitaciones de diversa índole.

Ecopetrol acometió de inmediato las gestiones conducentes a definir las modalidades de su encargo en El Cerrejón. Entretanto, el Gobierno Nacional estudiaba la creación de una entidad que se ocupara de acometer y dirigir el desarrollo de los recursos carboníferos del país . Ecopetrol abrió, a principios de 1976, una licitación para la exploración y desarrollo de los depósitos de carbón de los sectores norte y sur del área de El Cerrejón. El sector central se excluyó de la licitación por constituir área aportada al IFI. Simultáneamente, el Gobierno Nacional autorizó la creación de Carbones de Colombia S.A. (Carbocol), como empresa industrial y comercial del Estado, la cual se contituyó por escritura pública en Noviembre de 1976. Ecopetrol y otras entidades del estado, relacionadas con la gestión minera, participan en calidad de accionistas. Una vez constituida, Carbocol emprendió sus labores y el área de aporte de El Cerrejón le fué oficialmente transferida.

En la licitación abierta por Ecopetrol participaron 17 compañías, de las cuales sólo tres cumplían con todas y cada una de las condiciones establecidas en la misma. El contrato le fué adjudicado a International Colombia Resources Corporation (Intercor), compañía filial de Exxon Corporation, constituída en 1976 y encargada de ejecutar los términos del eventutal acuerdo.

El contrato establece una asociación de la cual participan por partes iguales Carbocol e Intercor. La máxima autoridad la ejerce un Comité Ejecutivo, con representación paritaria, el cual decide por consenso y ante el cual reponde Intercor, en su calidad de Operador del proyecto. Este se desarrollará en tres etapas:

- La etapa exploratoria cuya duración se fijó en 3 años, prorrogables a 4 años, durante la cual Intercor realizó la exploración, toda ella por su cuenta y riesgo. Esta etapa concluyó con la declaración de comercialidad del proyecto.

- La segunda etapa, a punto de concluir, es la de la construcción y el montaje. Se fijó en 4 años, prorrogables de año en año, hasta por dos años. Esta etapa culminará cuando se realice el primer embarque de carbón con destino a la exportación, fecha en la cual deberán estar construídas todas las instalaciones y disponibles los estudios y programas requeridos para la producción.

- La tercera etapa es la de producción comercial. Tiene una duración de 23 años, contados a partir de la fecha del primer embarque de exportación y al término de los cuales la propiedad total de los bienes e instalaciones del proyecto deviene gratuitamente en propíedad de Carbocol.

El contrato establece que el carbón producido por la asociación será de propiedad, por partes iguales, de Carbocol e Intercor. Pero ésta última pagará a Carbocol una regalía de 15%. En adición a esta regalía, Intercor pagará a Carbocol una regalía adicional, llamada "ingreso de participación", la cual se liquidará con base en una fórmula que establece aumentos progresivos de participación para Carbocol, en la medida en guq las utilidades de Intercor sobrepasen un nivel previamente acordado.

Se ha estimado que, durante los 23 anos de la etapa de producción, la participación total de Carbocol y el estado será de aproximadamente 83% del total de los ingresos generados por el proyecto, incluídos los provenientes de la venta del carbón propiedad de Carbocol, la regalía, el "ingreso de participación" y los impuestos. El 17% restante le corresponderá a Intercor. La inversion total ascenderá a US $3000 millones, apartados por partes iguales entre Carbocol e lutercer. La construcción del complejo se ha adelantado y se terminara dentro de los presupuestos y plazos pervistos.

El contrato consagra a Intercor como Operador del proyecto. Tal estipulación obedece más a la complejidad gerencial y ejecutiva del complejo que a las exigencias meramente técnicas de la minería del carbón. La transferencia techológica requiere elaboradas estructuras institucionales, capaces de transferirla y recibirla. No cabe duda de que Carbocol habrá de lograr el nivel y la estructura institucionales adecuados para acometer la operación de complejos mineros, a partir de las experiencias derivadas del proyecto de El Cerrejón-Zona Norte y de las que administre y opere directamente.

No sobra resaltar que los términos y las ejecutorias del contracto vigente configuran y determinan un aporte significativo y fundamental para la definición a aplicación de políticas adecuadas, oportunas y retributivas para el aprovechamiento de los recursos mineros y de energía de Colombia.

También cabe hacer énfasis en la valiosísima e indispensable contribución del debate institucional y público que tuvo lugar en todo momento desde que, a partir del balance de energía de 1970, se evaluaron los requerimientos de la demanda de energía en Colombia, hasta finales del presente siglo. Este análisis tuvo lugar a todos los niveles de la opinión púlica del país, a través de foros, seminarios, conferencias y debates adelantados en muy diversos escenarios y abiertos a todos los estamentos sociales, económicos, laborales, académicos y gubernamentales. El debate y su aporte continúan. Han sido y seguirán siendo determinantes de las decisiones y del éxito de la gestión que en este frente se adelanta.

Aspectos Cambiarios

Tal como ya se ha enunciado, a partir de 1974, Colombia comenzó a importar crudo y derivados del petróleo en volúmenes crecientes. El valor de estas importacones afectó notablemente la balanza cambiaria del país. El manejo acertado de los mercados externos y las exportacions de sobrantes de combustóleo permitieron atemperar parcialmente el efecto neto de estos intercambios. Pero aún así, estos arrojaron un saldo neto negativo, el cual llegó a fluctuar durante algunos años entre US$400 y US$600 millones. Sin embargo, las reformas de 1974 y el reajuste de los precios internos del crudo para refinación local, han reducido este impacto en los últimos años, en la medida en que ha aumentado la producción y ha disminuído la demanda, esto último como consecuencia del receso económico.

Cabría anotar, sinembargo, que auncuando Colombia importará crudo (29 kBD) y productos (13kBD) durante 1985, estos volúmenes se compensarán por los proventos de las exportaciónes de combustóleo. Ya a partir de 1986 no será necesario importar más crudo y las importaciones de derivados disminuirán acentuadamente. En cambio, en la medida en que se incorpore a la producción las reservas recientemente descubiertas en los Llanos Orientales, aumentarán paulatinamente las exportaciones de crudo y de sobrantes de productos lo cual redundará en beneficio de la balanza cambiaria del sector.

Por su parte, el desarrollo de la producción en el complejo de El Cerrejón, la cual deberá llegar a 15 M ton por año en 1988, y el de la de otros proyectos ya en operación o previstos para iniciar producción en los próximos años, generarán crecientes recursos adicionales de divisas, las cuales permitirán no sólo satisfacer las necesidades propias del sector de la energía, sino que también aportarán saldos significativos para suplir parte de los requerimientos globales del país.

Así, en 1990 las exportaciones de crudo y productos ascenderían a 212 KBD y las de carbón al equivalente de 228 kBD, lo cual arrojaría un total de 445 kBD. En el año 2.000 este total podría llegar al equivalente de 479 kBD. Sin embargo, no debería descontarse la posibilidad de descubrimientos adicionales de petróleo, los cuales podrían mejorar estas cifras proyecciones.

COAL DEVELOPMENT:
SOCIO-ECONOMIC IMPACTS, LESSONS FROM APPALACHIA

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The purpose of this presentation is to share with you some experiences we have had during our efforts to improve the life of the people of Appalachia. I hope that these experiences will be of interest to you and will guide you in seeking the most suitable policies for your own special needs.

Appalachia is a mountainous, hilly region. Elevations do not exceed 1,500 meters. The region includes 13 states, which run from a southwestern to a northeastern direction along the eastern third of the nation, a population base of 26 million, and no large metropolitan city areas. Unfortunately it is one of the nation's poorest regions. In central Appalachia approximately one half of the residents live below nationally established poverty levels. The native Americans were the Cherokee Indians. In recent years they have experienced a rebirth of self-awareness and have made efforts at tribal unity and independence. But there remain very few as residents.

Appalachia is blessed with unique beauty and vast natural resources. The economically most influential resource has been coal. Vast coal reserves lie relatively close to the surface. Those with an overburden of less than 30 meters are typically surface mined, the rest deep mined. But none of the coal is mined as deeply as for example German coal, where shafts reach down 1,300 meters. Going down 500 meters is considered deep for Appalachia. Most coal seams have names - one of the best is aptly named the 'Pokahantes Seam' -

after the beautiful Indian princess who saved Captain John Smith's life. The Indian legacy remains preserved even in coal.

Many other parts of the country have only lately discovered the richness of the traditional Appalachian mountain culture. One of the most famous department stores in Washington and New York now offers for sale Appalachian handicraft items - quilts, pottery, carvings, musical instruments. And songs and films of life in the coal fields, and the struggle to change conditions while preserving the culture, have mushroomed in recent years.

The Appalachian heritage has been remarkably resilient in its refusal to become simply a passive receptor of foreign mainstream culture. But the impact of big business and commercialization has begun to change the region's way of life. One hopes that the old heritage, which took form in the years before mechanized society penetrated the region, will endure along with the new.

In 1984, fifty percent of the nation's coal was mined in Appalachia - mainly in Eastern Kentucky, West Virginia, and Pennsylvania. Other states that produce coal are Virginia, Tennessee, Alabama, and Ohio.

Appalachian coal is the nation's best - high in Btu content, low in sulfur and ash. In 1984, 437 million short tons (396 million metric tons) were mined in the region, of which more that one half were produced underground, the rest on the surface. Despite its generous endowment with coal, or perhaps because of it, Appalachia today remains a poor underdeveloped region. Historically it has always been poor, and the post energy crisis decade unfortunately changed little.

Regional Economic Development in Appalachia

The economic development of any region is a complex process that involves more than economic variables alone. It includes a number of separate but interrelated activites, trends, policies, and decisions. In Appalachia we have encountered the full force of the complexity of the process for decades. And even though the U.S. Congress established about 20 years ago the Appalachian Regional Commission, the results of our development efforts have been generally disappointing. The principal source of Appalachia's slow progress is the region's dependence on a single industry - coal. This is an industry, and a region, that is strongly affected by external influences. For the most part, it responds directly to the surges and ebbs of the business cycle, both in the demand for electric power and for steel. It must not be forgotten that the demand for coal is a derived demand, derived from the demand for the products it helps produce. The demand for coal as an end-use commodity is small, confined to the portion of the market where coal is burned directly by consumers for home heating. By far the largest source of demand originates with the electric power producing companies - the electric utilities. In 1984, 62 percent of Appalachia's coal output was shipped to this user category. But this category is also quite unstable and flows with the vagaries of the business cycle. For example, fluctuations in economic activity directly affect coal output and employment. This in turn impacts on the region's ability to develop, expand, and maintain the social overhead capital that is one of the prerequisites for development. And the inability of the region to attract new industries capable of providing alternative employment opportunites has further exacerbated the already sensitive situation.

To counteract the lack of diversification in the Appalachian industrial base, the U.S. Congress created the Comprehensive Employment and Training Act of 1973 (CETA). Its objective was to assist Appalachia in developing state and local manpower training programs tailored for local needs. Several years later, a Private Sector Initiative Program was established to enhance the role of private industry in the local employment and training programs. But progress has been painfully slow. The CETA program has now fallen victim to general budget cuts and has been phased out.

The Process of Economic Development

In recent years, a number of scholars have reviewed the factors that typically contributed to regional economic growth.[1] They distinguish among three distinct transitional development stages:

(1) The primary - resource stage

(2) The secondary - manufacturing/industrial stage

(3) The tertiary - service industry stage

Under this simplified spectrum, the Appalachian region, and most probably the Peruvian coal region as well, are in the primary resource extraction stage. Mining, forestry, or agriculture are the principal employment generating, income producing industries. The second stage, where manufacturing industries can generate significant value-added has not been attained as yet. Consequently, Appalachia is a net exporter of raw materials which enter the processing flow elsewhere. As a net exporter the region is highly sensitive to the transmittal of economic fluctuations from elsewhere. Depending upon their nature, these transmissions create boom or bust periods which have highly unsettling impacts on the indigenous economies and population. In the past ten years alone, Appalachia has undergone two such periods - in 1974-75 and once again in 1980-81. Such a primary stage economy usually is also characterized by outmigration of the region's most talented and potentially most productive labor force. This deprives the economy of a valuable component of its human resources.[2] Finally, absentee ownership of the resources, poor educational facilities and incestuous political and social structures often leave such regions at a competitive disadvantage to attract the manufacturing industries of the modern world. Appalachia is a good example of such a situation. The population decline it has suffered during the post World War II period is clear evidence of that.

There exists another hypothesis which explains regional growth. It holds that as sales of commodities to users outside generate income, new service sectors such as retail trade, financial and recreational services can be developed at home. Unfortunately, because of the undiversified nature of the Appalachian economy, the new income derived from exporting coal is spent mostly on imports. Hence the secondary impact effect which might have been realized through local diversification is lost. And the tax base which might have been tapped to make infrastructure investments in public services and facilites remains small.

In Appalachia, the quantity and quality of raw materials is determined by physical factors. Government action has little influence here. In other regions, where the development process has matured beyond the primary stage, physical factors play a less important role and government actions and policies can influence significantly the nature of production and diversification.

In contrast to the physical resource base, the human resource base of the region is much more receptive to influence from state and federal policies, particularly in education. Although a formidable task, investment in human capital through education can have a high return in the long run. Properly structured, such investment can strengthen materially the competitive position of the region to attract new industries. But it must be an investment in much more than vocational and skills training only. It must be an investment designed to create an environment for learning and understanding. It is less the skill levels and more the comprehension levels that the industries of the future will be working with. Many existing skills may find the demand for their services waning as more sophisticated production techniques replace them. Consequently it is the adaptable educated worker whom industry will be seeking out first in the future.

The Development Linkages

The link between education and economic development is indivisible. It flows mostly through economic diversification. For economic diversification to be successful in Appalachia, where so far it has not, sizable public investments in human capital are necessary to attract new industries to the region. It has been true historically that the single most important factor that accounts for the impressive rise in the real earnings of workers in western societies is investment in education.[3] But in Appalachia, such investment has been missing, as has a sturdy infrastructure on which to build a robust economy.

The construction of public works such as roads, sanitation facilities, health care and educational centers can raise the expected rate of return from private investments significantly. It would also make the investment of locally generated profits and savings more attractive and stimulate economic diversification from within. But there remain obstacles to economic diversification and development in Appalachia. One is the scarcity of level land for factories, related service industries, and residential areas. Another is the long distance to major urban centers.

To overcome these and other obstacles, to attract new industries, and to begin the development process, it will be necessary to form joint public-private investment partnerships. These partnerships must be sufficiently large to initiate a self-perpetuating process, because private industry alone is unable and probably unwilling to make the necessary investments on its own. This is not surprising because as with all investments of this type, it is a long-run endeavor. Private time horizons in contrast are short. Few social investments yield early returns. But this fact in no way diminishes the potential contribution to a better life which such investments are capable of creating.

Economic development strategy contains numerous linkages. Two of them--the forward and backward linkages--are the most important. The backward linkage refers to the question of whether expanded coal production in Appalachia can lead to a similar expansion of regional industries supplying inputs to the coal industry. The answer is that it cannot because little if any equipment used to mine or transport coal is manufactured in Appalachia. Being an extractive industry, coal mining does not use raw materials or semi-manufactured goods. The capital equipment needed to mine coal and to rehabilitate the land is manufactured elsewhere, and the expanded production of such equipment does not benefit Appalachia directly.

In contrast, the prospects for forward linkages for economic growth are much better. Under favorable conditions, Appalachia could begin to attract energy intensive industries that have high energy/output ratios and use coal as an input. If, in addition, such industries use indigenous raw materials, then the prospects are even better. In time, obstacles such as a sparse infrastructure and low labor skill levels could be overcome. Attracting new industry is, after all, a long run endeavor. Some non-mining industries already have plants in Appalachia, others not yet. Included are firms producing glass, clay products, cement, and wood products, all of which not only use large amounts of energy, but also raw materials that are available in abundance in Appalachia.

Other likely candidates for locating in Appalachia are the electric power companies. Given the high costs of transporting coal, it would seem cost effective to build coal fired power plants near the source coal instead of some distance away. Technological advancements in electric power transmission have significantly lowered transmission loss ratios and therefore transmission costs. It surely is less costly to transport an electric kilowatt than an equivalent amount of coal.

Unfortunately the industries that would benefit most from locating in a region rich in coal would also be capital intensive. Their ability to create jobs would be limited. Therefore, if unemployment is to be reduced in Appalachia and the standard of living lifted, public policy must be structured so as to encourage the creation of jobs. Specifically, incentives are needed to encourage the location in the region of small scale labor intensive industries. In the long run this would lead to diversification and enhanced economic stability.

In summary the key to an improved standard of life in Appalachia lies in the development of employment opportunities in industries other than coal. In the past, the human resource, the most valuable of the resources with which Appalachia is endowed, has been greatly overshadowed by the emphasis placed on coal. As a consequence, the region remains largely underdeveloped.

The Distributional Aspect of Development

There exist in Appalachia a number of counties where manufacturing and farming are the principal sources of income for the residents. These counties lie mostly on the periphery of the coal region, but are still part of Appalachia. Recent studies conclude that in contrast with coal counties, manufacturing counties have better health, education, housing, and sanitation - in short a better life.[4] They have this even though on a per capita basis their income is lower. The explanation is that jobs and income are more widely distributed among the residents of the manufacturing counties. More jobs means more working people and fewer poor people. It also means that more people are contributing in an ongoing manner to the local economy and that more support the furnishing of community goods and services. The coal counties have a lower quality of life, the studies conclude, because job opportunities are distributed less equally there. Fewer are working, although those who are earn relatively high incomes. Moreover, structural unemployment in these counties creates a dependent population that is unable to contribute to the local economy. This fact reflects the general fragility of the coal county economies. It also permanently limits the funds available for public investments in education, housing, health care, and other social services.

The obvious policy lesson for underdeveloped non-homogeneous regions is that economic growth does not necessarily benefit all people in all phases. Poor people and poor places are often bypassed by a development process that can be unequal in the distribution of jobs and incomes. Thus an effective development strategy must focus not only on economic growth, but also on the question of equality in the distribution of employment opportunities and income. In the Appalachian coal counties, employment is unstable and dependent upon volatile world energy markets. In the non-coal counties this is less so the case. It is evident that an intervening step between the desire to improve the quality of life of a community and its economic growth is the question of distributional equity. In fact, how successful development strategy is in breaking the poverty cycle depends finally upon who benefits from economic growth.

Contemporary Issues Affecting the Appalachian Coal Industry

Twenty years ago U.S. industry faced few environmental or other limitations on the way it operated. The environment was regarded as a public resource for all to use at no cost. But as the demand for environmental use expanded, scarcities soon developed. Today, the environment is an important consideration in nearly all activities. It has become clear that as an economy develops, at zero cost too many of the good qualities of the environment will be consumed to the detriment of public welfare. In Appalachia, the quality of air, land, water resources, health and safety had deteriorated at an unacceptable rate; environmental resources had been depleted much more rapidly than they could be replaced.

With the possible exception of ambient air standards, Appalachian environmental resources had been affected adversely by decades of unregulated mining. In particular, the damage wrought upon the environment by accelerate and often irresponsible surface mining had created irreversible costs. From the standpoint of resource management, which is at the core of most regulation of the coal industry, the market had failed because environmental resources are not governed by a well defined and enforceable set of property rights. They also have no prices. Consequently, a non-private, i.e. public, intervenor was needed to restore order. The U.S. Congress became such an intervenor and began to provide the necessary statutory foundation in the form of the 1969 Federal Health Mine and Safety Act, the 1970 Uniform Air Quality Standards Act (which amended the Clean Air Act of 1963) and the 1977 Surface Mining Control and Reclamation Act.

The environmental legislation passed by the U.S. Congress has led to a considerable improvement in the use of our environmental resources. Appalachian land is now being restored after mining much more respo sibly, underground mining has become safer and cleaner, and over all air quality has improved in coal using regions. But still more needs to be done. The northeastern states in the United States, and Canada, contend that sulfur dioxide (SO_2) from the industrial Midwest is carried by prevailing air currents to their regions. This SO_2 affects human health, plant life and crops, and leads to higher concentrations of acid depositions. Lakes die, crop yields fall, forests weaken and become diseased, and human health deteriorates. Consequently, this continues to be an issue of considerable concern in the U.S. Congress. In all likelihood it will lead to further legislation.

Finally there is the unsettling question of the greenhouse effect. With increased energy production and consumption come greater emissions of carbon dioxide and water vapors into the atmosphere. And with that, more infrared light and heat is retained in it. There is the danger that the Earth's surface will warm to a point at which the balance of all of its life systems will be endangered. Consequently scientists recommend improved efficiency in the way we use energy. They also recommend the use of substitute fuels such as solar power, nuclear fusion, biomass combustion, and technological improvements in energy-using machinery and equipment.

Many of the issues and problems discussed pertain more to industrialized societies than to those still in the process of development. In the former energy use is intense, in the latter it is not. For developing societies it is mainly a matter of priorities. Given low levels of air pollution, the benefits from building another electric power plant may overshadow those derived from retrofitting existing furnaces with electro-static filters. Ultimately this question must be decided by the appropriate public assembly or authority.

Footnotes

1 H.W. Richardson, Regional Growth Theory, (Loudon: Macmillan, 1973) and Regional Economics, (Urbana: University of Illinois Press, 1979).

2 Parenthetically, this regional phenomena also can be generalized to describe an entire nation.

3 Theodore Schultz, "Investment in Human Capital," American Economic Review, March, 1961.

4 A. Tickamyer and C. Duncan, "Economic Activity and the Quality of Life in Eastern Kentucky," Growth and Change, Spring 1985.

Social Impact of Coal Development

- Case of Korea -

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I. Introduction

Korea has steadily developed with a high economic growth the last 20 years. The annual increase of GNP 8.6% from 1965 to 1983. However, due to the international oil shock in 1979, the real GNP fell to 4% in 1980. As a result, energy growth rate was sharply decreased. In 1983 per capita income rose to 1,880 U.S. Dollars.

Energy consumption has similarly increase with the economic growth. During the same period, energy consumption was estimated at 49.7 million TOE which is 5 times as much as in 1961. Although oil was largely consumed as the main energy source since early 1970's, the coal requirment has steadily increased as an important energy source since. In 1983, coal in total energy occupied 33.1% of total. Nuclear power first introduced in 1978, amounted to about 4.5% by 1983.

According to energy consumption of the industrial sector, coal was mainly used for industrial, residential and commercial purposes. In 1983, coal consumption occupied 35.8% of total energy consumption in the industrial sector. Especially, anthracite alone consumed 60.4% of the total amounts for residential and commercial purposes.

The consumption of anthracite has gradually increased since early 1960, bituminous coal came into use from the middle 1970's. Based on details on coal consumption in 1983, anthracite consumption was 69.2% of the total coal of 31 million tons. Besides, bituminous coal consumed 30.8% of the total.

II. Industrial Coal

Bituminous coal is the main source for industrial use but a little anthracite is also supplied for the same purpose. Most industrially used coal is imported from foreign countries like U.S.A, Australlia, China, Africa and South East Asian countries.

Bituminous coal for electrical generation had limited use until the early 1960's, and was again supplied in the amount of 546,000 tons from 1983. The demand in iron and steel industies has gradually increased from 1973. Especially the domestic cement industry has changed its burning system for substantial savings in fuel cost because of the influence of international oil shock.

Although about 64% of total bituminous coal was used in iron industry in 1983, it expects to increase to 13,119,000 tons by 2001. Its proportion in total demand is actually declining to about 24% of total demand.

Coal requirment in cement industry will also decrease from about 30% in 1983 to 10% by 2001.

However, the power generation sector requires gradually increasing demand. 6% of total demand was required in 1983, but its proportion will reach to about 57% of total demand.

III. Domestic Coal

1. General Aspects

Despite that fire wood has been popularly used as a major source of energy until early 1960's, it tended to be reduced by the adoption of government forest conservancy policy and coal supply expansion policy.

Anthracite is the only indigenous fossil fuel reserved in Korea and is an important main source of domestic fuel. It reserves approximately 1.5 billion tons and recoverable reserves are about 0.65 billion tons.

Most coal mines are located in the north-east region of the country which is several hundred kilometers from Seoul, the capital city. Anthracite of about 20 million tons is annually produced from 7 coal fields.

On the basis of investigation of number of coal mines, 54 have an annual production capacity of more than 60,000 tons among total 346 coal mines. The remaining, 292 have a small scale capacity of less than 60,000 tons per annum.

Those coal mines belong to 3 categories such as Daihan coal co., Consolidated co. and private companies. In 1982, 62,310 people were engaged in the production of coal.

2. "Yontan" Coal Briquette Industry

A) Contribution of "Yontan" Coal Briquette

The only way to use Korean anthracite for domestic fuel has to make briquettes due to its particular inherent characteristics. Korean coal briquette, so called "Yontan", is a great discovery with less than 50 year history. It made great contribution to low and middle income households.

As shown in the figure, it is normally a cylindrical briquette of 3.6 Kg with 22 holes in the axial direction. It is usually used in a pair with one briquette placed on top of the other. When the bottom briquette is almost burnt, ignition is transfered to the top briquette. In this case alignment of the vertical holes between two briquettes has an important function as draft chimneys for combustion air. When the top briquette is burnt within almost 80-90%, it should be laid down and replaced by new one, simultaneously by removing the completly burnt bottom one.

During the combustion period of briquettes, the heat can be used for dual purposes, i.e, heating household and cooking meals.

There are two reasons why the "Yontan" coal briquette has been so popular for Koreans. The first thing is that it is suitable for a heating system of the Korean house. The room floor, finished with cement concrete, is directly heated by heat passing through airduct system under the room floor (Ondol system). At that case heat can be provided fixed stove which is installed out of the room. Recently, instead of fixed stove, a small boiler system is popularly used. "Yontan" coal briquette is also used to boil water in boiler, from which hot water is circulated through plastic pipes embeded in the concrete floor of a room. In accordance with heating the household, house wives can also prepare cooked meals on the burning coal briquette.

The second reason why the coal briquette is popular is that it is relatively cheap price. This will be illustrated in later column.

Actual demand for such coal briquetting has steadily increased since early 1960's. In 1962, 501,000 tons of anthracite was used for making briquettes, eventually reaching 19 million tons in 1983. Its proportion of total consumption was 87.5%. This trend will continue to the year of 2000.

B) Coal Characteristics

It is well known, that coal is generally classified into four groups such as anthracite, bituminous, sub-bituminous and lignite. Korean coal belongs to common anthracite ammong the anthracite group. It originally contained high fixed carbon of 92-98% and low moisture content of 2-8%.

According to ultimate analysis, hydrogen content is 1.05%, which is slightly lower than of alien anthracite.

On the contrary the oxigen content is 2.8%, which is slightly higher than that of others.

Originally it contained high quality fixed carbon. But Korean coal was badly mingled with clayceous materials during severe geological movements. Thus, the raw coal naturally contains a considarable amount of ash. When processing the coal this is an advantageous factor in making the "Yontan" coal briquette without an additional binder. According to proximate analysis of raw coal, it contains normally 4,400-4,600 Kcal/Kg, 3-5% V.M, 35-45% Ash, 0.5-2% H_2O and less than 1% S.

Based on the chemical analysis of ash, it contains 47-52% SiO_2, 35-40% Al_2O_3, 0.5-1.2% Na_2O and 1.5-2.7% K_2O. Those chemical components are relatively similar to those in common clay.

Another advantageous characteristic is that it contains high proportion of finers in the raw coal. The fine size coal is more than 10mm and makes up more than 70% of raw coal. This results in a reasonable opportunity to make coal briquettes.

C) "Yontan" Briquetting Technics

"Yontan" coal briquette is simply manufactured by a routine process. Firstly raw coal is crushed into finer size and then it is blended with water. The crushed coal, containing 10% water, is poured into cylinder which is a part of the briquetting machine. A compacting pressure mechanism is provided to manufacture briquette at 250Kg/Cm^2.

Several kinds of briquettes are produced for multi-purposes. The coal briquette demension most popular is 150mm diameter by 142mm height with 22 vertical air holes and 3.6 Kg weight. It can be used for 10-12 hours when average heat value is maintained at the level of 4,600 Kcal/Kg.

According to the test result in laboratory, the variety of coal briquette results in many different combustion effects. The decrease of heat value of briquette has tendency to increase uncombustibility. The increase of briquette weight results in increase of burning temperature, ranged on 550°C-600°C, as well as combustion time increases. As a result, the decision of optimum briquette is an important factor for effective use of the briquette.

In the use of the "Yontan" coal briquette, the worst problem was a fatal disaster due to CO gas poisoning. In early stages there were some fatal accidents due to particular heating system of Korean houses. But the problem is gradually being solved by modern inventory of combustion facilities. On the basis of measuring gas in laboratory, at the initial stage CO gas of 1.4% after two hour burning. After that the CO gas content is slowly decreased to less than 0.4%.

However this problem may not be so considerable in the use of a movable stove in an open space where it is used for cooking purposes.

D) Practical Aspects on Coal Briquetting Industry

Generally raw coal is stored at the mine or a rail terminal near the mine. Then it is transported to a terminal very close to the briquette manufacturer. After manufacturing briquettes, these are distributed either directly to the private consumer or through retailers to the consumer.

The manufacturing process normally includes size reduction, blending and briquetting procedures. Optimum particle size of coal for making briquette is normally below 10mm. Water is sprayed on the raw coal in the conveyer belt and water content is about 10% in weight. For the purpose of contineous manufacture and production, a rotary processing machine which includes 12 pressing actions in one turn can produce 3,800 briquettes an hour. Besides, there are several facilities necessary for mixing and conveying.

The 17 briquetting plants among 258 plants are located in Seoul area and have production capacity of 31.6% of total production. Besides small and medium scale briquetting plants are almost evenly distributed over each province. In the winter season about 20 million briquettes are produced daily by these plants.

The production cost of a briquette is roughly estimated at 15.4 cents U.S. Main expenditure is material cost which occupies 93.6% of the total production cost. The final consumer's price per briquette estimates about 20 cents, in U.S. dollars.

The price of coal briquette is relatively competitive with other energy sources. Although some inconveniencies may be confronted in its handling, the advantageous aspect is off-set by price structure per unit. Based on unit price per kilocalories, gas is almost 4 times of coal briquette.

Daily consumption is commonly 2-3 briquettes for heating house including 3 cooking meals. The price of coal briquette can be roughly compared with that of other daily commodities. A coal briquette of 3.6Kg weight costs about 20 cents U.S. that is almost same as of one kilogram of cabbage, a pack of milk and one kilogram of flour.

IV. Coal Policy

1. Industrial Coal

The country has made a great effort to promote the use of industrial coal which it expects to import from alien sources. Current 3 coal fired power stations are in operation and previous 3 oil fired power stations are also being converted to coal fired units. The cement industry, having 34 kilns with total production of 20 million tons have already been converted to coal fired ones.

In order to achieve a portion of the goals, Korea has already participated in development projects in some alien countries. And expects to import certain amount of industrial coal in order to stabilize energy demands in the future.

2. Domestic Coal

A) The main target of domestic coal policy is the support for low and middle income people to maintain satisfactory lives. The domestic coal prices have been strongly regulated at both wholesale and retail levels. Therefore, the country operates a complex system of many subsidies in various sectors such as boring and tunnelling for prospecting, mining safty, transportation, housing for coal miners, education for miners childeren, R&D project and etc..

B) Current emphasis is the introduction of mechanization in the coal mines. This mechanization is an important program to increase productivity, safty and recovery of reserves. In 1984 mechanization rate was 27% of total, the proportion will be increased to 69% of total by 2001.

C) Active research work is also in progress at public centers to improve the techniques of briquetting.

V. Conclusion

1. To achieve the 5,103 U.S. dollars per person of GNP in the year of 2000's, Korea makes a great efforts to fullfil effective energy policies. The total energy consumption will increase from 49.7 million TOE in 1983 to 130 million TOE by the year of 2001.

2. Bituminous coal had contributions not only domestic fuel but also in industrial sectors. For the purposes of industry in cement, iron and power sectors, the bituminous coal demand will reach to 55.3 million tons in the year of 2001.

3. Domestic anthracite, having great contributions to low and middle income households, will still remain as the most popular household fuel during the next couple of years. Therefore the briquetting business will be protected along with other related coal industries. Institutions like KIER perform active research works in search of new replaceable fuels.

POSIBILIDADES CARBONIFERAS DEL ECUADOR

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Junio, 1985

INTRODUCCION

La gran dependencia que el sistema energético del Ecuador tiene respecto a la producción y utilización de hidrocarburos, para el desarrollo de sus actividades socio-económicas, ha motivado a que el Gobierno Nacional, a través del Instituto Nacional de Energía promueva una serie de acciones tendientes a diversificar la oferta de energía primaria con la incorporación de fuentes alternativas de energía; para lo cual, viene trabajando con organismos de carácter público y privado en la investigación, el conocimiento del potencial energético del País y la adaptación de tecnologías para el aprovechamiento adecuado de los recursos energéticos.

Dado que el carbón mineral ha retomado su importancia en varios de los procesos energéticos de los sectores industrial y residencial, principalmente en países donde el recurso petrolero es limitado o inexistente como consecuencia de los ajustes en los precios internacionales de los hidrocarburos y considerando que la Dirección Nacional de Geología y Minas, ha emprendido en trabajos iniciales de prospección y evaluación de los afloramientos carboníferos existentes, el Gobierno del Ecuador, con el objeto de motivar y concientizar al pueblo acerca del uso del carbón mineral, ha trazado una serie de políticas tendientes a lograr tales objetivos, entre ellas tenemos:

a) Incrementar el conocimiento de los recursos carboníferos elaborando su inventario, mediante la urgente realización de investigaciones y estudios correspondientes.

b) Asimilar y desarrollar tecnologías apropiadas que permitan la explotación y el uso racional del carbón.

c) Planificar el aprovechamiento de los recursos carboníferos, en el contexto de los planes energéticos nacionales.

d) Crear las condiciones institucionales y financieras apropiadas para desarrollar la industria del carbón mineral, a través de una entidad especializada.

CONTENIDO

Con lo que , se podrá elaborar el mapa índice de carbones; realizar actividades de investigación sobre reservas, posibilidades de explotación y usos; diseñar un programa de aprovechamiento industrial; reducir las importaciones de carbón; y, diversificar la oferta energética.

Se considera la conveniencia de la participación integrada de los sectores público, privado y universitario, para lograr los objetivos trazados por el Gobierno.

En el presente "documento", se trata de dar a conocer los aspectos mas sobresalientes de la geología y de las manifestaciones carboníferas del Ecuador.

La mayor parte de la información que se publica, corresponde al inventario de recursos energéticos, realizado por el Instituto Nacional de Energía "INE" en 1982 y a estudios desarrollados por Dirección General de Geología y Minas hasta la presente fecha.

1. MARCO GEOLOGICO GENERAL

La configuración geográfica del Ecuador y su división clásica en regiones de Costa, Sierra y Oriente corresponde al resultado geomorfológico de la evolución tectónica y sedimentaria de esta parte del continente.

En cada una de estas regiones es posible distinguir características propias que obedecen a la particularidad de su evolución estructural, a la mecánica de las deformaciones ocurridas, a la secuencia estratigráfica y asociación de rocas; consecuencia de lo cual, cada zona presenta actualmente una disposición de cuencas y subcuencas sedimentarias de edad, extensión y profundidad diferentes. (Véase Figura No. 1).

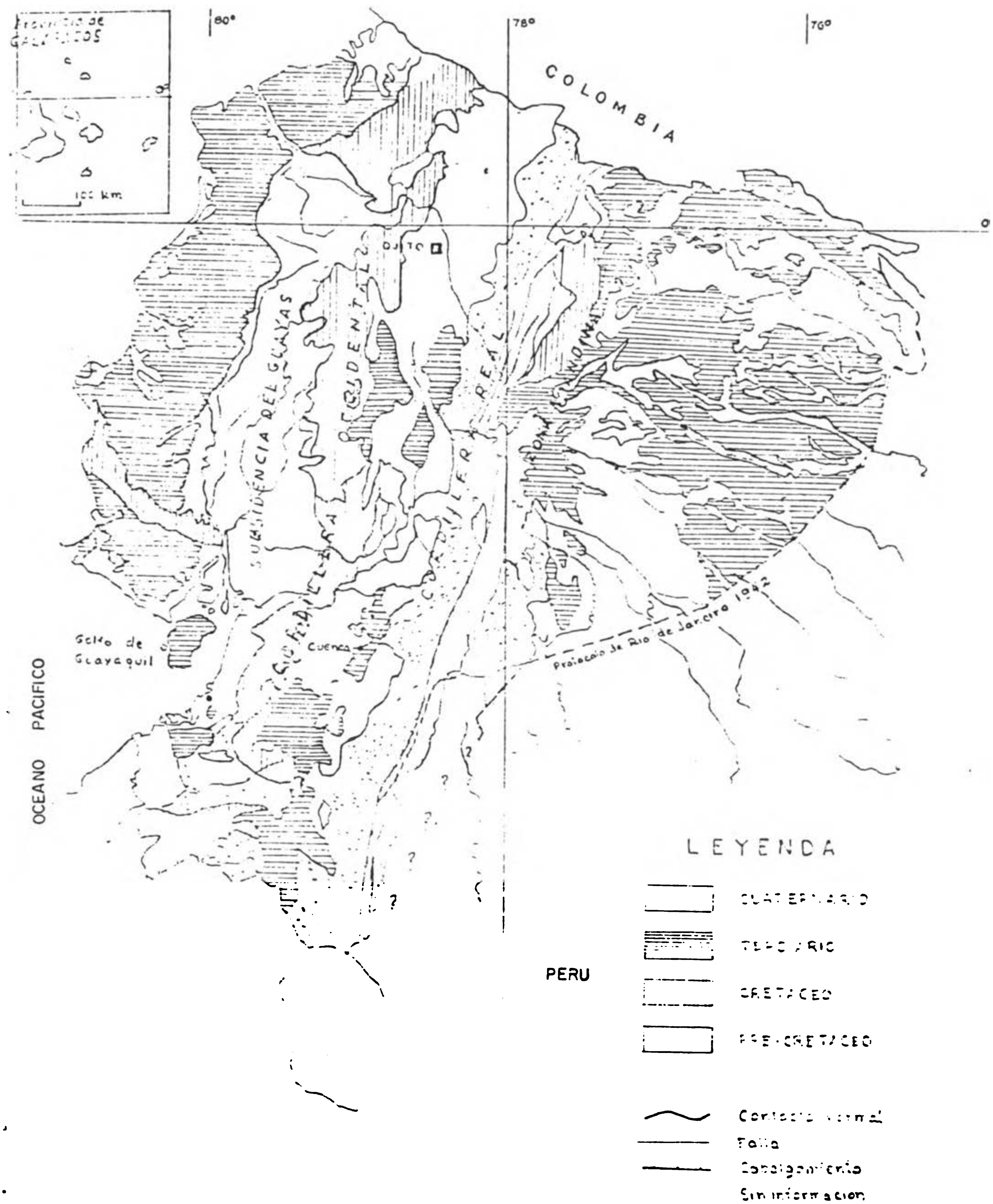
En el Ecuador existen diversos tipos de cuencas, distribuidas sobre todo en el Litoral (Costa Adentro y Costa Afuera) y en la Región Amazónica (Cuadros Nos. 1 y 2). Sus características generales son las siguientes:

1.1 Región Litoral.

Esta región está constituida por una serie de cuencas costaneras que se extienden al oeste de la Cordillera Occidental, tanto al norte como al sur de la Cordillera Chongón-Colonche.

Las cuencas (o subcuencas, según la escala regional que se adopte como referencia) septentrionales son las de Esmeraldas y Manabí, separadas de la plataforma submarina por el arco cordillerano que forma las montañas de Jama y Cuaque. Se trata de depósitos cretácicos, parcialmente erosionados y recubiertos por transgresiones de terrenos terciarios, fracturados por fallas verticales contempóraneas de los movimientos andinos. Estudios recientes, desarrollados por CEPE han permitido detectar profundidades de hasta 9.000 metros, en la subcuenca Manabí

FIGURA N° 1



MAPA GEOLOGICO SIMPLIFICADO

ESC. 1 : 4 000 000

Al sur de la Cordillera de Chongón-Colonche (provincias de Guayas y El Oro) se encuentra una zona de sedimentación profunda y subsidente que se extiende hasta la Sierra de Amotape, en el Perú, y comprende las Cuencas Progreso y Talara, así como la zona alta de Santa Elena y la plataforma continental del Golfo de Guayaquil.

Esta región está atravesada por fallas tectónicas de grandes dimensiones, ligadas a la colisión de la placa oceánica, las mismas que han ejercido un rol importante en el desarrollo estructural de esta zona, particularmente en la conformación de la Isla Puná y el Canal de Jambelí. En el área del Golfo de Guayaquil, la cuenca Progreso alcanza 12.000 metros de profundidad.

En cuanto a la estratigrafía, la serie comprende un basamento o zócalo de "rocas verdes" (doleritas, basaltos) y aglomerados piroclásticos de espesor no determinado. Excepcionalmente afloran esquistos, cuarcitas y anfibolitas. Las rocas verdes constituyen el llamado Complejo Piñón, del cretácico inferior, general en toda la Costa y sobre el cual reposa una serie de sedimentos cretácicos y terciarios detríticos, de areniscas y arcillas, localmente intercaladas por calizas arrecifales. La nomenclatura y extensión de las formaciones es sumamente variable, según se trate de la región norte o sur del Litoral (Cuadro 1).

1.2 Región Amazónica.

El Oriente Ecuatoriano forma parte de la cadena de cuencas que sucesivamente se desarrollan desde Venezuela hasta Bolivia entre la Cordillera de los Andes y el Cratón Guayano-Brasileño. Está limitada al oeste por la Cordillera Real, contra la cual se arriman algunos levantamientos que corresponden a las Cordilleras de Cutucú y del Cóndor y al Domo Anticlinal de Napo. Al este, la cuenca se eleva paulatinamente cerrándose contra un levantamiento del zócalo denominado Saliente de Vaupés y manteniéndose bastante superficial en la zona de Tiputini.

ESTRATIGRAFIA GENERALIZADA COMPARATIVA

DE LA REGION LITORAL

CUADRO N° 1

EDAD		SUBCUENCA MANABI	SUBCUENCA BORBON	SUBCUENCA PROGRESO
CUATERNARIO		TABLAZO	TABLAZO	TABLAZO
PLIOCENO	SUP.	Fm. BALZAR	?	Fm. PUNA Subsidente
PLIOCENO	INF.	Fm. BORBON	Fm. BORBON	Fm. PROGRESO
MIOCENO	SUP.	Fm. ONZOLE	Fm. ONZOLE	Fm. SUBE Y BAJA
MIOCENO	MEDIO	Fm. ANGOSTURA	Fm. ANGOSTURA	Fm. SUBE Y BAJA / /////
MIOCENO	INF.	Fm. TOSAGUA	Fm. TOSAGUA	Fm. TOSAGUA
OLIGOCENO	SUP.	Fm. TOSAGUA	Fm. TOSAGUA	Fm. TOSAGUA
OLIGOCENO	MEDIO	/////	Fm. PLAYA RICA	/////
OLIGOCENO	INF.	/////	Fm. PLAYA RICA	/////
EOCENO	SUP.	Fm. PUNTA BLANCA (= CERRO) Neritico	Fm. ZAPALLO Neritico	Gr. ANCON Abisol / /////
EOCENO	MEDIO	Fm. SAN EDUARDO Suborrecifal	Fm. SAN EDUARDO (?)	Fm. SAN EDUARDO Abisol
EOCENO	INF.	Fm. MONGOYA (?)	?	Gr. AZUCAR
PALEOCENO	SUP.	/////	/////	/////
PALEOCENO	INF.	Fm. CAYO + Volcanico Tardío	Fm. CAYO Espesor Reducido	Fm. CAYO
CRETACEO		Fm. CAYO + Volcanico Tardío	Fm. CAYO Espesor Reducido	Fm. CAYO
CRETACEO		Fm. PIÑON	Fm. PIÑON	Fm. PIÑON

///// HIATO SEDIMENTARIO

La parte norte se continúa en Colombia, entrechándose, en la región petrolífera de Orito, en tanto que al sur se abre hasta el Perú. Una zona alta orientada ENE-WSW entre Vuano y Cononaco separa una subcuenca septentrional, en donde se ubican las principales estructuras hidrocarburíferas, de otra meridional más profunda y menos tectonizada.

Varios ejes estructurales atraviesan la cuenca en su parte más subsidente, controlados generalmente por fallas submeridionales, ligadas a la fase laramídica.

La serie sedimentaria comprende terrenos que van del Paleozóico al Mesozoíco y Cenozóico. (Véase Cuadro No. 2).

El término más antiguo de la cuenca es la Formación Pumbuiza (Devoniano), compuesta litológicamente de esquistos grafíticos y areniscas cuarcíticas. Reposa discordante sobre la anterior la Formación Macuma (Carbonífero) constituida por lutitas, calizas y areniscas.

La Formación Santiago, datada en parte del Liásico (Jurásico inferior), transgresiva sobre la anterior, se compone de calizas, areniscas y arcillolitas.

Una discordancia mayor la separa la Formación Chapiza (Jurásico medio a superior), caracterizada por depósitos continentales con intercalaciones marinas, comportando en su parte superior un miembro de elementos piroclásticos violáceos (Misahuallí), con lavas y tobas andesíticas y basálticas.

En transgresión y ligeramente discordante se desarrolla la serie cretácica, representada por un término inferior continental y litoral, la Formación Hollín, compuesta por areniscas blancas, masivas o en bancos potentes, de grano mal clasificado pero limpio, a menudo de aspectos sacaroide y estratificación cruzada con intercalaciones de lutita. El término superior cretácico constituye la Formación Napo, de origen marino y deltáico, compuesta por una alternancia de areniscas, calizas y lutitas.

COLUMNA ESTRATIGRAFICA GENERALIZADA DE LA CUENCA ORIENTAL

CUADRO N° 2

ERA	PERIODO	EPOCA	PISO	OROGENESIS: CICLO	OROGENESIS: FASE	FORMACION	AMBIENTE	LITOLOGIA	ESPESOR (m)	BREVE DESCRIPCION LITOLOGICA
CENOZOICO	CUAT.	PLEISTOCENO / HOLOCENO		ANDINO	PAROXISMO ANDINO	VOL				TERRAZAS ALUVIALES Y BRECHAS VOLCANICAS
	NEOGENO	PLIOCENO				MERA	CONTINENTAL		0-1200	ARENAS AMARILLAS Y ARCILLAS ROJAS MATERIAL VOLCANICO
						CHAMBIRA			700-1000	CONGLOMERADOS, ARCILLAS Y ARENAS
		MIOCENO				ARAJUNO			400-1000	ARENISCAS FRIABLES DE COLOR PARDO, INTERCALADAS CON ARCILLAS MULTICOLORES Y CONGLOMERADOS
	PALEOGENO	OLIGOCENO				ORTEGUAZA / CHALCANA			350-800	LUTITAS FISILES, VERDE-GRISACEAS, SEMIBLANDAS
		EOCENO			LARAMIDICA	TIYUYACU	CONTINENTAL FLUVIAL		70-880	ALTERNANCIA DE LIMOLITAS Y ARCILLAS SEMIBLANDAS MULTICOLORES CON CONGLOMERADOS DE CUARZO Y NIVELES DE CHERT DE VARIOS COLORES
MESOZOICO	CRETACICO	SUPERIOR	MAESTRICHTIENSE			TENA	CONTINENTAL		260-1000	ARCILLAS BLANDAS DE COLOR ROJO LADRILLO MOTEADAS DE BLANCO
			ALBENSE - SENONIENSE			NAPO	MARINO NERITICO		240-400	LUTITAS CALCAREAS INTERCALADAS CON CALIZAS CALIZAS FOSILIFERAS, MACIZAS ARENISCAS FRIABLES, GLAUCONITICAS Y CALIZAS CRIPTOCRISTALINAS Y ORGANOGENAS
		INFERIOR	APTENSE			HOLLIN			80-220	ARENISCAS CUARZOSAS DE GRANO FINO A MEDIO
	JURASICO	MEDIO-SUPERIOR			JURASICA	MISAHUALLI	CONTINENTAL			SECUENCIA DE LAVAS Y TOBAS ANDESITO-BASALTICAS
						CHAPIZA			2300-4800	ARENISCAS Y LUTITAS ARENISCAS Y LUTITAS INTERCALAS CON ANHIDRITA
		INFERIOR	SINEMURIENSE			SANTIAGO	MARINO NERITICO		1300-2700	CALIZAS INTERCALADAS CON ARENISCAS CUARCITICAS Y ARCILLAS ESQUISTOSA
PALEOZOICO	CARBONIFERO	SUPERIOR		VARISTICO	DEVONIANO PERMICO	MACUMA	MARINO NERITICO		1400	CALIZAS, LUTITAS Y ARENISCAS
	DEVONICO					PUMBUIZA	MARINO BATIAL		?	ESQUISTOS GRAFITICOS Y ARENISCAS CUARCITICAS
						BASAMENTO CRISTALINO				SERIE METAMORFICA

Esta formación representa la parte marginal de un conjunto sedimentario mas completo y subsidente, desarrollado sobre todo en el Perú.

Las formaciones Hollín y Napo contienen los intervalos detríticos que constituyen tanto la roca madre como los reservorios hidrocarburíferos de la Región Amazónica. Estas formaciones están recubiertas por terrenos predominantemente continentales, correspondientes a las Formaciones Tena, Tiyuyacu, Orteguaza, Arajuno, etc., desarrolladas luego de una fase de epirogénesis precursora de paroxismo andino.

1.3 Región Andina.

Los Andes Ecuatorianos forman dos Cordilleras mayores, separadas por un corredor (o altiplano) interandino. La Cordillera Occidental es la prolongación natural de la de Colombia. La Cordillera Real pertenece a la misma unidad que la Central del vecino país, la Cordillera Oriental se presenta como elevaciones anticlinales y se encuentra en la zona subandina, sus caracteres geográficos, como la sencillez de su estilo tectónico, la relacionan más con la Región Oriental.

En la parte septentrional, entre los paralelos 1° N y 2°30' S, Los Andes ofrecen su aspecto más esquemático. Comprende dos cordilleras bien dibujadas y coronadas por imponentes aparatos volcánicos cuaternarios o actuales.

La Cordillera Real verdadera columna vertebral de Los Andes Ecuatorianos, está constituida por rocas metamórficas, separado del corredor interandino por fallas, sobre las que se edificó una alineación de volcanes jóvenes. La edad de la serie metamórfica es todavía insegura y parece variar según los sectores; en algunos sitios el metamorfismo remontaría a principios del Mesozóico.

La Cordillera Occidental comprende esencialmente rocas cretáceas, en las que dominan formaciones volcánicas y piroclásticas. Se observa también, intrusiones granodioríticas postcretácicas. Excepcionalmente en los ejes anticlinales asoman esquistos semi-metamórficos.

Entre las dos cadenas, el corredor, con una altura media de 2.500 a 3.000 m constituye una manera de zanjón o "Graben" que no ha seguido el movimiento ascendente de las cordilleras vecinas.

La historia Terciaria está marcada por algunos depósitos continentales y productos volcánicos, difícilmente estudiables en esta parte, debido al enorme manto formado por los productos volcánicos cuaternarios y sus derivados.

En la parte meridional al S del paralelo 2°30' S, Los Andes Ecuatorianos ofrecen un estilo muy distinto. La región de Cuenca hace transición, y permite reconocer todavía las dos cordilleras, separadas por una hoya bastante clara. Pero hacia el S, las cadenas se dividen y divergen en un amplio abanico, a la vez morfológico y estructural, cuyos ejes son todavía N-S en la parte oriental, pero casi E-O, en la vecindad de la Costa.

En varios puntos de Los Andes meridionales, asoman núcleos de esquistos semi-metamórficos de edad incierta.

El cretáceo marino y su fase piroclástica se expanden y colindan con las series metamórficas.

En cuencas mas elevadas, por ejemplo alrededor de Malacatos, Loja, Girón, Nabón, Cuenca, Azogues, Biblián, se formaron lagos neogénicos cuyos depósitos han sido plegados tardíamente. Se observan también en toda la zona, aparatos volcánicos desmantelados, que corresponden al Terciario (sobre todo Plioceno) y Pleistoceno. Pero es notable que no existe ninguna manifestación volcánica holocénica en el S del Ecuador.

2. PRINCIPALES MANIFESTACIONES CARBONIFERAS DEL ECUADOR.

A través del estudio de la geología general del País, y de trabajos de prospección minera, se han determinado la presencia de numerosas manifestaciones carboníferas, las mismas que han sido estudiadas en mayor o menor grado. En este sentido, las manifestaciones carboníferas han sido clasificadas en yacimientos, al que corresponden las acumulaciones de carbón, mejor estudiadas y depósitos, que comprenden las acumulaciones o manifestaciones en proceso de evaluación y análisis.

2.1 Yacimientos Carboníferos.

Los yacimientos de carbón mineral conocidos, se localizan a lo largo de la depresión interandina, entre las cordilleras predominantes de Los Andes. Los yacimientos importantes en el actual momento están localizados en el Austro del País, especialmente en las provincias de Cañar y Loja; depósitos que corresponden al Cenozóico.

Los depósitos están altamente perturbados y la calidad de carbón va de sub-bituminoso a lignito.

Existen manifestaciones interesantes en la Región Amazónica y en menor grado en el Litoral.

2.1.1 Yacimientos Carboníferos de Azogues - Biblián.

Las vetas de carbón de esta localidad, se encuentran ubicadas en la sección más alta de la cuenca sedimentaria terciaria (edad mioceno). Se presentan dentro de alternancias de tobas de grano grueso, conteniendo bancos de areniscas y arcillas pizarrosas obscuras.

Las vetas están distribuidas en un espesor de 500 m. El piso y el Techo de cada veta es en la mayoría de los casos de arcilla pizarrosa.

Los depósitos explotables se encuentran al Oeste del Cerro Cojitambo, en una franja de 1 km de ancho por 20 km de longitud, con dirección Norte - Sur.

Los horizontes carboníferos de esta zona se los denomina Washington y Cañari, en los cuales cuatro capas corresponden al primero y una capa principal al segundo, afloran una de otra a una distancia de 500 a 700 metros, paralelas entre sí, con buzamientos que oscilan de 60° a 85° hacia el Oeste y en algunos casos hacia el Este, por dislocaciones de carácter local; sus potencias varían de 0.45 a 1.00 m en el grupo Washington y 0.85 a 1.10 en el Cañari.

Las reservas probables calculadas para estos yacimientos oscilan en el orden de los 22.5 millones de toneladas métricas (Véase Cuadro No 3), con un poder calorífico de 4.880 a 5.500 kcal/kg y es tipificado desde sub-bituminoso a lignito, su calidad está dada por los siguientes parámetros: humedad de 13 a 19%; volátiles de 28 a 43%; carbón (combustible) de 55 a 68%; cenizas del 15 al 30%; cenizas en el carbón puro de 10 a 30%; azufre de 3 a 7%.

Las actividades de explotación en la actualidad se limitan al trabajo de obreros que obtienen el carbón de manera artesanal para el funcionamiento de pequeñas industrias y artesanías locales, principalmente caleras y hornos de ladrillo.

2.1.2 Yacimiento Carbonífero de Loja.

En la cuenca de Loja, las capas de carbón ocurren en la Formación San Cayetano (terciario superior), constituidas por intercalaciones de argilitas, lutitas y areniscas. Las cinco capas de carbón existentes, se extienden con rumbo Norte-Sur y buzan entre los 20° y 85° al Este, separados de 3 a 10 metros entre sí, variando su potencia de 0.65 a 1.20 metros.

Las reservas calculadas como probables son del orden de 3.8 millones de toneladas métricas (Véase Cuadro No. 4), con un poder calorífico medio de

RESERVAS PROBABLES DE CARBON EN LA CUENCA "CAÑAR-AZUAY"

CUADRO N° 3

VETA DE CARBON	LONGITUD DEL ESTRACTO (m)	LONGITUD DESDE LA SUPERFICIE (m)	ESPESOR PROMEDIO (m)	GRAVEDAD ESPECIFICA t/m^3	RESERVAS DE CARBON (Toneladas Métricas)
Cañari	14.000	500	0.95	1.4	9'300.000
Washington 4	2.000	250	0.65	1.4	450.000
Washington 3	10.000	400	1.10	1.4	6'200.000
Washington 2	8.000	400	1.10	1.4	4'900.000
Washington 1	5.000	400	0.60	1.4	1'700.000
T O T A L					22'550.000

4.000 kcal/kg. Siendo tipificado como carbón sub-bituminoso C, su calidad está dada por los siguientes parámetros: humedad 3 a 12%; ceniza de 8 a 48%; azufre de 2 a 11%.

2.1.3 Yacimiento Carbonífero de Malacatos.

La cuenca sedimentaria se encuentra al sur de Loja y toma el nombre del pueblo de Malacatos.

Los sedimentos son de edad terciaria y tienen una alineación aproximada N-S y separadas por fallas de dirección Nor-Oeste, cubierta por gravas jóvenes. Tienen una inclinación que varía de 30° a 50° hacia el Este. Las secuencias terciarias consisten en su parte baja de clásticos, conglomerados, pizarras y arcillas; y en su parte alta, las capas de carbón están intercaladas con pizarras, arcillas y areniscas.

Una gran parte del área central está cubierta por conglomerados cuaternarios.

El análisis del carbón da los siguientes valores: humedad 1.2 a 7.5%; contenido de ceniza 11.5 a 48.3%; azufre 2.9 a 9.9%; y, el poder calorífico varía de 2.342 a 5.033 kcal/kg y es similar al de Loja y está clasificado como sub-bituminoso C.

Las reservas probables calculadas para 5 capas de carbón da un potencial aproximado de 4.0 millones de toneladas (Véase Cuadro No. 5).

2.2 Depósitos Carboníferos.

Se conoce de la presencia de aproximadamente 40 manifestaciones de carbón en todo el País (Véase Anexo No 1), la mayoría de las cuales no han sido suficientemente estudiadas; sin embargo, existen algunos trabajos realizados por la Dirección General de Geología y Minas que teniendo

RESERVAS PROBABLES DE CARBON EN LA CUENCA DE LOJA

CUADRO N° 4

VETA N°	PROFUNDIDAD (m)	PROMEDIO DEL ESPESOR DE LA VETA DE CARBON (m)	RESERVAS
1	300	1.00	840.000
2	300	1.00	840.000
4	300	1.10	924.000
5	300	0.80	672.000
6	300	0.80	504.000
T O T A L			3'780.000

RESERVAS PROBABLES DE CARBON DE LOS DEPOSITOS DE MALACATOS

CUADRO N° 5

VETA DE CARBON	ESPESOR PROMEDIO DE LA VETA (m)	PESO ESPECIFICO t/m^3	RESERVAS DE CARBON (TONELADAS METRICAS)
VETA 8	2.0	1.4	1'400.000
VETA 1	2.7	1.4	1'890.000
T O T A L			3'290.000
VETA "A"			
VETA "B"			712.500
VETA "C"			
T O T A L			4'002.500

el carácter de preliminar, han servido para elaborar un inventario de los principales depósitos carboníferos, entre los que se pueden citar:

2.2.1 Cuenca de Nabón (Provincia del Azuay).

Se trata de dos lentijas de carbón brillante de poco espesor; la primera intercalada con arenisca arcillosa de grano fino, de edad terciaria, pudiendo reconocerse como cinta de carbón esquitosa de 0.10 a 0.20 metros de potencia, cuya calidad está dada por los siguientes parámetros: humedad 17.2%; ceniza 21.3%; volátiles 34.7%, carbono sólido 26.8%; la segunda lentija se forma de un banco de 4 a 5 metros de espesor de arcillas esquitosas carboníferas con intercalaciones de areniscas de grano grueso y lignito bandeado, con parámetros que están dados por: humedad 25.8%, ceniza 25.7%, se considera como explotable un estrato de 0.70 a 0.80 metros de potencia.

2.2.2 Cuenca "San Antonio" (Provincia de Pichincha).

Se localiza a 35 km al Norte de Quito, el yacimiento de lignito se halla en el Pleistoceno, el techo y el lecho están formados de estratos fluviales y arenosos de grano fino, constando principalmente de cenizas volcánicas, socavadas con algunas bombas volcánicas; la capa consta de una lignita terrosa negra en forma de estratos delgados, con potencia de 2.30 a 2.60 m, con grandes cantidades de ceniza volcánica y arena. Los resultados de laboratorio son los siguientes: humedad 20.96%; volátiles 28.86%; partes macizas 21.95%, cenizas 26.98%.

2.2.3 Cuenca de "El Derrumbo" (Provincia de Chimborazo).

Se localiza hacia el Oeste de la ciudad de Alausí, las formaciones geológicas del manto de carbón consisten en capas de areniscas y arcillas interestratificadas, que tienen un rumbo general Norte-Sur con marcadas tendencias al Este.

De una manera general, el horizonte carbonífero de "El Derrumbo", se encuentra cubierto por una gruesa capa de toba cuaternaria.

El carbón es brillante y de buena calidad, se presenta en franjas o módulos fraccionados. Todo el conjunto indica que se trata de un manto carbonífero, con una franja de buen carbón de 1 metro de espesor más o menos.

2.2.4 Cuenca "Oriental".

Son muy escasos los estudios geológicos llevados a cabo en la Región Amazónica, para la prospección y exploración de yacimientos de carbón. La mayoría de los estudios han sido encaminados a la búsqueda de petróleo.

En las formaciones sedimentarias del Oriente, se ha encontrado pequeños lentes o intercalaciones de carbón. Actualmente se está tratando de dar una correlación a la presencia del carbón en las diferentes formaciones, gracias a los datos proporcionados por los diversos registros obtenidos en las perforaciones petroleras, lo cual dará una pauta para iniciar la búsqueda de carbón en los afloramientos de cada unidad.

Las manifestaciones más significativas ocurren entre el cretácico y el mioceno, en profundidades que alcanzan hasta los 12.000 pies; determinándose las siguientes estructuras carboníferas:

a) <u>Formación Arajuno (Mioceno Superior).</u>

Se compone de areniscas y arenas de grano fino, hasta grueso de color pardo; se presentan algunos conglomerados e intercalaciones discontínuas de arcilla abigarrada. Es en la parte superior donde se presentan arenas predominantes, con algunos lignitos, arcillas ligníticas y vetas de carbón autóctono.

El ambiente de depositación es de agua dulce y en parte agua salobre, aflora en el Río Arajuno a 15 km al Sur-Este del pueblo de Napo.

b) Formación Curaray (Mioceno Superior).

Se trata de una serie potente que comprende arcillas bien estratificadas, de color verde, azul o rojizo, localmente yesosas, alternando con areniscas de grano fino a medio. Mezclas tobáceas, vetas de lignito y arcillas carbonosas negras son comunes en la parte superior.

La formación aflora a lo largo del Río Curaray, con buzamientos subhorizontales.

c) Formación Chambira (Mioceno Superior).

Se conocen 3 niveles, el inferior con areniscas de grano medio a muy grueso, comúnmente conglomeráticas con numersos horizontes de guijarros de arcilla e intercalaciones delgadas de lutitas verde-azul, parcialmente micáceas y arenosas con abundante restos de plantas; el nivel medio, de areniscas tobáceas con magnetita dispersada y conglomerados interestratificados con arcillas bentoníticas quebradizas con impresiones de hojas, y el nivel superior, de capas de conglomerados bastos y de grava. Esporádicamente, troncos lignitosos o silicificados se encuentran en la formación.

d) Formación Napo (Cretáceo Albiano - Santomiano).

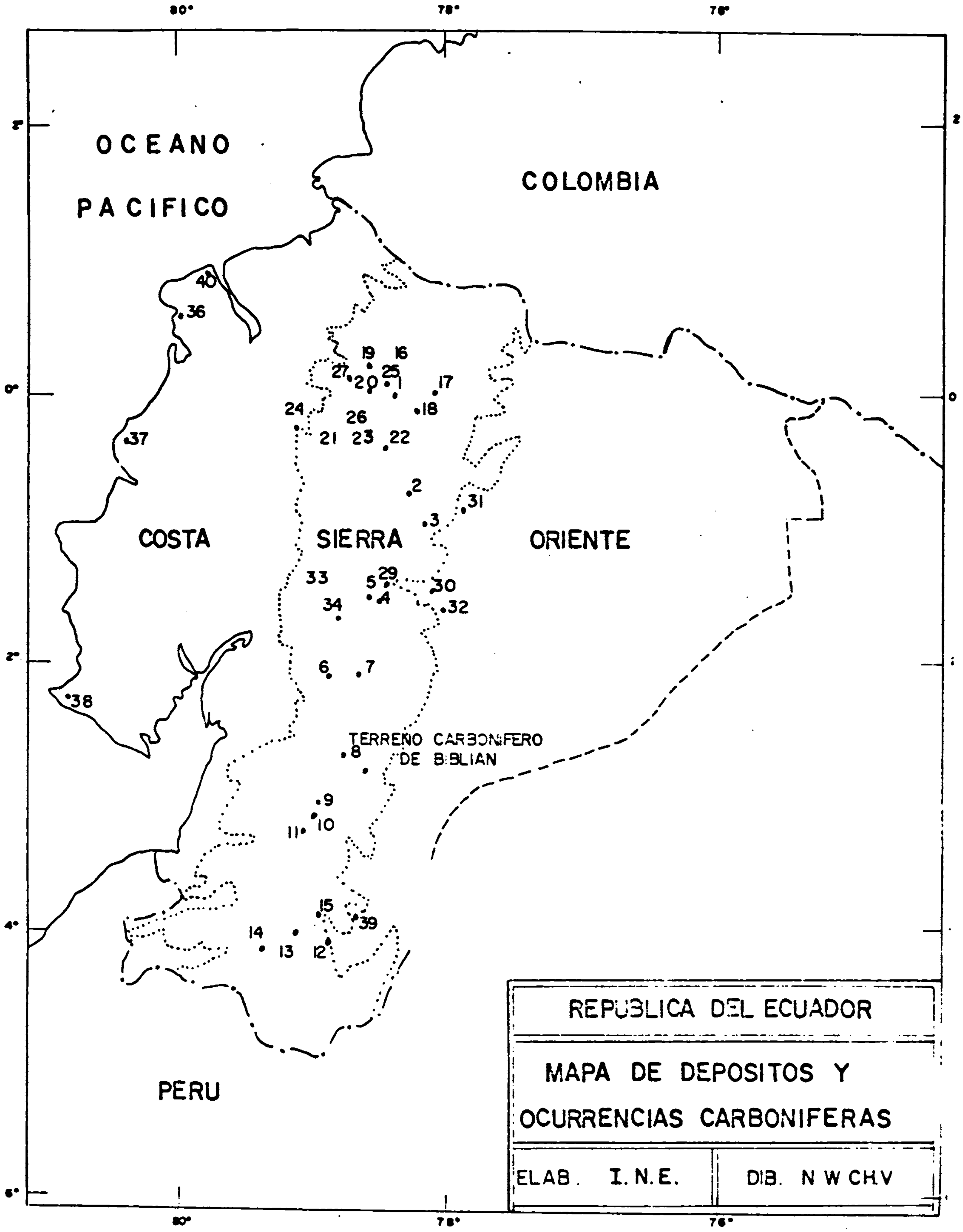
Es una serie variable de calizas fosilíferas grises a negras, entremezcladas con areniscas calcáreas y abundantes lutitas negras y azules.

Dentro de las lutitas se presentan pequeñas vetillas de carbón brillante, así como lutitas carbonosas.

e) Formación Hollín (Cretáceo Inferior, Aptiano-Albiano).

Es una arenisca cuarzosa blanca, porosa; de grano medio a grueso, maciza o con estratificación cruzada, mostrando ocasionalmente ripple marks. A veces hay capas guijarrosas delgadas e intercalaciones de lutitas arenosas obscuras, localmente micáceas y también de lutitas carbonosas negras en su parte superior. En la parte superior se ha determinado la presencia de capas de lignito con potencias de hasta 2 metros.

La característica principal es la presencia de ámbar (resina fósil), con tamaños que van de milimétricos, hasta del huevo de una gallina.


80°
78°
76°
2°
0°
2°
4°
6°
OCEANO
PACIFICO
COLOMBIA
COSTA
SIERRA
ORIENTE
PERU
TERRENO CARBONIFERO
DE BIBLIAN
REPUBLICA DEL ECUADOR
MAPA DE DEPOSITOS Y
OCURRENCIAS CARBONIFERAS
ELAB. I. N. E.
DIB. N W CH.V

INVENTARIO DE LOS DEPOSITOS DE CARBON EN EL ECUADOR

REFERENCIA AL MAPA	LOCALIZACION DEL DEPOSITO DE CARBON (TURBA, GRAFITO)	PROVINCIA	TIPO DE DEPOSITO	GRADO DE INVESTIGACION (PROSPECCION, EVALUACION)	GRADO DE DESARROLLO
1	SAN ANTONIO DE PICHINCHA	PICHINCHA	LIGNITO	CARBON SUPERFICIAL	N.E.
2	MONDAYACU	NAPO	LUTITA CARBONOSA	REGISTRO DE AFLORAMIENTO, DURANTE EL VIAJE DE INSPECCION	N.E.
3	MISAHUALLI	NAPO	LIGNITA + INCLUSIONES DE AMBAR	ESTUDIO PRELIMINAR Y COLECCION DE INFORMACION	N.E.
4	MERA	PASTAZA	TURBA	AFLORAMIENTOS DESCUBIERTOS DURANTE EL VIAJE DE INSPECCION	N.E.
5	RIO BLANCO	PASTAZA	GRAFITO	INFORMACION ESCASA, INDICIOS EN AFLORAMIENTOS	N.E.
6	EL DERRUMBO	CHIMBORAZO	LIGNITO	INFORMACION ESCASA	N.E.
7	PALMIRA	CHIMBORAZO	LIGNITO	N. IF.	N.E.
8	BIBLIAN	CAÑAR	LIGNITO	INFORMACION ESCASA, PROSPECCION NO DETALLADA	OPERACIONES EN PEQUEÑA ESCALA
9	NABON	AZUAY	LIGNITO	N.IF.	N.O.
10	CARBONCILLO	LOJA	TURBA	N.IF.	N.O.
11	PICHIG[illegible]	LOJA	GRAFITO	INDICIOS EN AFLORAMIENTOS	N.O.
12	EL TAMBO	LOJA	LIGNITO	INDICIOS EN AFLORAMIENTOS	N.O.
13	LA TOMA	LOJA	LIGNITO	INDICIOS EN AFLORAMIENTOS	OPERACIONES EN PEQUEÑA ESCALA
14	MALACATOS	LOJA	LIGNITO	LA INFORMACION DISPONIBLE ES INCOMPLETA	OPERACIONES EN PEQUEÑA ESCALA
15	LOJA	LOJA	LIGNITO	LA INFORMACION DISPONIBLE ES INCOMPLETA	OPERACIONES EN PEQUEÑA ESCALA

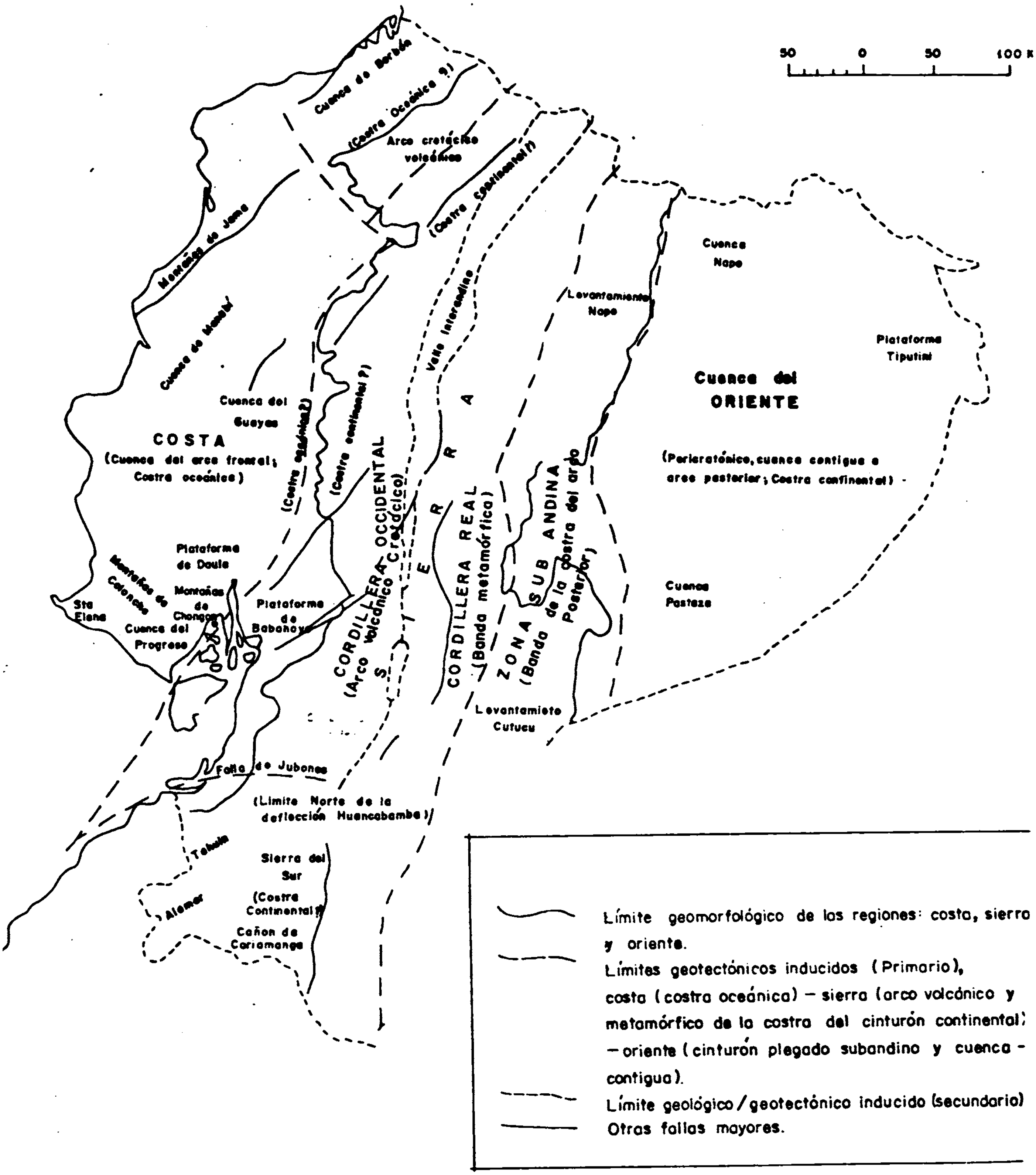
Nº REFERENTE AL MAPA	LOCALIZACION DEL DEPOSITO DE CARBON (TURBA, GRAFITO)	PROVINCIA	TIPO DE DEPOSITO	GRADO DE INVESTIGACION (PROSPECCION, EVALUACION)	GRADO DE DESARROLLO
16	SAN JOSE DE MINAS	PICHINCHA	N.I.	N.IF.	N.O.
17	CAMBALINA	PICHINCHA	N.I.	N.IF.	N.O.
18	QUINCHE	PICHINCHA	N.I.	N.IF.	N.O.
19	NANEGAL	PICHINCHA	N.I.	N.IF.	N.O.
20	CALACALI	PICHINCHA	N.I.	N.IF.	N.O.
21	LLOA	PICHINCHA	N.I.	N.IF.	N.O.
22	MACHACHI	PICHINCHA	N.I.	N.IF.	N.O.
23	ALOAG	PICHINCHA	N.I.	N.IF.	N.O.
24	TANDAPI	PICHINCHA	N.I.	N.IF.	N.O.
25	POMASQUI	PICHINCHA	N.I.	N.IF.	N.O.
26	CHILLOGALLO	PICHINCHA	N.I.	N.IF.	N.O.
27	GUALEA	PICHINCHA	N.I.	N.IF.	N.O.
28	PENIPE	CHIMBORAZO	N.I.	N.IF.	N.O.
29	SANTA CLARA	PASTAZA	N.I.	N.IF.	N.O.
30	RIO CURARAY	PASTAZA	N.I.	N.IF.	N.O.
31	RIO CHONTAYACU	PASTAZA	N.I.	N.IF.	N.O.
32	CANELOS	PASTAZA	N.I.	N.IF.	N.O.
33	PARAMOS DEL CORAZON	COTOPAXI	N.I.	N.IF.	N.O.

N° REFERENTE AL MAPA	LOCALIZACION DEL DEPOSITO DE CARBON (TURBA, GRAFITO)	PROVINCIA	TIPO DE DEPOSITO	GRADO DE INVESTIGACION (PROSPECCION, EVALUACION)	GRADO DE DESARROLLO
34	CUENCA DEL CHIMBO	BOLIVAR	N.I.	N.IF.	N.O.
35	RIO NEGRO	PASTAZA	N.I.	N.IF.	N.O.
36	PEDERNALES	MANABI	N.I.	N.IF.	N.O.
37	F. SAN MATEO	MANABI	N.I.	N.IF.	N.O.
38	PUNTO CENTINELA	GUAYAS	N.I.	N.IF.	N.O.
39	RIO NANGARITZA	ZAMORA	N.I.	N.IF.	N.O.
40	CIUDAD DE ESMERALDAS	ESMERALDAS	LIGNITO	N.IF.	N.O.

N O M E N C L A T U R A

N.I. : Ninguna Identificación
N.IF.: Ninguna Información
N.O. : Ninguna Operación
N.E. : No Explotado

ANEXO 2



Marco general de la geomorfología y geología del Ecuador

ANEXO 3

IMPORTACIONES DE CARBON

(kg)

TIPO DE MINERAL	AÑOS 1979	1980	1981
Antracita	15.731	56.320	115.961
Coques, Semicoque de hulla y Turba	1'240.000	197.582	1'200.700
Carbón de Retorta	124	4.975	96
Alquitrán de Hulla	59.414	66.739	67.681

REVIEW OF U.S. COAL MINING TECHNOLOGY FOR SMALL MINES: APPLICABILITY TO THE COAL DEPOSITS OF THE ANDEAN REGION

by
DR. TONY SZWILSKI, P.E.

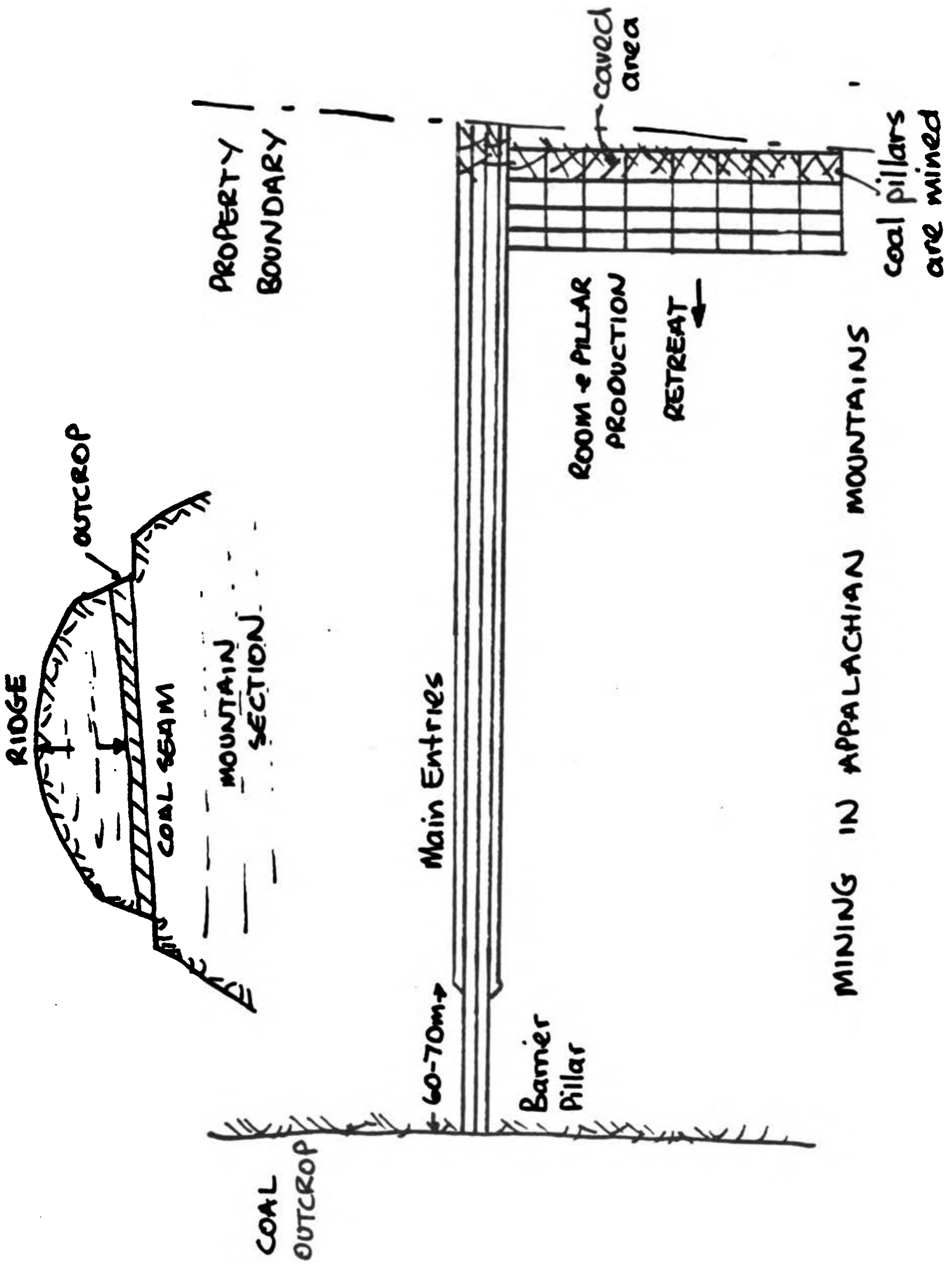
Written for presentation at Cooperative Workshop on the Utilization of coal as an alternative to Petroleum Fuels in the Andean Region

June 24-28, 1985

TITULO: TECNOLOGIA DE MINAS PEQUEÑAS DE CARBON: APLICABILIDAD DE LOS YACIMIENTOS DE CARBON DE LA REGION ANDINA.

OBJETIVO:

- PRESENTAR LA TECNOLOGIA DE MINERIA QUE SE PUEDE APLICAR A LAS MINAS PEQUEÑAS DE LA REGION ANDINA.
- CONSIDERAR LOS FACTORES TECNICOS VARIABLES DE LOS MANTOS DE CARBON Y SU INFLUENCIA AL SISTEMA MINERO, SELECCIONADO PARA CONDICIONES GEOLOGICAS ESPECIFICAS.
- UTILIZAR LAS EXPERIENCIAS DE LAS MINAS CARBONIFERAS EN LAS MONTAÑAS DE APPALACHIA (EE.UU).
- EXAMINAR LAS CIFRAS DE COSTOS Y PRODUCTIVIDAD DEL SISTEMA MINERO DE CAMARA Y PILARES (ROOM AND PILLAR).
- CONSIDERAR LA APLICABILIDAD DE VARIOS SISTEMAS DE MINAS CARBONIFERAS DE LA REGION ANDINA.


PROPERTY BOUNDARY
caved area
coal pillars are mined
ROOM & PILLAR PRODUCTION
RETREAT
MINING IN APPALACHIAN MOUNTAINS
OUTCROP
RIDGE
COAL SEAM
MOUNTAIN SECTION
Main Entries
60-70m
Barrier Pillar
COAL OUTCROP

MINABILIDAD DE LOS MANTOS DE CARBON LOS FACTORES INDEPENDIENTES PRINCIPALES:

- PENDIENTE DEL MANTO DE CARBON
- ALTURA (POTENCIA) DEL MANTO (Y VARIABILIDAD)
- CONTINUIDAD Y TAMAÑO DE LAS RESERVAS DE CARBON
- PROFUNDIDAD DE LOS MANTOS
- COMPETENCIA DEL PISO
- CANTIDAD DE LIBERACION DEL METANO
- DUREZA DEL CARBON
- PRESENCIA DEL AGUA

FACTORES PRINCIPALES DE DISEÑO

- TAMAÑO DE LOS PILARES
- ANCHURA DE LAS GALERIAS
- PORCENTAJE (RENDIMIENTO) DE EXTRACCION DEL CARBON
- LARGO DEL CORTE (AVANCE) DE LA MAQUINA (CONTINUOUS MINER) DURANTE LA EXTRACCION DE CARBON

OPTIMA PRODUCCION DE LA MAQUINARIA DEPENDE:

- ALTURA (POTENCIA) DEL MANTO
- DUREZA DEL CARBON
- VETAS DE ROCA UBICADAS EN EL MANTO MISMO
- AVANCE PERMITIDO DE LA MAQUINA MINERA ANTES DE COLOCAR LOS PERNOS
- HABILIDAD DE LOS OPERADORES

LA PRODUCCION MAXIMA CON CONDICIONES IDEALES:

- 1800 MT POR TURNO

COSTS OF PRINCIPAL MINING EQUIPMENT FOR ONE UNIT OPERATION (PURCHASED IN U.S.):

CONTINUOUS MINING UNIT

	Cost, $
• 1 x CONTINUOUS MINER	550,000
• 3 x SHUTTLE CARS (3 x $135,000)	405,000
• ROOF BOLTER	150,000
• FEEDER BREAKER	80,000
• LOAD CENTRE (1000 KVA)	50,000
TOTAL	$1,235,000

CONVENTIONAL MINING UNIT (BLASTING FROM SOLID COAL)

	Cost, $
• 3 x BATTERY SCOOPS (3 x $105,000)	315,000
• BATTERIES/CHARGER (3 x $20,000)	60,000
• ROOF BOLTER	150,000
• FEEDER BREAKER	80,000
• LOAD CENTRE	50,000
TOTAL	$655,000

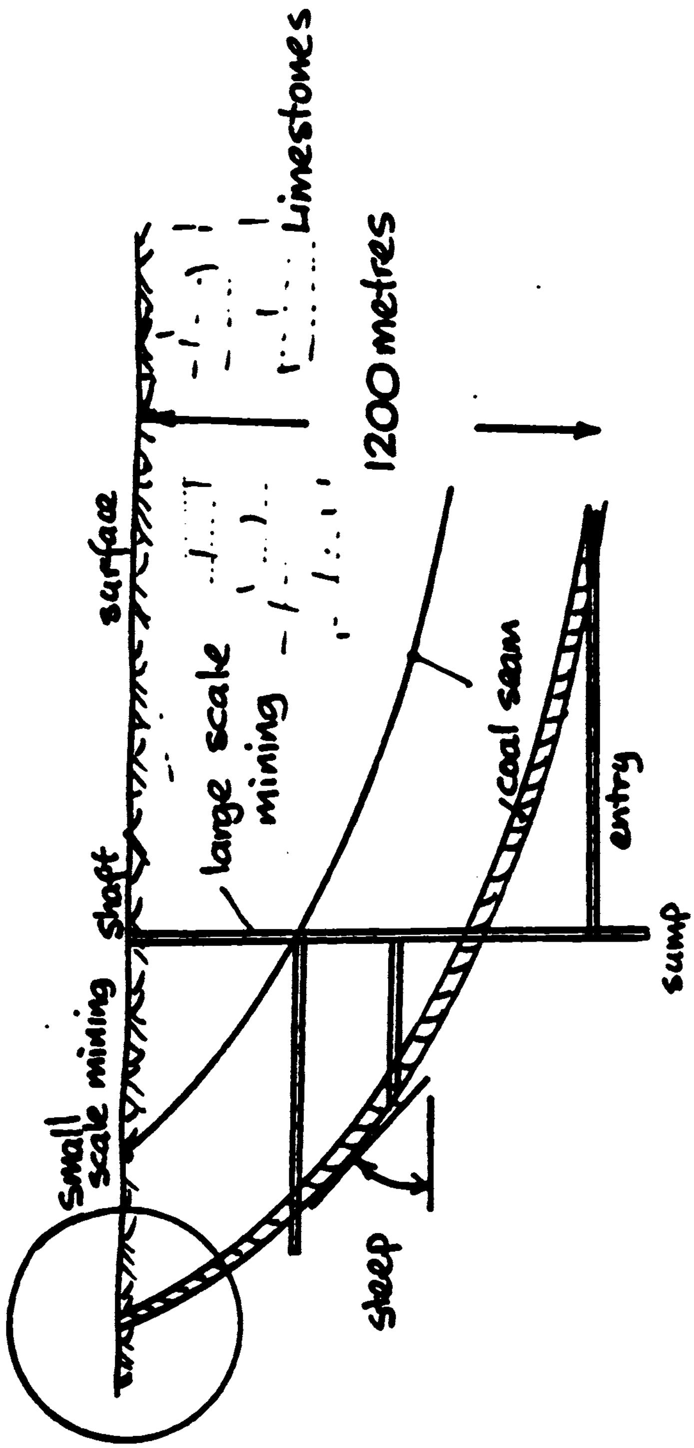
Note:
These figures do not include site preparation, installation and ancillary equipment costs.

MINAS DE ANTRACITA EN LAS MONTAÑAS DE APPALACHIA:

- PROFUNDIDAD DE LOS MANTOS: 61 A 305 METROS
- POTENCIA DE LOS MANTOS: 0.6 A 6.1 METROS
- ANCHURA DE LAS GALERIAS: 2.4 A 3 METROS
- AVANCE DEL CORTE (PRODUCCION): 2.4 A 3 METROS
- PRODUCTIVIDAD: 50 A 250 MT POR TURNO
- MINEROS: 3 A 4
- SOPORTE DE MADERA (NO HAY PERNOS)

FACTORES QUE INFLUYE LA EFICIENCIA DE EXTRACCION (CARBON):

- RESERVAS DE CARBON Y PROBABILIDAD DE EXTRACCION
- CONDICIONES GEOLOGICAS: POTENCIA DE LOS MANTOS
- CAPACIDAD Y MOTIVACION DE LOS OPERADORES (MINEROS)



JATUNHUASI COAL DEPOSIT (simplified)

CONTENTS

INTRODUCTION

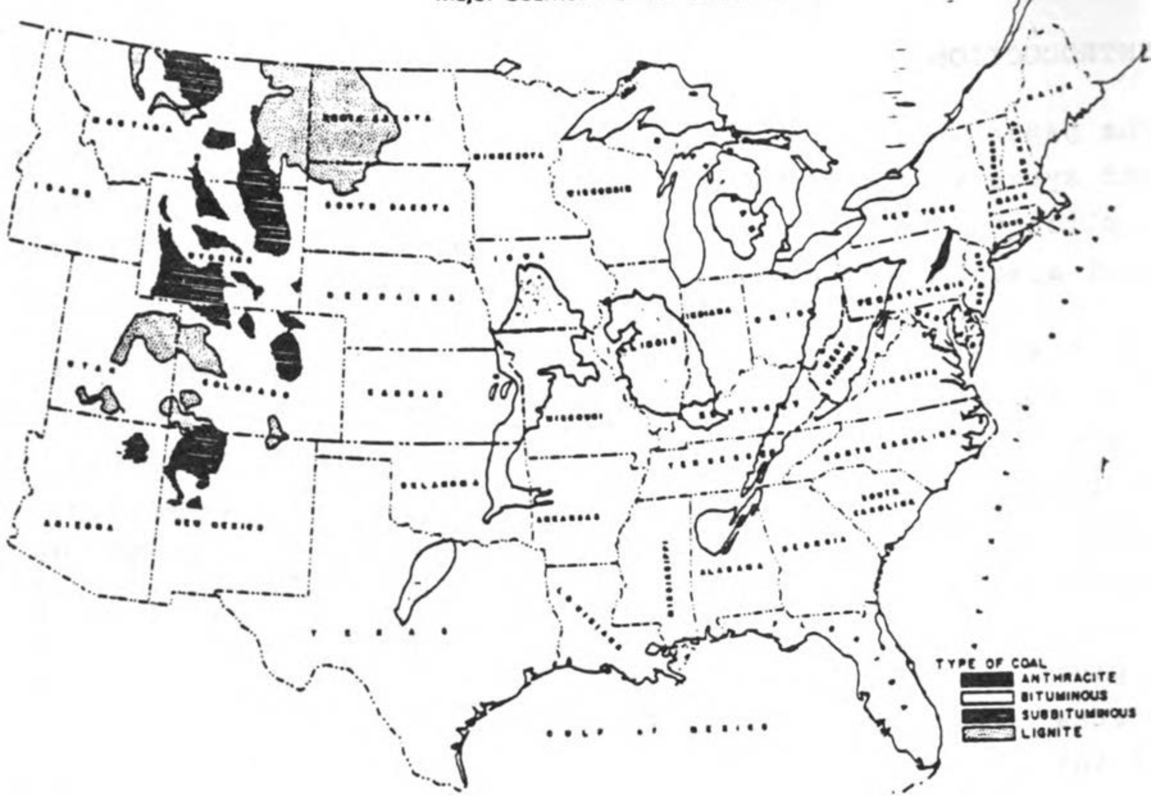
The paper will focus on the state of the art coal mining technology and systems in small medium sized underground mines, and the possible application to the coal deposits of the Andean Region. A brief review will also be made of surface mining of coal deposits.

Obviously, the mining conditions in the Andean Region is a lot different from those of the Appalachian Mountains. The Andean Region has substantial deposits of Lignite, Bituminous and Anthracite coal but the geological conditions have made the coal deposits discontinuous and generally difficult to mine, especially by mechanized methods. Whereas, the Appalachian mountains has good quality bituminous coal that is relatively easy to mine, with 2 metre thick and flat coal seams being typical. Figure 1 shows the location of coal deposits in the United States and the Appalachian Mountain Region in particular. The coal of Eastern Kentucky has an average calorific value of 13,540 Btu; Sulfur 1.2%; Ash 8.9%.

Although the geological and economic condition of the Andean Region are generally considerably different than those of the Appalachian Region, there are many practical mining operational experiences that may be of benefit to the miners of the Andean Region. Unquestionably, the mines and geologists of the Andean Region are the experts of their mining conditions and as such, are in the best position to evaluate and decide on the applicability of outside technology and systems for their coal mines.

The Room and Pillar mining method is the most productive and popular mining method in the Appalachian Region; both continuous mining machines and blasting/loading methods (Conventional) are used. However, mechanized Room and Pillar mining is suitable only for coal seams of inclination less than 20°. Mechanized mining operations will be described for bituminous coal seams of thickness 0.76 metres to 3.05 metres.
Anthracite is also mined in Northern Pennsylvania, see Figure 1. The traditional methods used to mine the steep coal seams are outlined in the case study section.

Major Coalfields of the United States



Distribution of Coal in the Eastern United States

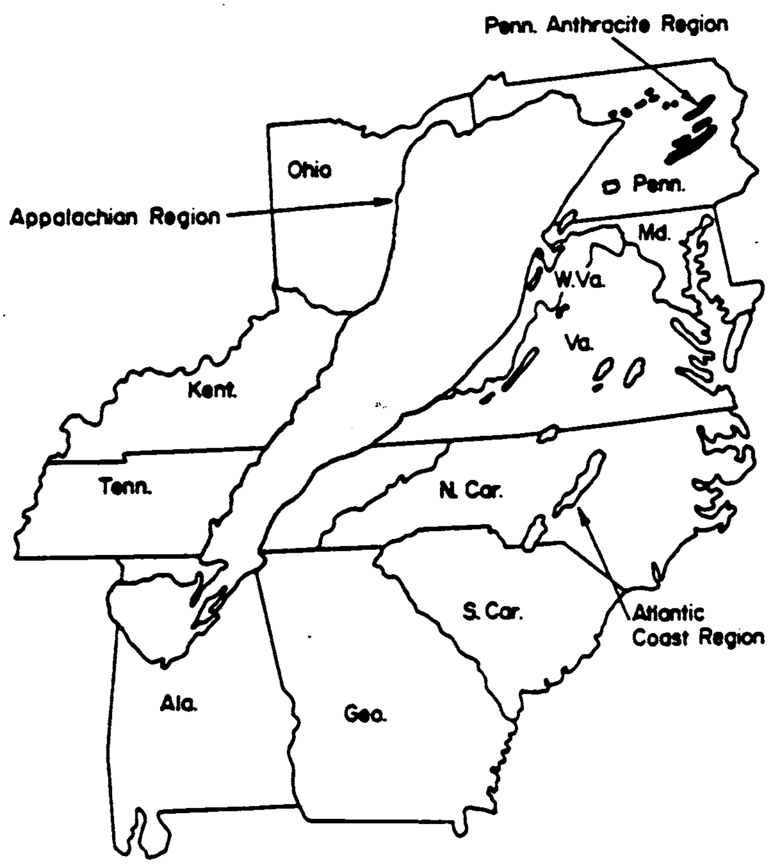


Figure 1

CHAPTER I

MINEABILITY OF COAL SEAMS

Before a mining method is chosen the mining variables, associated with the coal seam to be developed, must be examined.

The principal independent mining variables are:

- Dip of coal seam
- Seam height (and variability)
- Continuity and size of coal reserves
- Depth of coal seam
- Competence of floor
- Degree of methane liberation
- Hardness of coal seam (rank)
- Presence of water

Many of these mining variables are interrelated combine to define the MINEABILITY of a coal seam. For example, the hardness of coal, presence of water and degree methane liberation are often a function of the depth of coal seam. Also, free running water may directly or indirectly affect the competence of the roof and floor rocks. In choosing a production system and mining equipment all these factors must be considered in the design details.

Principal Design Features

- Pillar Sizes
- Widths (span) of entries
- Percentage recovery (retreating?)
- Roof support techniques
- Depth of cut.

The depth of cut, for example, together with the height and width, affects the loading and hauling efficiency of the coal production system. The height of cut is dependent on the coal seam height, and the width of cut is a function of the competence of the roof.

CLASSIFICATION OF INDEPENDENT MINING VARIABLES

HEIGHT OF COAL SEAM

- less than 1.0m
- 1.0 to 1.4m
- 1.4 to 2.5m
- 2.5 to 4.6m
- greater than 4.6m

FLOOR QUALITY

- Excellent: smooth, hard dry with grades less than 1½%
- Good: smooth, soft, dry, grades < 3%; possibilty of floor heave; cautious mining operations required to maintain competence of floor
- Fair: soft, damp; may interfere with equipment operation, requiring use of four wheel drive shuttle cars, floor ruts with regular use, grades 5 to 7% occasional steep rolls.
- Poor: soft, wet; requires floor pads to support equipment; grades > 7%; frequent steep rolls.

ROOF QUALITY

- Excellent: No roof falls; no roof support required during initial production cycle.
- Good: No roof falls, bolting pattern 1.2m x 1.2m or 1.5m x 1.5m required, with bolt lengths ≤ coal seam height; use of wooden posts, without bolts on 1.2m x 1.2m or 1.5m x 1.5m pattern.
- Average: Occassional roof falls: ≥ seam height ≮ 2m; also a good roof that is difficult to drill.
- Fair: Frequent spot bolting in addition to the regular bolt pattern required; shorter or narrower cuts required.
- Poor: Roof fall certain without cave support; combination of bolts, crossbars, posts; yielding supports; truss-type support.

DEPTH OF COAL SEAM

- Shallow: < 60m
- Moderate-shallow: 90 to 120m
- Moderate: 135 to 270 m
- Deep: 240 to 900m
- Very Deep: > 1,000m

HARDNESS OF COAL SEAM

- Soft: Easily cut by continuous miner; can use plow for longwall.
- Average: Easily cut by miner; use shearer for longwall.
- Hard: Difficult cutting for miner unless the lacing (pattern), angles and sharpness of bits are well maintained; slower cutting rate.
- Very Hard: Significant thickness of rock partings; barely cut by miner.

DEGREE OF METHANE LIBERATION

- None: No methane detected.
- Low: No methane build up at the coal face even with minimum ventilation requirements.
- Moderate: Curtains maintained tight; tubing close to face without these precautions the methane concentration may increase to 1%.
- High: Methane concentration will increase to 1% if miner is operated at the normal rate, even with correct ventilation precautions.

PRESENCE OF WATER

- Dry:
- Damp: Floor damp, no standing water.
- Wet: Water collects in pools to depths of ≤ 0.3m (0 to 0.15m for coal seams < 1m); runs to or from coal face.
- Flooded: Water collects > 0.3m depth.

A production system now can be chosen that best suites the mining conditions or variables.

Example: A continuous miner would require the following minimum mining conditions to be able to operate well:

SEAM HEIGHT: 1.4 to 2.5m
FLOOR QUALITY: Good, less than 10%
ROOF QUALITY: Fair
DEPTH OF COAL SEAM: 90 to 120m
HARDNESS OF COAL SEAM: Hard*
DEGREE OF METHANE LIBERATION: Low
PRESENCE OF WATER: Dry

* A HARD coal seam gives greater coal recovery as coal pillars can be small. However, of less importance, coal is more difficult to cut by machine.

	Mining Variables		
MINING METHOD	Depth, Metres	Dip	Thickness, Metres
Room and Pillar			
• Conventional	→ 700	→ 15°	1-6
• Continuous	→ 800	→ 18°	0.7-5
Shortwall	→ 850	→ 10°	1.8-3.5
Longwall			
• Advance	→ 1500	0-70°	0.5-4
• Retreat	→ 850		
Hydraulic	*	8-90°	2.5 +
Open Stopes	*	45-90°	*

* Insufficient practical data to determine limits of mining coal seams.

Transport System		Dip
Rope Haulage	• Direct Rope	10-90°
	• Endless/Main and tail	0-90°
Locomotives (special)		8°
Rubber Tired Equipment		0-15°
Cat Track Equipment		0-28°
Belt Conveyors		0-18°
Hydraulic Conveyors		8-90°

PRINCIPAL MINING VARIABLES THAT DETERMINE THE APPLICABILITY OF MECHANIZED COAL MINING METHODS TO COAL SEAMS.

GRADE	
%	Degrees
6	3.4
8	4.6
10	5.7
12	6.9
14	8.1
16	9.2
18	10.4
20	11.5
25	14.5
31	18.0

COAL MINE DEVELOPMENT

Assuming that the coal property to be developed is suitable for mining, there are a few initial considerations that need to be taken into account prior to opening the mine.

Location of Portal

The selection of the portal site is influenced by:

- method of access
- method of mine ventilation
- type of haulage system
- life of the coal mine

The portal area should be free of the danger of flooding (low areas) and be close to the center of the coal properties, to be mined, minimizing the costs of power distribution, ventilation, water drainage and coal haulage. The portal should be as near as possible to highways and coal transportation terminals.

Type of Portal

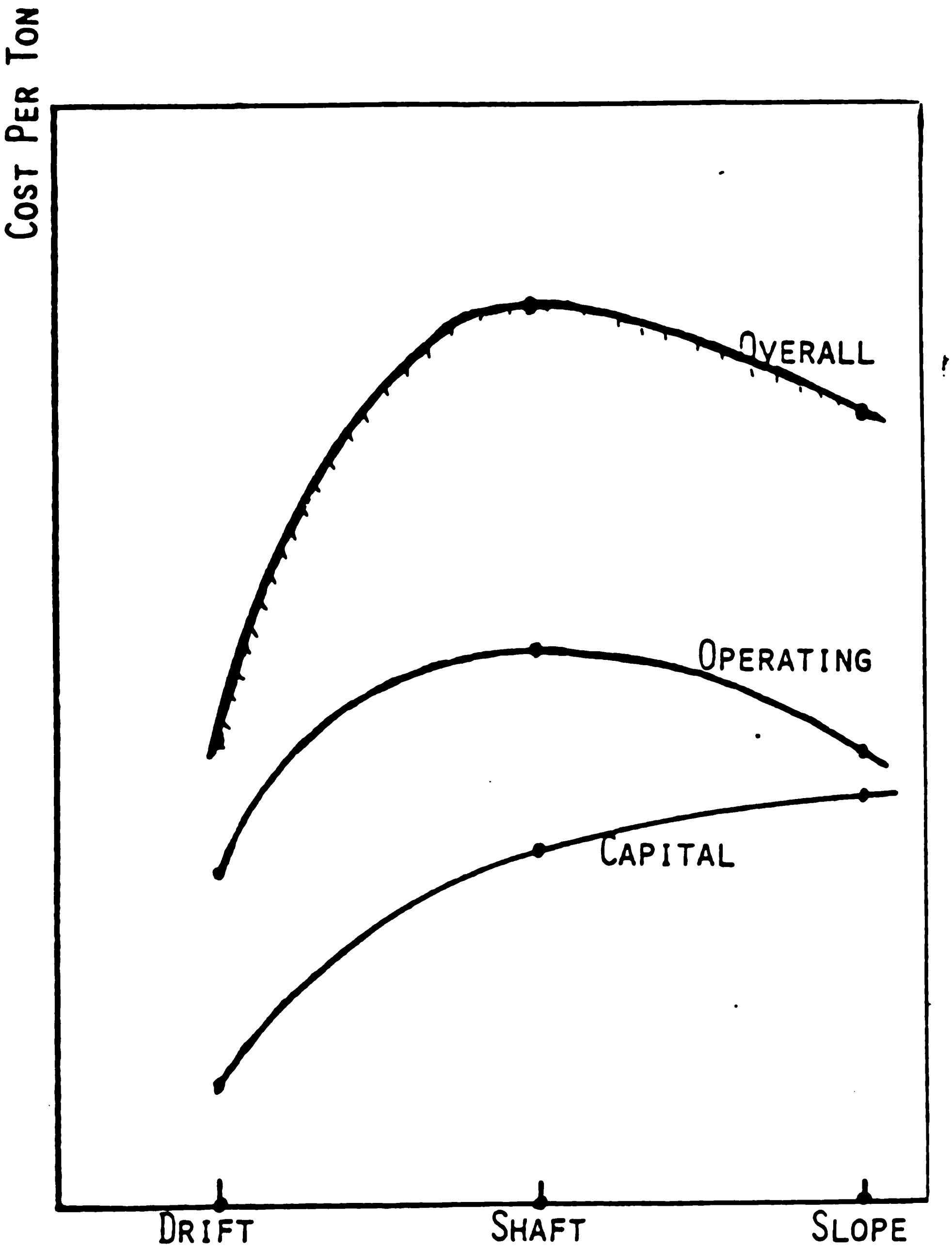
The type of mine entrance depends on access to and size, shape number and depth of coal seams.

The three main types are:

- drift
- shaft
- slope

The drift is the most convenient for mining purposes, but is limited to outcropping coal seams. The drift would be especially suitable for small underground operations working in small or irregular coal deposits.

The vertical shaft provides the least length of portal from the surface to the coal seam, minimizing the materials required for linings and equipping the shaft. Shafts are particularly advantageous for mine ventilation. (See Figure 2)



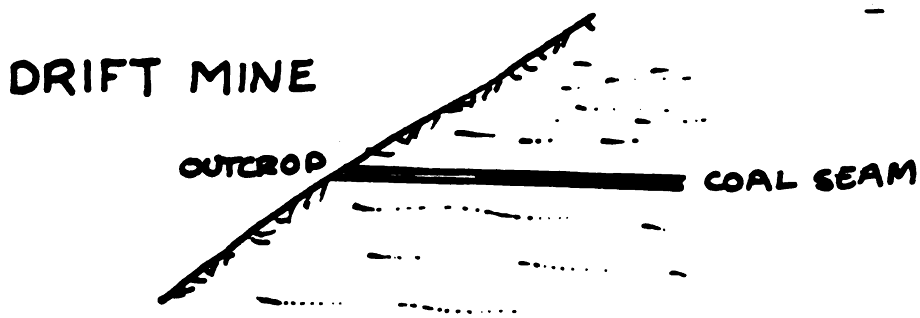
ECONOMIC ANALYSIS OF TYPE OF MINE PORTAL AT MEDIUM DEPTH FOR HIGH-TONNAGE, LONG-LIFE MINE

FIGURE 2

CHAPTER II: ROOM AND PILLAR MINING

CONTINUOUS MINING

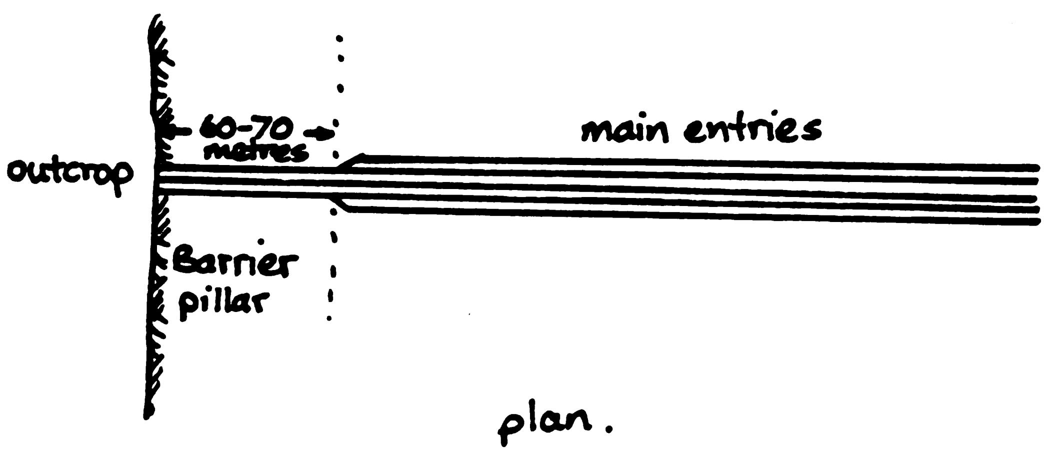
Initial Coal Mine Development



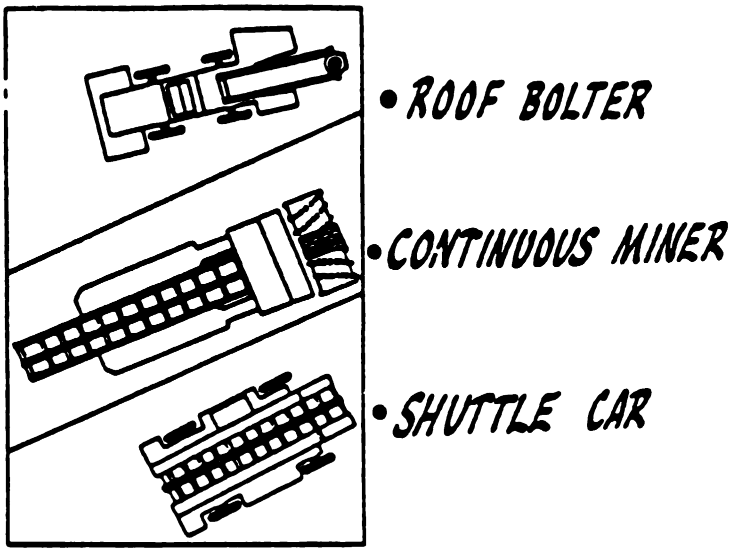
The DRIFT MINE is the simplest and most economical mining method. There are over 2,000 small mining operations that are typically family owned having one unit (one mining machine/section).

MULTIPLE ENTRIES are developed from the coal outcrop inbye to the other end of the property line. The number of entries depends on the ventilation requirements of the mine.

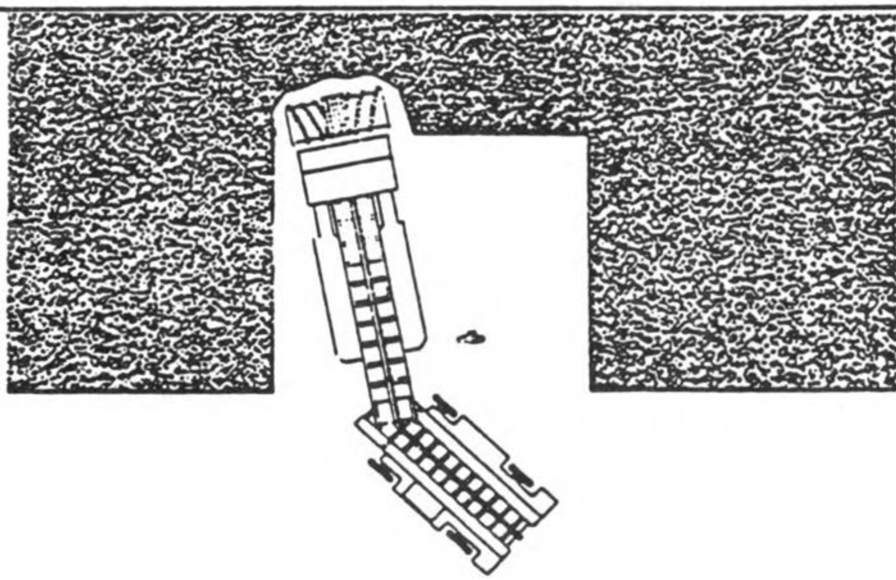
Generally, three entries are developed into the coal seam. At about 60 to 70 metres inbye extra entries are added.
A barrier pillar (of coal) is left between the outcrop (hillside) and the MAIN ENTRIES. Therefore, a small number of entries (in this case three) developed so that the overlying rocks are not disturbed.



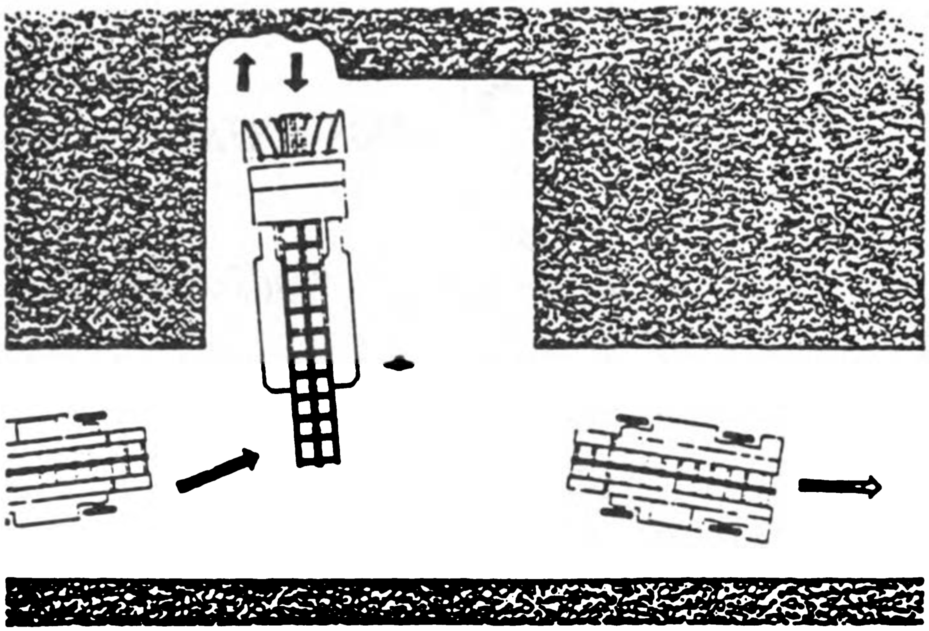
This procedure is outlined in greater detail in the CASE STUDIES that are presented later in the report. (Chapter III)



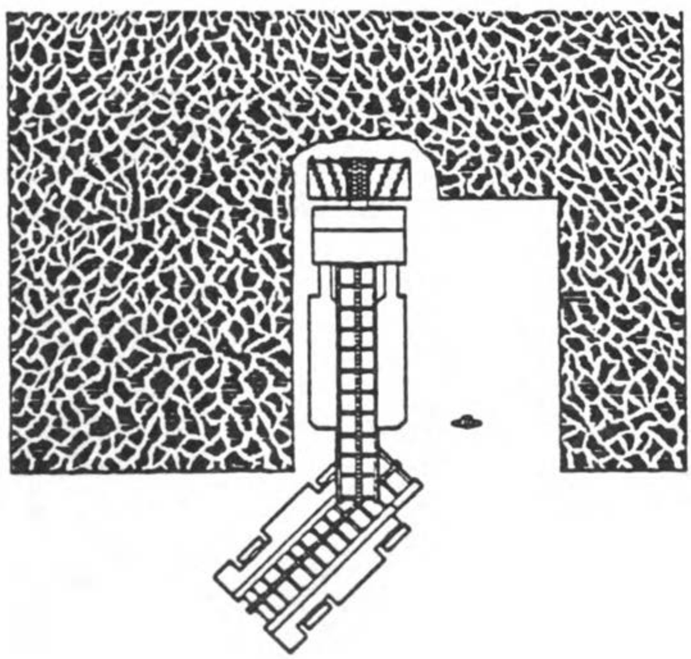
Now you will see the basic operations of continuous mining. During the continuous mining procedures, only three types of equipment are needed--the continuous miner, which rips the coal from the face and the shuttle cars which haul the coal to the main haulage system. After the continuous miner finishes the face cut and moves to a new face, it is followed by the roof bolter. The roof bolting operation that takes place in continuous mining is the same operation you have already seen take place in conventional mining.



After tramming to the face, the continuous miner enters into the face on the left, and mines the coal which is then brought back to a shuttle car.



Shuttle cars enter from one direction--another moving in after one has been loaded and has moved out.



The continuous miner can mine into the face only as far as the operator is under supported roof. Then the roof bolter must come in to provide support.

From the main entries, panel entries are developed. Barrier pillars are usually left between the working sections. The room and pillars are developed and the coal pillars extracted in a following operation. A system of BLEEDER entries are left around the perimeter of the working panels. The bleeders allow the waste gas products from the waste/gob areas to filter out of the mine through the return air entries. The typical mine layout is shown in Figure 3.

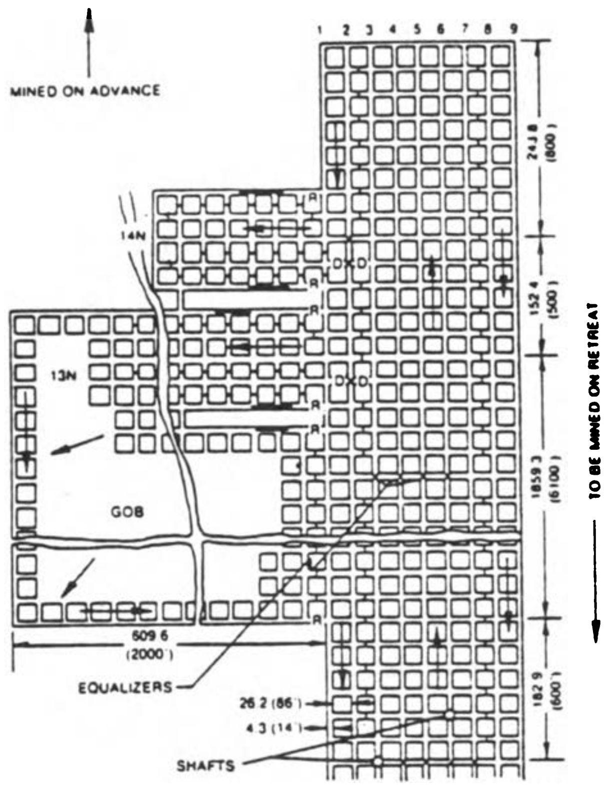


Figure 3

Pittsburgh block room-and-pillar slicing system

The WIDTH OF ENTRIES generally vary between 5 to 6.1 metres. The Mines Safety and Health Administration (MSHA) prohibits entries wider than 6.1 metres, from rock mechanics principles, the wider the entries, the less stable the roof.

Advance/Retreat Mining

Whether a coal mine can retreat i.e. extract the coal pillars, depends on whether surface subsidence can be permited.

As the working sections (panels) are advanced/developed about 40 to 50% of the coal is extracted.

If retreating is allowed, the extraction of the coal pillars yields a recovery of 70 to 85%.

Figure 4 shows the development of the MAIN ENTRIES using a continuous mining machine.

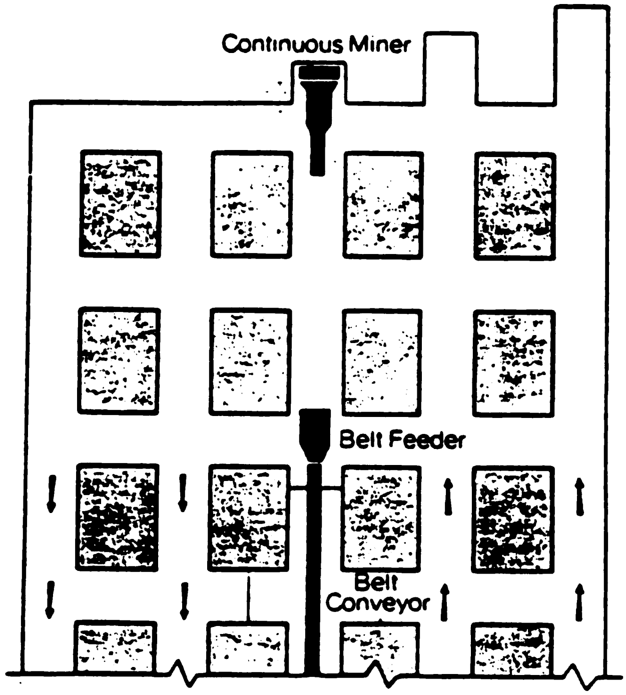


Figure 4

Typical five-heading development plan

Figure 5 shows the room and pillar working section (panels) that are developed (turned-off) from the main entries.

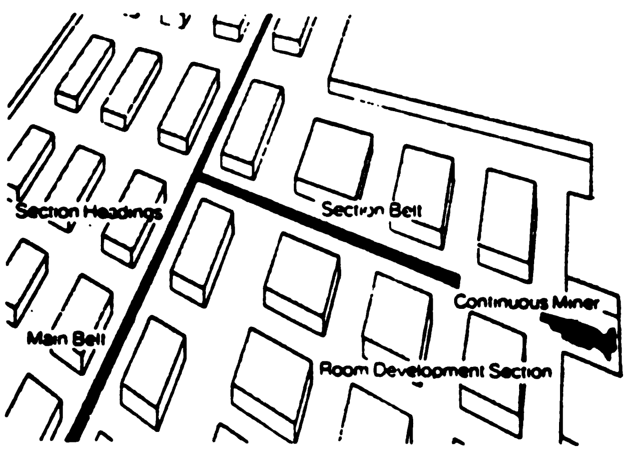


Figure 5

Typical room development section for room-and-pillar mining.

Figure 6 shows the continuous miner extracting the coal pillars in the RETREAT OPERATION.

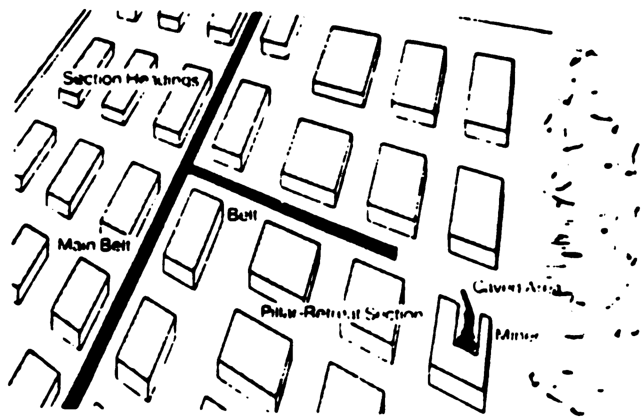


Figure 6

Typical method of pillar removal in room-and-pillar mining.

METHODS OF RETREAT MINING

There are numerous methods of coal pillar extraction (retreat). Figure 7 gives some examples of these methods.

Continuous Mining Machine (Miner).

The most recent cost figures obtained from Joy Manufacturing for continuous mining equipment, 3rd May 1985.

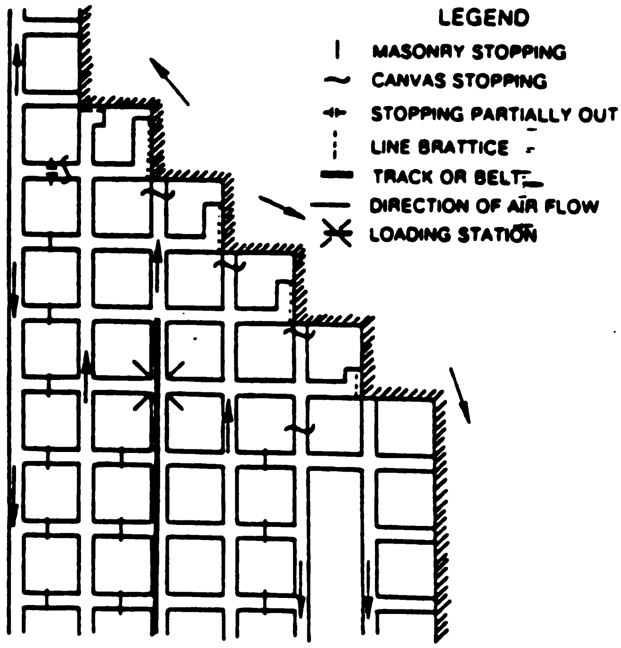
- 15CM Continuous Miner $550,000
- 21SC2 Shuttle Car $135,000
- RBD-8 Roof Bolter $150,000
- Feeder Breaker $80,000
- Load Centre (1000 KV) $50,000

Table 1 gives a list of specifications for various continuous miners.

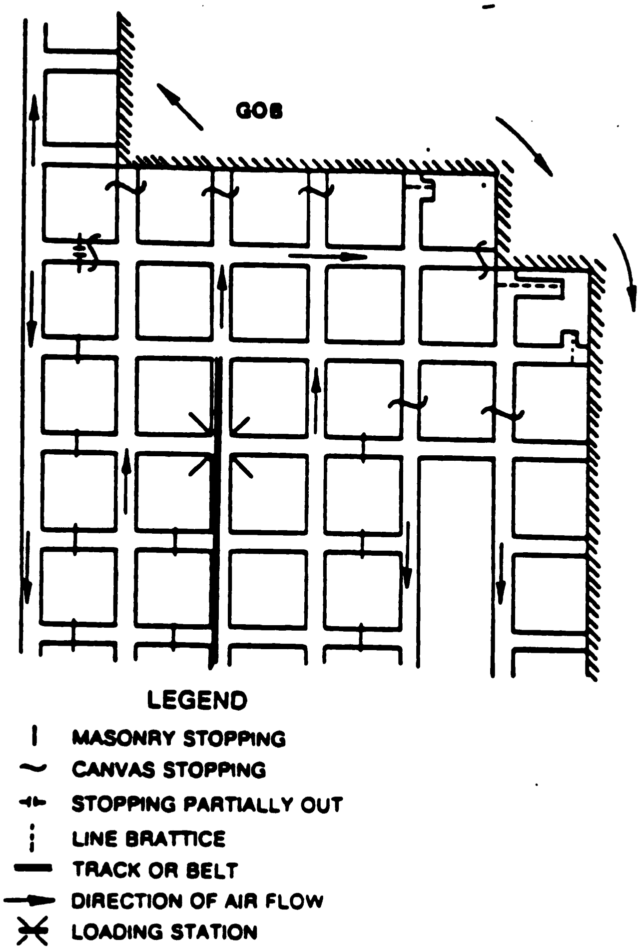
Table 1. Comparative Specifications for Continuous Mining Machines

Model	Weight, kg (lb)	Chassis Height, mm (in.)	Cutting Height Range, mm (in.)	Overall Length m (ft)	Chassis Width, m (ft)	Cutting-Head Width, m (ft) †
*101MC	20 480 (45 180)	610 (24)	760-1220 (30-48)	9.69 (31.8)	2.60 (8.6)	3.05 (10.0)
12OL	36 000 (80 000)	710 (28)	970-1980 (38-78)	10.03 (32.9)	2.74 (9.0)	3.35-4.72 (11.0-15.5)
12OM	43 000 (95 000)	940, 990 (37, 39)	1190-2340 (47-92)	10.05 (33.0)	2.56 (8.4)	3.29-4.57 (10.8-15.0)
12OH	46 000 (102 000)	1170 (46)	1420-3050 (56-120)	9.98 (32.8)	2.65 (8.7)	3.29-4.57 (10.8-15.0)
12OHR	59 100 (130 400)	1520 (60)	1780-2970 (70-117)	10.18 (33.4)	2.77 (9.1)	3.29-4.57 (10.8-15.0)
11CM-1A	36 000 (80 000)	810 (32)	1070-2290 (42-90)	10.49 (34.4)	2.51 (8.3)	3.29 (10.8)
11CM-2A	37 300 (82 300)	910 (36)	1170-2440 (46-96)	10.55 (34.6)	2.51 (8.3)	3.29 (10.8)
12CM3	41 000 (90 000)	910, 1020 (36, 40)	1170-3050 (46-120)	10.00 (32.8)	2.59 (8.5)	3.29-4.72 (10.8-15.5)
12CM4	43 000 (96 000)	1270 (50)	1520-3660 (60-144)	10.00 (32.8)	2.97 (9.75)	3.29-4.72 (10.8-15.5)
12CM5	36 000 (80 000)	910, 2030 (36, 80)	1170-3050 (46-120)	10.00 (32.6)	2.44 (8.0)	2.62-3.05 (8.6-10.0)
12CM11	38 700 (87 500)	910, 1020 (36, 40)	1170-3660 (46-144)	10.00 (32.8)	2.59 (8.5)	3.29-4.72 (10.8-15.5)
14CM3	36 000 (78 000)	660 (26)	890-1830 (35-72)	9.94 (32.6)	2.83 (9.3)	3.35 (11.0)
14CM4	36 000 (78 000)	640 (25)	890-1830 (35-72)	9.94 (32.6)	2.83 (9.3)	3.35 (11.0)
14CM5	35 000 (78 000)	690, 760 (27, 30)	940-2290 (35-90)			3.29 (10.8)
*15CM	29 300 (62 500)	560 (22)	810-1830 (32-72)		*2.19 (7.2)	2.63-3.05 (8.66-10.0)
12HM	46 000 (102 000)	1120 (44)	1370-3660 (54-144)	10.24 (33.7)	2.44 (8.0)	2.59 (8.5)
CM245	24 000 (52 000)	610 (24)	860-1370 (34-54)	9.65 (31.7)	2.54 (8.3)	3.05 (10.0)
CM285	30 000 (66 000)	710 (28)	970-1980 (38-78)	10.03 (33.9)	2.66 (8.8)	3.05 (10.0)
CM295E	30 000 (66 000)	710 (28)	970-1980 (38-78)	10.03 (32.9)	2.66 (8.8)	3.05 (10.0)
HM265	31 000 (68 000)	790 (31)	1040-1930 (41-76)	9.89 (32.4)	3.12 (10.8)	3.28 (10.75)
HM386	37 000 (82 000)	970 (38)	1220-2970 (48-117)	10.08 (33.1)	2.21 (7.3)	2.44 min (8.0 min)
HM106	38 500 (85 000)	970 (38)	1220-3070 (48-121)	10.08 (33.0)	2.51 (8.3)	2.94 (9.66)
HM115	39 500 (87 000)	1240 (49)	1500-3580 (59-141)	10.13 (33.3)	2.44 (8.0)	2.94 (9.66)
HM455	44 000 (97 000)	1350 (53)	1600-3250 (63-128)	10.73 (35.2)	2.62 (8.6)	3.15 (10.33)
HM606	46 000 (102 000)	1780 (70)	2030-4270 (80-168)	10.69 (35.1)	2.66 (8.6)	3.12 (10.25)
3080LP	39 400 (86 000)	970 (38)	1220-2440 (48-96)	10.12 (33.2)	2.66 (8.8)	3.35 (11.0)
3080HP	39 600 (87 400)	1300 (51)	1550-2440 (61-96)	10.12 (33.2)	2.66 (8.8)	3.35 (11.0)
5012N	50 000 (110 000)	1100 (43)	1350-3660 (53-144)	10.18 (33.4)	2.59 (8.5)	2.59 (8.5)
5012S	45 000 (100 000)	1300 (51)	1550-3660 (61-144)	10.21 (33.5)	2.38 (7.8)	2.59 (8.5)
Mark20PJ		660 (26)	760-1270 (30-50)	7.32 (24.0)	2.29 (7.5)	Variable Variable

* Mining machines so designated are operated only by SDRC
† Cutting-head widths are specified for single-pass operations

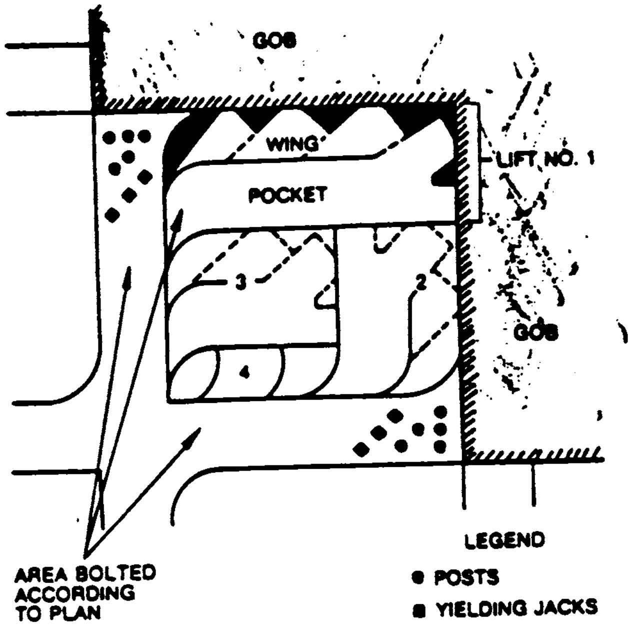


Pillar extraction on a 0.78 rad (45°) angle.

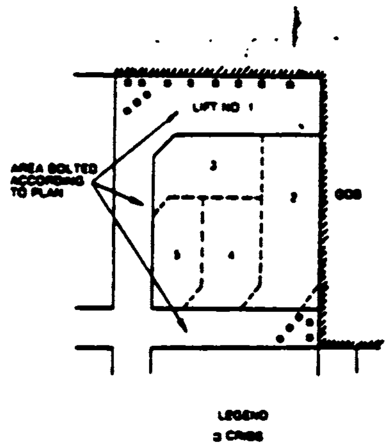


Pillar extraction on a flat rib line.

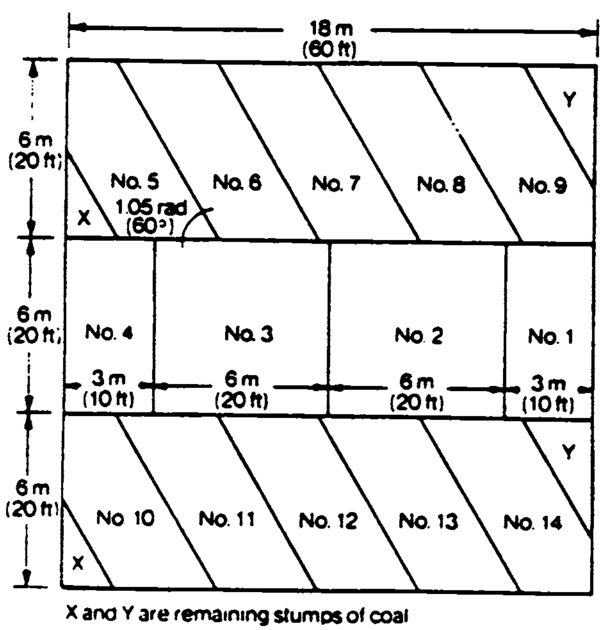
Figure 7 (a)



Detail sequence of extraction of a block of coal by the pocket-and-wing system.



Detail sequence of mining a pillar by the open-end system. Instead of cribs, many mines employ clusters of posts or multiple rows of posts.



X and Y are remaining stumps of coal

Typical plan for the extraction of a pillar.

Figure 7 (b)

Coal Seam Heights

Most of the mines in the United States operate in the range 0.89 to 6.1 metres. Seam heights above 3.66 metres require MULTIPLE PASSES. In Eastern Kentucky some success has been achieved in low coal seams of about 0.76m, especially with hard floors. Mining thin/low coal seams continues to be a large problem in Eastern Kentucky as billions of tons of coal reserves are in thin coal seams.

Width of Entries (coal face).

The continuous miner can mine narrow entries of 3.3 to 4.7m, in a single pass. This is usually done in areas of bad roof conditions. The majority of the mines use continuous mining machines with cutter-head widths of 2.4 to 3.4 m. Multiple passes are made to mine the coal face of 4.9 to 6.7m width.

Machine cutting and Loading

Maximum machine production rates depends on:

- SEAM HEIGHT
- HARDNESS OF COAL
- DIRT (ROCK) BANDS
- DEPTH OF PENETRATION (SUMP)
- OPERATORS SKILL

Maximum coal production rates have been measured at up to 13.6 to 18.1 mt/min.

Typically the continuous miner will mine a total of 1½ hours in an 8 hour shift i.e. about 19% of the available time. Under ideal conditions, a continuous mining section has produced over 1800mt per shift (one machine). But this is under ideal conditions as the average production is much lower.

However, in order to assure a high average production 'PEAK PRODUCTION RATES OF AT LEAST TWICE THE REQUIRED AVERAGE' must be attained.

Bit-Tip Speed, m/s (fpm)	Total Advertised Power kW (hp)	Traction Drive for Mining	Traction Drive for High Speed	Traction Ground Pressure, kPa (psi)	Ground Clearance mm (in.)
2.59 (510)	210 (285)	Hydraulic Cylinder Sump	----	165 (24.0)	152 (6)
3.84 (755)	330 (450)	Mechanical Clutch	Mechanical Clutch	181 (26.3)	127 (5)
2.87-3.89 (565-765)	410 (550)	Hydraulic	Mechanical Clutch	207 (30.0)	178-229 (7-9)
2.87-3.89 (565-765)	450 (600)	Hydraulic	Mechanical Clutch	207 (30.0)	229 (9)
1.86 (366)	450 (600)	Hydraulic	Mechanical Clutch	248 (36.0)	279 (11)
3.02 (595)	400 (535)	Electric, ac	Electric, ac	172 (25.0)	152 (6)
2.97 (585)	400 (535)	Electric, ac	Electric, ac	176 (25.5)	254 (10)
3.02 (596)	400 (535)	Electric, dc	Electric, dc	172 (25.0)	229-330 (9-13)
3.02 (595)	400 (535)	Electric, dc	Electric, dc	186 (27.0)	330 (13)
2.99 (588)	280/340 (375-455)	Electric, dc	Electric, dc	152 (22.0)	229-330 (9-13)
2.87 (565)	400 (535)	Electric, dc	Electric, dc	169 (24.5)	229-330 (9-13)
2.27 (446)	260 (350)	Electric, dc	Electric, dc	157 (22.8)	152 (6)
2.97 (585)	260 (350)	Electric, dc	Electric, dc	157 (22.8)	152 (6)
2.97 (585)	330/390 (440-520)	Electric, dc	Electric, dc	157 (22.8)	152-229 (6-9)
3.23 (635)	250/280 (340-380)	Electric, ac	Electric, ac	152 (22.0)	152 (6)
3.36 (662)	400 (535)	Electric, dc	Electric, dc	193 (28.0)	318 (12.5)
3.18 (625)	220 (290)	Hydraulic	Hydraulic	124 (18.0)	152 (6)
2.97 (585)	320 (425)	Hydraulic	Hydraulic	138 (20.0)	152 (6)
2.97 (585)	280 (385)	Electric, ac	Electric, ac	138 (20.0)	152 (6)
2.65 (522)	220 (300)	Hydraulic	Hydraulic	141 (20.5)	165 (6.5)
2.54 (500)	340 (450)	Hydraulic	Hydraulic	172 (25.0)	178 (7)
2.54 (500)	340 (450)	Hydraulic	Hydraulic	179 (26.0)	178 (7)
2.54 (500)	340 (450)	Hydraulic	Hydraulic	186 (27.0)	279 (11)
2.77 (545)	340 (450)	Hydraulic	Hydraulic	196 (28.5)	279 (11)
2.77 (545)	340 (450)	Hydraulic	Hydraulic	210 (30.5)	279 (11)
2.74-3.07 (540-585)	370 (500)	Electric, ac	Electric, ac	193 (28.0)	152 (6)
3.18 (625)	370 (500)	Electric, ac	Electric, ac	193 (28.0)	229 (9)
3.18 (625)	370 (500)	Electric, ac	Electric, ac	193 (28.0)	229-305 (9-12)
3.18 (625)	370 (500)	Electric, ac	Electric, ac	172 (25.0)	229 (9)
3.18 (625)	----- -----	None	None	----- -----	----- -----

Table 2. Specification for a Continuous Miner.

Maintenance

Time Cost due to broken down machines results in lost coal production. Additionally, there is the cost of the replacement parts. This would be of particular importance in the Andean Region, where the transportion and parts cost will be significantly higher. Table 3 gives an outline of the maintenance history of a continuous miner.

Maintenance History, Miner No. 1375

Shifts worked	207	Date purchased	5-01-73
Tonnage produced	31,528	First rebuild	7-15-77
		Second rebuild	9-12-79

Date of Service	Hr Down-time	Hr Repair Time	Cost of Repair	Part No.	Description of Part
1-05-80	3.00	4.00	$ 4,115	11723	Cutterhead motor
1-15-80	0.75	0.75	138	07663	Methane monitor
1-27-80	0.50	1.00	178	01856	Tram pump
2-13-80	2.75	2.00	205	11754	Cutter head drive shaft
2-29-80	18.00	25.00	14,903	11700	Complete cutterhead
2-29-80	1.00	1.67	171	02333	Power pack
3-07-80	4.50	3.50	588	01823	Tram motor
3-15-80	4.00	4.50	4,294	11723	Cutterhead motor
Total through 3-15-80	34.50	42.42	$24,592		
Cost per ton *			$ 0.78/ton		

* Metric equivalent: 1 st × 0.907 184 7 = t.

Table 3

Size of Coal Produced

The size of coal produced by the continuous mining machine can have an effect on the conveyance and coal preparation (cleaning) costs. Also, the machining of coal tends to produce a greater volume of dust. Table 4 gives a screen-size analysis of the run-of-mine coal produced, after being mined by a continuous miner.

Screen-Size Analyses of Material Taken by Continuous Mining Machines

Screen Size, in.	Chain-Head Miner 2.1 m (7 ft) Pitts Seam, %	Rotary-Drum Miner 2.1 m (7 ft) Pitts Seam, %	Rotary-Drum Miner-1370 mm (54 in.) Cedar Grove Seam, %	Rotary-Drum Miner 1350 mm (53 in.) Chilton Seam, %	Conventional Section-1370 mm (54 in.) Winifred Seam, %	Conventional Seam 1220 to 1370 mm (48 to 54 in.) Dorothy Seam, %
+ -2	25.0	7	12	6	37	17.0
2 × 1	20.0	15	14	17	21	17.0
1 × 1/2	18.0	20	12	15	17	19.0
1/2 × 3/8	6.0	8	13	16	5	6.0
3/8 × 1/4	7.0	10	9	10	5.5	8.0
1/4 × 1/8	10.0	14	12.5	15	6.5	12.0
1/8 × 50	11.0	21	20.7	26.5	8.8	16.4
50 × 100	1.0	2	2.6	3.7	0.6	1.8
100 × 0	1.5	3	4.2	6.8	0.6	2.8
Totals	100.0	100	100	100.0	100.0	100.0

* All percentages are by weight. Screens are US Standard screens with round screen openings. Total average sample weights are unknown.

Table 4

CONVENTIONAL MINING

The conventional (traditional) mine layout and development is very similar to the continuous mining system. However, the CONVENTIONAL MINING SYSTEM ulitizes a larger number of entries; as shown in Figure 8 .

Loading and hauling variables in a conventional mining plan showing cut sequence of seven entry plan.

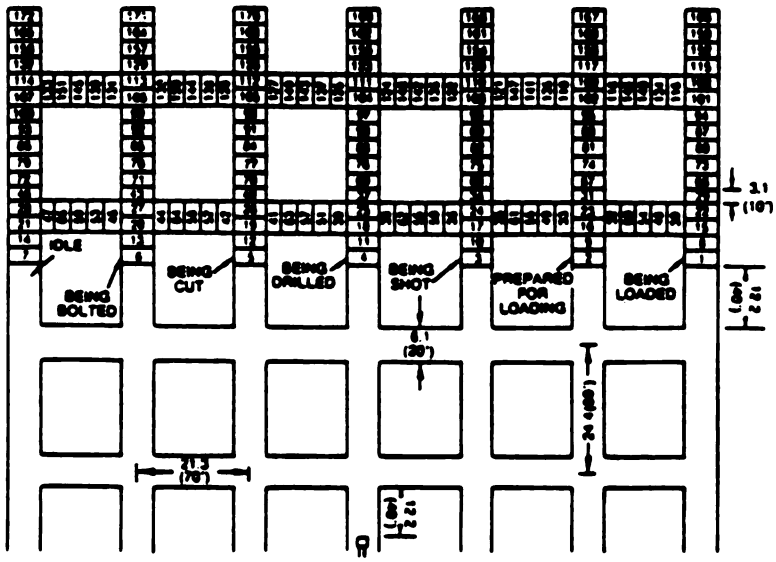


Figure 8

Figure 8 also shows the principal operations of conventional mining:

- CUTTING
- DRILLING (COAL)
- BLASTING
- LOADING
- BOLTING

As there are five distinct mining operations a minimum of five entries is required. However, to 10 entries are preferable.

CUTTING

An undercutting machine cuts a 12.7 to 17.8 cm slot at the bottom of the coal. The slot provides a free face for the blast, as shown in Figure 8 .

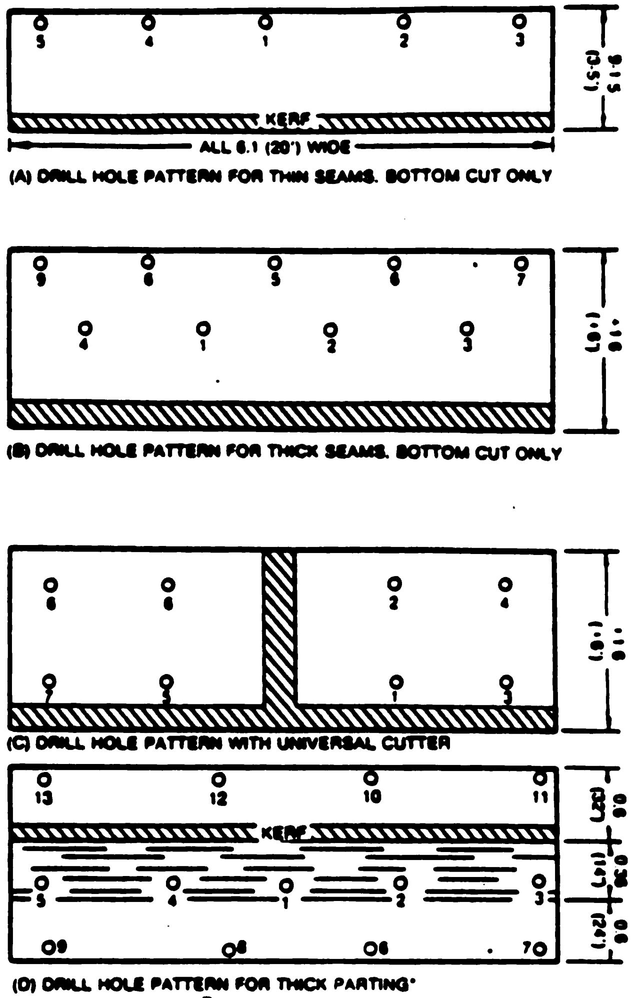


Figure 9

Cut-and-drill hole patterns used

The cuts, by the universal (chain saw) cutter are generally 2.4 to 3.0 m deep.

DRILLING and BLASTING

Figure 9 shows the drill hole pattern for thick and thin coal seams.

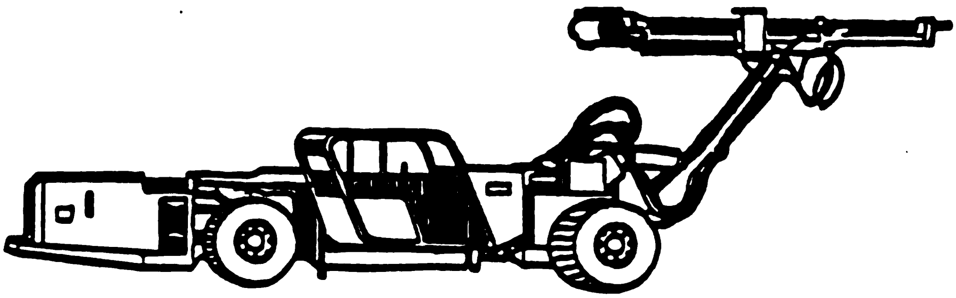
Blasting is carried out either by chemical explosives or compressed air.

COMPARING THE CONTINUOUS AND CONVENTIONAL ROOM AND PILLAR OPERATION

Both continuous and conventional mining systems can be very productive when th operations are organized well and the mine management and miners are motivated.

The conventional (blasting) method usually has an advantage in hard coal seams, such as anthracite. Also, in thin coal seams where the height clearance is too small for a continuous miner.

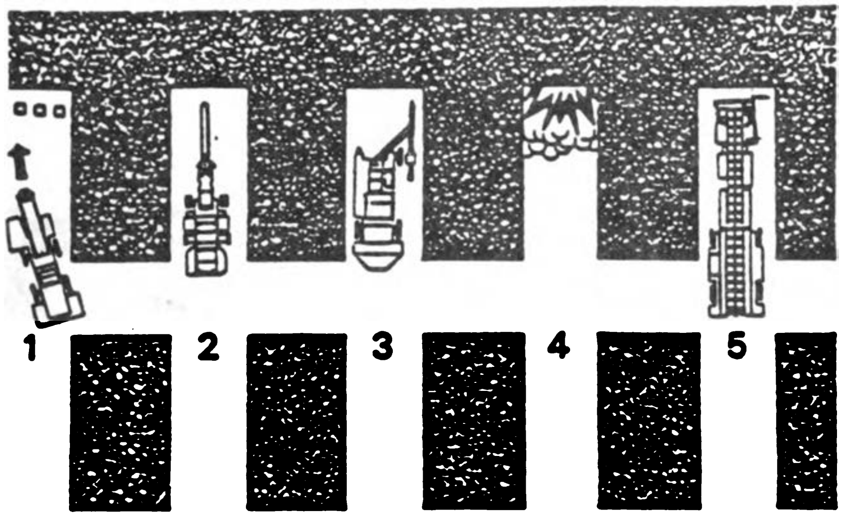
MINING PROCEDURE FOR CONVENTIONAL ROOM AND PILLAR MINING



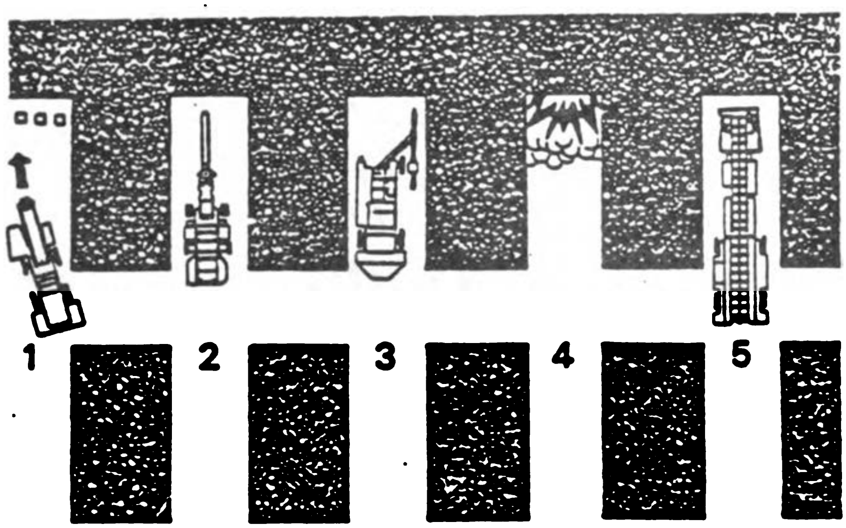
Often the face drilling operation is done by a hand-held drill operating off the cutter. Face drills, like the one shown here, are also used.

- ROOF BOLTING
- UNDERCUTTING
- DRILLING
- SHOOTING
- LOADING
- ROOF BOLTING

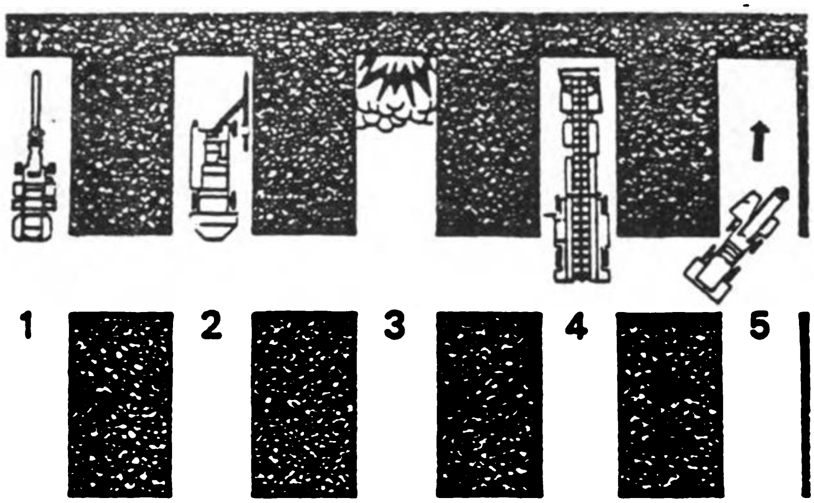
You will now see the movements of conventional mining machines and operators. The normal sequence of movement is: roof bolting; undercutting; drilling; shooting; loading; and roof bolting. Again, remember that the drawings are not to scale, but are intended to give you a clear picture of mining operations.



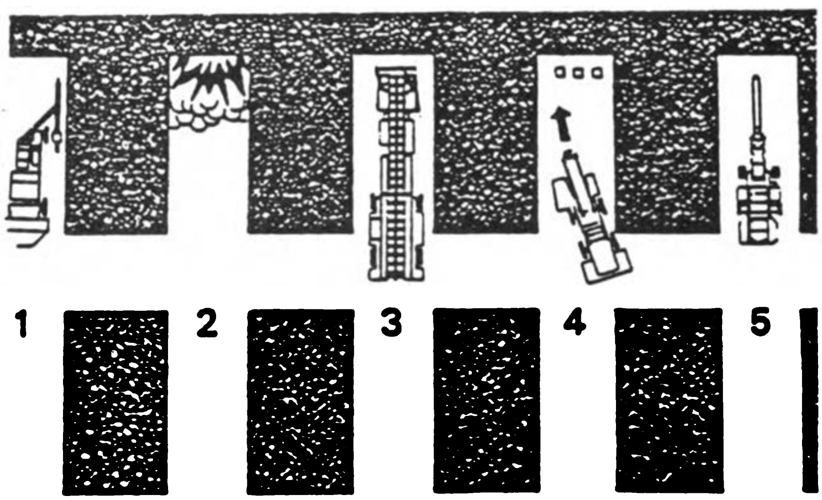
Here you see each of five entries or faces being worked simultaneously by the various pieces of equipment. Actual entries are much narrower, but in order to clearly show the operations in a coal mine, we have drawn them a little wider. Let's give each face being worked a number. The numbers get higher as you go from left to right--that means the first entry on the left is entry number one. You will see that the equipment moves in a fixed order from right to left, or from a higher numbered entry to a lower numbered one.



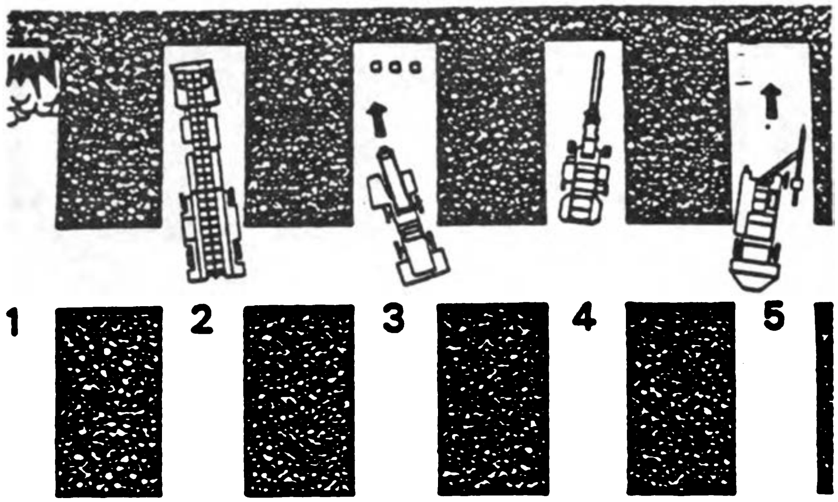
The roof bolter goes first. . . .



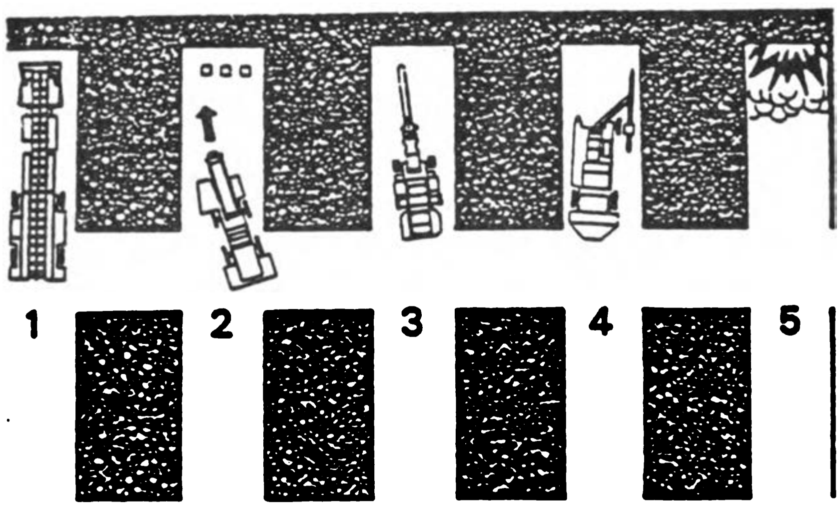
Followed by the cutting machine . . . .



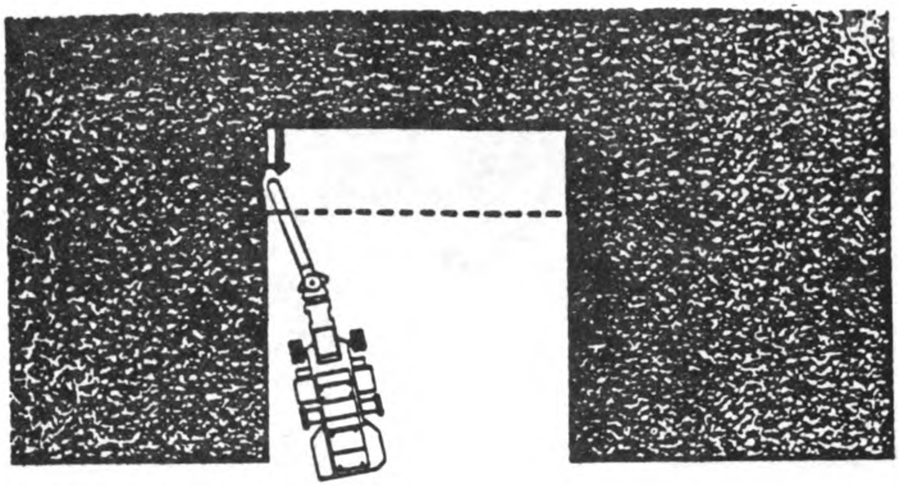
Followed by the face drill . . . .



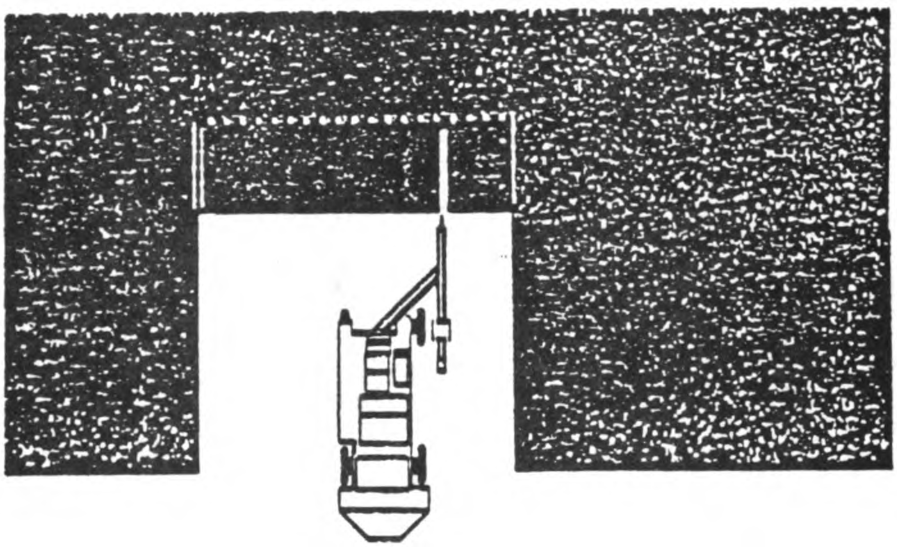
Followed by the shot fireman and then . . . .



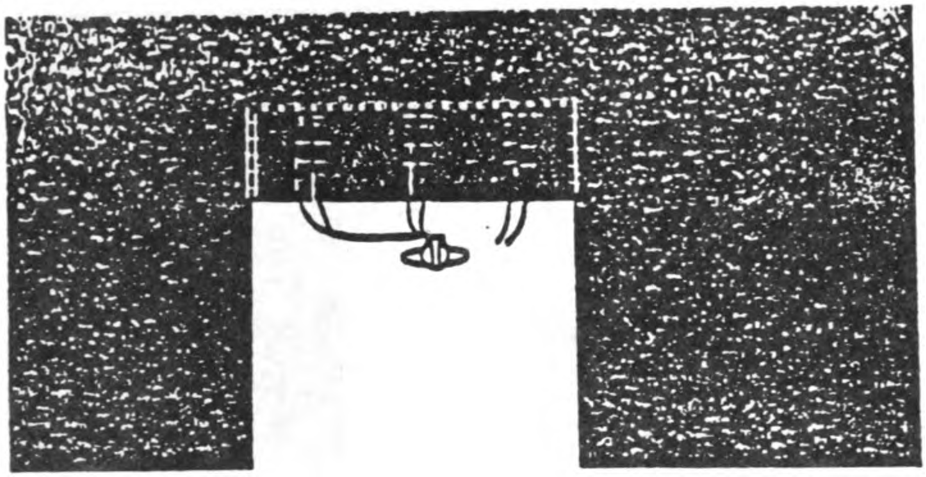
The loader and shuttle cars.



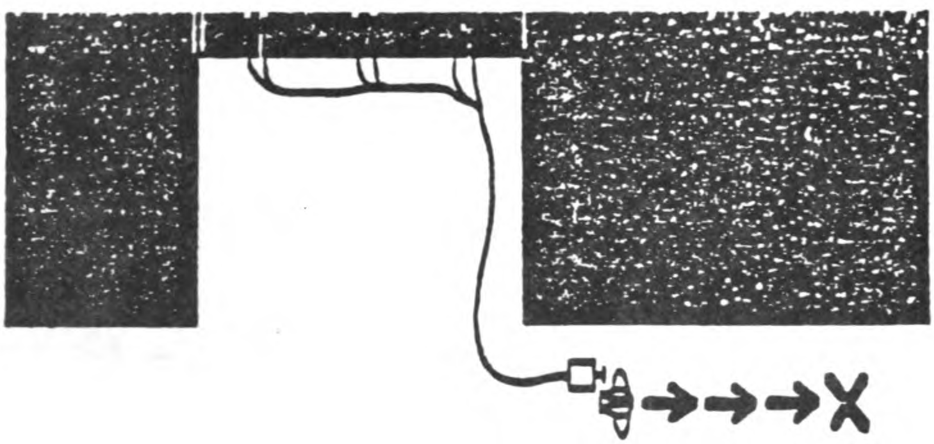
The roof has been supported. Here you see the undercutter getting in position into the face after tramming (moving along). The undercutter is then positioned to cut. Its force cuts the face from right to left as it moves into the face. The undercutter cuts the face square up to the corner, moves the equipment out of the face, and is ready to tram to a new face to repeat the entire procedure.



After the undercutting is completed, the holes for blasting must be drilled. Holes are drilled in special patterns in order to control the way in which the coal falls after it is blasted. There are various patterns used for drilling depending on the hardness of the coal and other characteristics, such as the width of the face, height of seam, and type of explosive used.

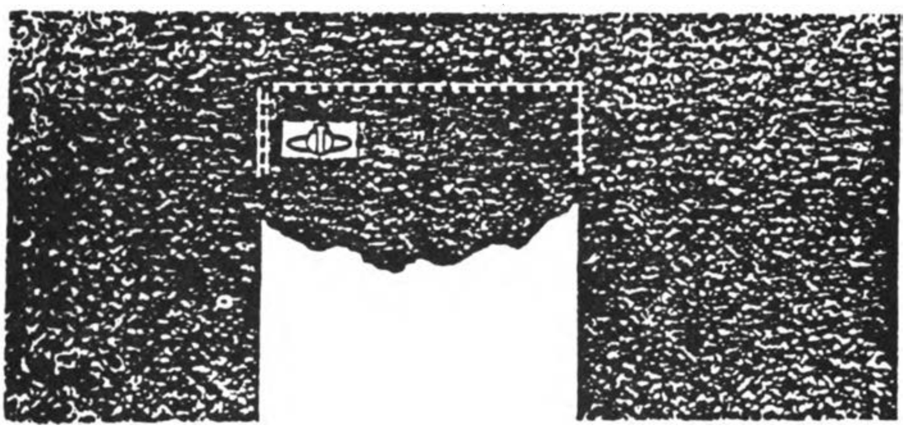


The holes are now ready to receive the charges for blasting. In the shooting operation, the operator first measures how deep the hole is. In our example, there are six holes. The permissible explosives and electric detonators are loaded and stemmed into the first high hole, then the second hole, third hole, fourth hole, fifth hole, and sixth hole. For other blasting patterns, there may be a different number of holes. Wires from the charges are connected.

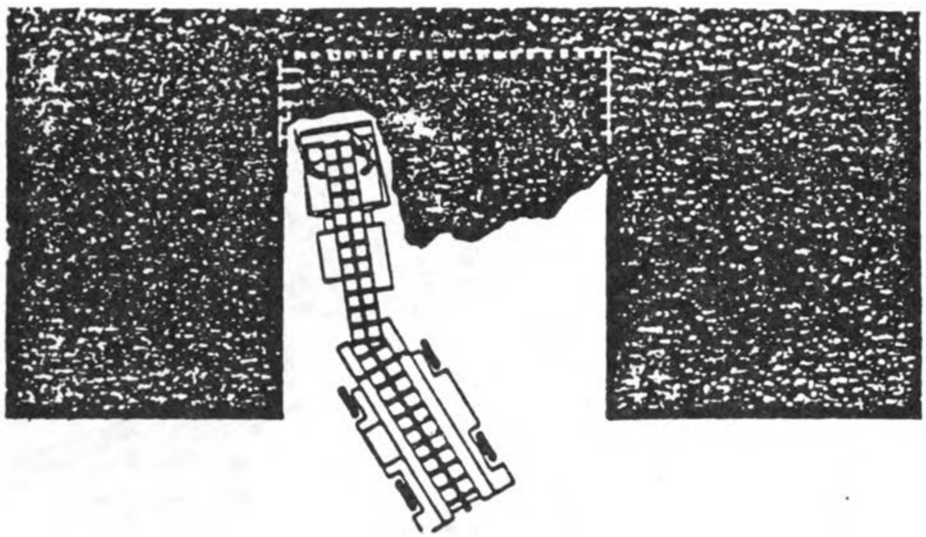


The wire is then unreeled to a safe position far enough away from the holes, connected to the blasting machine and the rest of the crew is warned about the coming explosion. The warning "fire in the hole" is shouted.

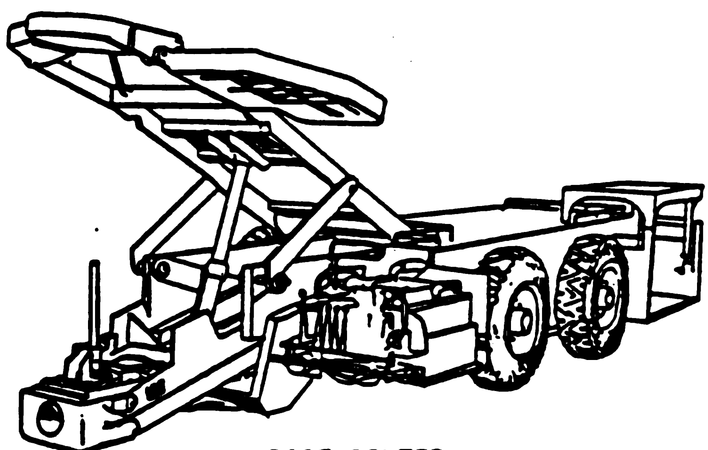
The charges are then set off, blowing the coal from the face. Because of the drilling pattern used, the coal is blown down and not, for example, blasted out of the working place into the crosscut.



Now the amount of methane over the "shot" coal must be tested at the level of the ceiling not less than within 12 inches of roof face and rib.

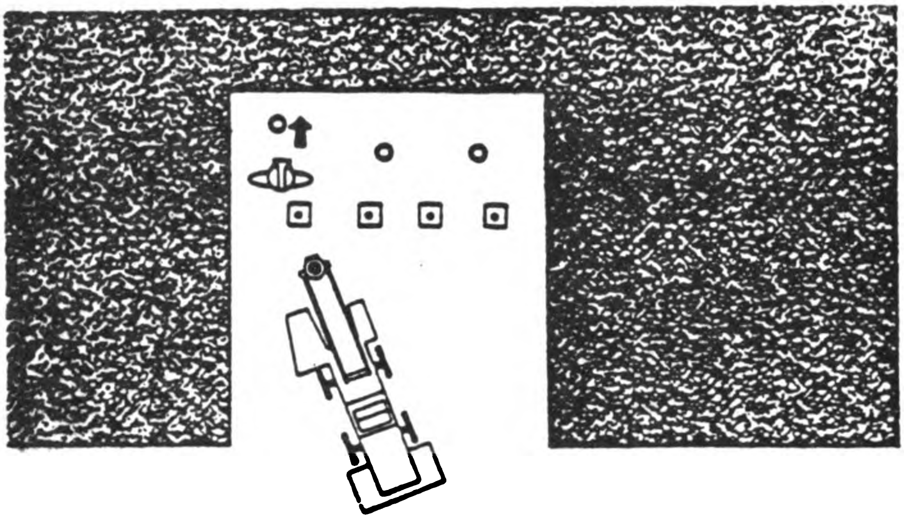


The next operation is loading the coal in order to remove it to the outside. After the loader has been trammed to the face, it is positioned into the "shot" coal. The operator of the loading machine can not go inby the roof supports. The gathering arms of the loading machine move the coal onto a conveyor, which is part of the loading machine, then into a shuttle car. The shuttle car carries the coal to either a mine car or conveyor.

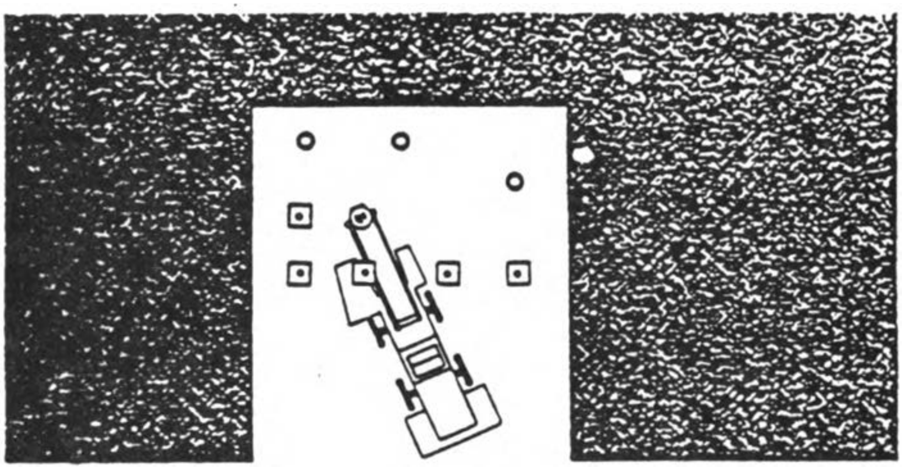


ROOF BOLTER

Now there has been a new working area created. The roof must be supported first. Before bolting is done, temporary roof supports are put in place. These are either timbers or metal jacks and are placed according to a definite plan.



Once the temporary supports are in place according to the plan, the roof is bolted.



First the roof bolter enters the new working area and tests the roof. He scales the roof, sets the first post, and tests for methane. He continues to reposition and drill and bolt, each time testing and scaling the roof. Temporary supports are not removed until bolts are in place.

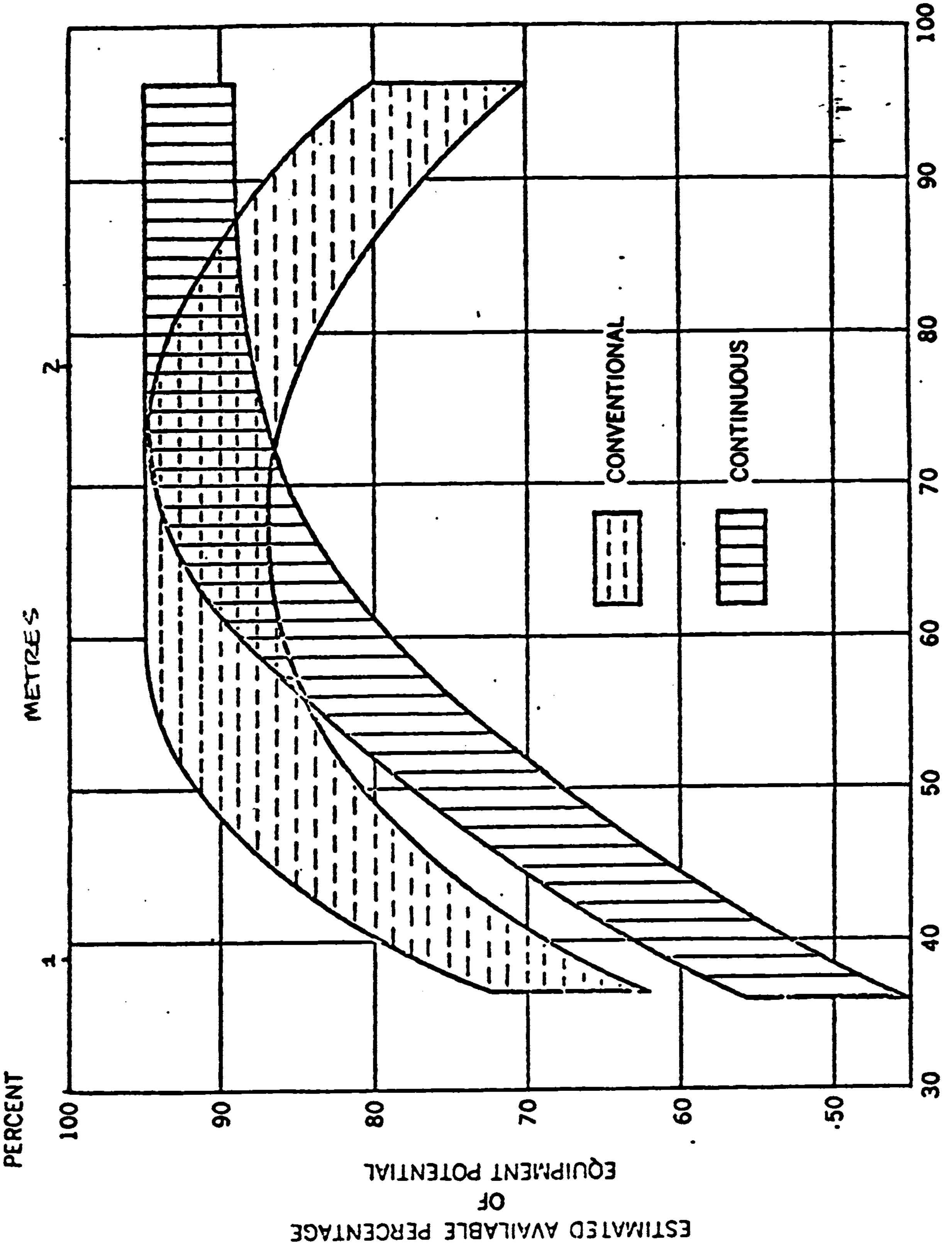
Figure 10 shows the 'estimated available percentage of conventional and continuous equipment' for different coal seam heights. It indicates that the continuous mining machine is more efficient approaching a coal seam height of 2 metres. This diagram gives just a general estimation, as operation efficiency largely depends on the mining conditions and operator skill.

Table 5 shows the comparison of changes in productivity, from 1969 to 1974, for conventional and continuous room and pillar mining. From 1974 to 1985 there has been a overall decline in coal mine productivity in the United States. Much of this decline can be attributed to the increasing introduction of safety regulations and the changing behavior and motivation of the workers. Unions also have an influence on mine productivity. Generally, the well organized mine with motivated personnel has a higher productivity and safety record.

Productivity of Conventional and Continuous Room-and-Pillar Mines (Tons per Unit Shift)

	Seam Thickness, m (in.)	No. of Mines	Tons (st) per Unit Shift					
			1969	1970	1971	1972	1973	1974
Conventional section	1.1 42	5	232 256	215 237	179 197	250 276	241 266	210 232
	1.1 to 1.4 42–54	27	336 370	307 339	272 300	257 283	242 267	215 237
	1.4 to 1.8 54–72	29	470 518	397 438	462 509	356 393	354 390	335 369
	1.8 to 2.1 72–84	9	408 450	373 411	364 401	366 403	335 369	344 379
Continuous section	1.1 42	6	243 268	187 206	161 178	229 252	239 264	233 257
	1.1 to 1.4 42–54	33	277 305	261 288	253 279	249 274	238 262	227 250
	1.4 to 1.8 54–72	41	369 407	327 360	292 322	287 316	276 304	269 297
	1.8 to 2.1 72–84	22	349 385	317 349	307 336	307 339	304 335	269 297
	2.1 to 2.4 84–96	7	395 435	465 513	453 499	472 520	513 566	490 540
	2.4 to 3.0 96–120	3	544 600	490 540	470 519	416 459	443 488	457 504

Table 5



EQUIPMENT AVAILABILITY AS A FUNCTION OF SEAM HEIGHT

Figure 10

Mine Personnel

Table 6 gives an outline of the recommended mine personnel for a conventional and continuous mining unit.

Minimum Recommended Organization for Typical Room-and-Pillar Coal Mine

Conventional Hourly Payroll/Section		Salary	
Cutting machine operator	1	Section foreman	1
Coal drill operator	1		
Shot fireman	1		
Roof bolt operator	2		
Loading machine operator	1		
Shuttle car operator	3		
Utility man	3		
Maintenance man	2		
	14		
		Total	15
Continuous Hourly Payroll/Section		**Salary**	
Continuous miner operator	1	Section foreman	1
Roof bolt operator	2		
Shuttle car operator	3		
Utility man	3		
Maintenance man	2		
	11		
		Total	12
Other Hourly Payroll People Needed/Shift		**Salary**	
Timberman	2–10	Assistant general mine foreman	1
Block mason	2–10	Fire bosses	1
Beltman	1/belt	Clerks (average)	1
Belt controller	1	Surveyor (average)	1
Pumper	2–4	Maintenance supervisors	1
Chief electrician	1		
Where track is used:			
Trackman	2–8		
Locomotive operator	1–2		
Dispatcher	1		
Hoist engineer	1		

Table 6

Table 7 shows the classification of various jobs in an underground mine that gives an indication of the order of pay scale.

Underground Mining Job Classifications

All classifications within one group receive the same rate of pay. (Each pay classification is further subdivided into job titles which are not shown. The number of job titles within each classification varies from 1 (for continuous miner-operators and for first class welders) up to 73 (for unskilled laborers).)

6	Continuous mining machine operator
	Electrician
	Mechanic
	Fireboss
	Longwall machine operator
	Welder, first class
5	Cutting machine operator
	Dispatcher
	Loading machine operator
	Machine operator helper
	Inside repairman and welder
	Roof bolter
4	Driller, coal
	Shooter
	Precision mason constructor
	Faceman
	Dumper
3	Motorman
	Shuttle car operator
2	Beltman
	Bonder
	Brakeman
	Bratticeman
	General inside laborer
	Electrician helper
	Mason
	Mechanic helper
	Pumper
	Timberman
	Trackman
	Wireman
1	Laborer-unskilled

Table 7

Mine Productivity

Table 8 gives an outline of the estimated productivity for conventional and continuous mining units for COAL SEAM THICKNESS 1.2, 1.5, and 1.8 metres.

Estimated Productivity for Conventional vs. Continuous Mining, 1.2, 1.5, and 1.8-m (48, 60, and 72-in.) Seam Height

Production Data	Conventional	Continuous	Conventional	Continuous	Conventional	Continuous
Seam height, m (in.)‡	1.2 (48)	1.2 (48)	1.5 (60)	1.5 (60)	1.8 (72)	1.8 (72)
Width of place, m (ft)	6.1 (20)	6.1 (20)	6.1 (20)	6.1 (20)	6.1 (20)	6.1 (20)
Depth of cut, m (ft)	2.4 (8)	5.4 (18)	2.4 (8)	5.4 (18)	2.4 (8)	5.4 (18)
Tons per cut, t (st)	23 (26)	53 (58)	29 (32)	65 (72)	34 (38)	78 (86)
Cuts per shift	20	8.7	20	8.3	18	8.2
Tons per shift	464	454	581	544	617	635
Short tons per shift	512	500	640	600	680	700
Work minutes per shift	400	400	400	400	400	400
Face Crew						
Continuous miner	—	1	—	1	—	1
Loading machine	2	1	1	1	2	1
Shuttle cars	2	2	2	2	2	2
Cutting machine	2	—	2	—	2	—
Drill	1	—	1	—	1	—
Shooting	1	—	1	—	1	—
Roof bolt machine	2	2	2	2	2	2
Total face crew	10	6	10	6	10	6
Man Minutes per Cut*						
Continuous miner	—	31.0	—	33.0	—	33.5
Loading machine	30.0	31.0	30.0	33.0	34.0	33.5
Shuttle cars	30.0	62.0	30.0	66.0	34.0	67.0
Cutting	30.0	—	30.0	—	35.0	—
Drilling	13.0	—	13.0	—	15.0	—
Shooting	17.0	—	17.0	—	20.0	—
Roof bolting	30.0	72.0	30.0	72.0	30.0	75.6
Total man minutes per cut*	150.0	196.0	150.0	204.0	168.0	209.6
Man minutes per shift at the face*	3000	1700	3000	1700	3024	1720
Man minutes per						
Ton	5.32	3.07	4.25	2.59	4.01	2.21
Short ton*	5.86	3.38	4.69	2.86	4.42	2.44
Tons per manshift	48.4	75.6	58.1	90.7	61.7	105.8
Short tons per manshift†	51.2	83.3	64.0	100.0	68.0	116.6

* Working at the face; does not include moving or delays.
† Short tons per 8-hr manshift.
‡ Good mining conditions suitable for either conventional or continuous.

Table 8

Although these estimated production figures show a distinct bias towards the continuous mining method, especially in the thicker coal seams, they have been determined for a specific set of fixed mining conditions (parameters).

Many of the operation parameters such as advance of continuous miner (sump) and bolting are governed by MSHA regulations.

Profit Factor

The business factors may change in each country. But the principal factor can be generally considered to be MAXIMISING PROFITS for a private company. Therefore two important factors to consider are:

- SELLING PRICE
- PRODUCTION
- EMPLOYMENT
- MINING COSTS

DETERMINING MINING COSTS

It is the intention of this report to present information that may be of use for the coal mines of the Andean Region. There is not much use in giving splendid illustrations of sophisticated mining equipment and methods which bear no relation to the scale of mining that is anticipated for the Andean Region.

This report will present an outline of costs for a unit operation in the mountains of Kentucky. Although the geological conditions are dissimilar the mining in the mountains in Eastern Kentucky and the Andean Region have many things in common. In both areas, the principal aim is to maximize productivity based on limited resources. In this case the principal resources of LABOR and MATERIALS/SUPPLIES are different in magnitude of cost and availability.

PLANNING a coal mine venture requires an estimation of mine costs. The behavior and nature of the costs are very similar from mine to mine, but will differ in magnitude depending on the location of the mine and supply of the labor and materials.

PRODUCTION COSTS FOR A ONE UNIT (MACHINE) COAL MINE

The following is an outline of the costs for a small-one unit coal mine in Eastern Kentucky. Although the cost of materials and labor will be considerably different, the nature and behavior of the costs should be similar, for the same type of mining operation.

Obviously, the largest difference between the United States and the Andean Region are:

	Labor Cost	Material Cost
United States	High	Low/Medium
Labor Cost	Low	High

Therefore, when choosing a mining system for the coal deposits of the Andean Region, obviously different criteria must be used than those of the United States. A low labor cost would favor conventional mining.

Until now, only the basic mining operation parameters have been considered. Later in the report, mine costs and mine case studies will be discussed.

TABLE. OUTLINE OF COSTS FOR A SMALL COAL MINE IN EASTERN KENTUCKY

ITEM	COST	COMMENTS
Roof bolts	$4 per assembly	For thin coal:one bolt/ft of advance
Wood supports	$0.21/ft advance	2 rows x 2 headings(belt & escapeway)
Roof drill bits	$4.60 each	3 per 10ft advance (sharpened twice)
Roof bolt steel	$30/month	
Cutter bits	$3 each	160 per month
Coal drill bits	$7.50 each	30 per month (bituminous coal) with dirt bands
Coal drill augers	$30 per month	
Blasting Powder	$52/case of 68 sticks of TOVEX	3 sticks per hole: 0.76 seam(4 holes) 0.91m, 1.07m, 1.22m (5 holes)
Blasting cable	$0.40 per metre	122 metres per week
Blasting Caps	$410 per 500	one per hole
Rock dust	$0.05 per Kg	6.4 Kg of rock dust per ton of coal
Brattice Cloth	$20 per day	Guide for ventilation
Stoppings	$1 per block	1 block per $0.1m^2$ of entry
Conveyor belt and Structure	$100 per metre	Rubber belt
High voltage cable	$20 per metre	4160 volts
Water lines	$7 per metre	7.6m Diam; 6.4m sections
Water lines	$5 each	couplings; Average $8.20 per metre
Grease	$10 per day	
Oil	$1.7 per litre	36 litres per day
Telephone cable and hangers	$20 per break	Break is the distance between cross-cuts
Repairs & Maintenance	$300 per day	
Cable splices	$40 per day	Includes cable replacement
Welding	$50 per day	Includes rods; O_z; acetylene
Shovels, picks	$7,000 per year	Also hammers, axes, pliers
Fuel: FEL	$9 per hour	Fuel for
Miscellaneous	$5,000 per year	Road maintenance etc.

CHAPTER III

CASE STUDIES

MINE A: CONTINUOUS MINING AND DIESEL HAULAGE (REPLACING CONVENTIONAL MINING)

Location: UTAH

Topography: Flat

Overburden:
- Upper Cretaceous
- 60 percent Sandstone
- 40 percent Shales
- 30.5 to 46 metres deep

Coal Seam:
- Bituminous, 3.66 metres (12 ft) thick
- Rock parting 0.3 metres
- 12,000 BTU; 1% Sulfur; 8% thick
- Steam market quality
- Inclination (grade) $\underset{\sim}{}$ 2% (average)

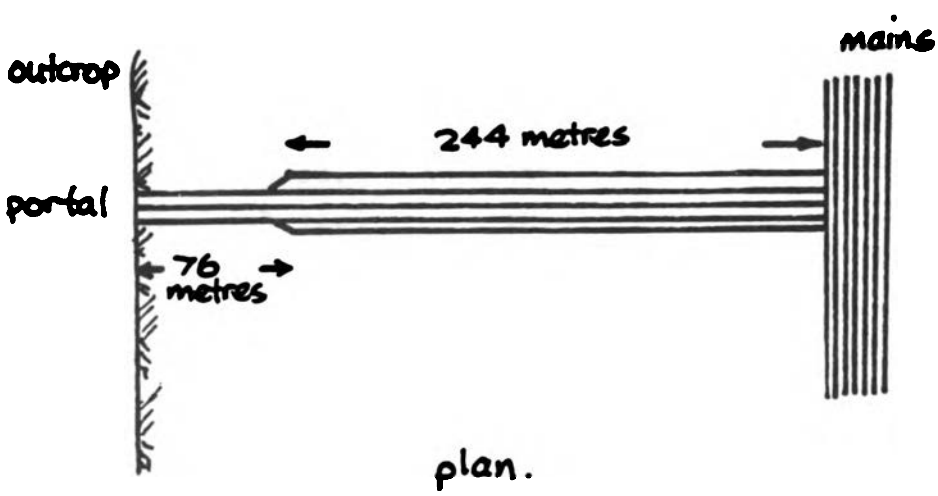
Roof Bolting:
- 1.2 to 1.8 metres long (into sandstone)
- Spacing 1.5 metres
- Resin bolts

Floor:
- Fire clay (dry)

Seam Conditions:
- Methane free
- Above drainage (dry)

Mine Access:
- Three (3) entries driven from the outcrop

At 76 metres, two additional entries developed.



At 76 + 244 metres (320) seven (7) main entries were turned at right angles to initial entries.

Entry Width:
- 6 metres
- Centers 21 metres
- Pillar size = 21 - 6 = 15 metres

Coal Extraction: As shown in Figure 11, the room and pillar system is developed to the property boundary. The coal is then taken on a RETREAT SYSTEM, extracting five (5) pillars at a time.

CONVENTIONAL MINING SYSTEM

The mine had earlier been mining using the conventional system of cutting, blasting and loading. Then it decided to switch to continuous mining.

Conventional Equipment

1 Joy 15 RU cutter
1 Schroeder coal drill
2 Wagner LHD loaders
1 Lee Norse roof bolter
1 Stamler feeder breaker
1 John Deere tractor-diesel
42 inch (1.07m) panel conveyor belt

Coal Production:
- 500 raw tons (metric) per shift
- 364 clean tons (metric) per shift

Unit Personnel: 9 miners

Coal Haulage: A diesel Teletrain hauls coal from the loader to the feeder breaker; a maximum haul distance of 152 metres. The panel conveyor belt is advanced every fifth cross cut (107 metres)

CONTINUOUS MINING SYSTEM

Mining Equipment

1 Marietta drum miner
2 Wagner Teletrains-diesel
1 Lee-Norse roof bolter
1 Stamler feeder breaker
42 inch (1.07 metres) panel belt conveyor

Coal Production: • 272 mt (raw) per shift INITIAL STAGES
• 820 mt (raw) per shift is planned with gained experience.

Unit Personnel: 9 miners

General: Coal production on two (2) shifts is planned. The third shift will be used for maintenance and utility work. The run of mine coal is conveyed to a grizzly chute and crusher. The 4 x 0 coal is then stockpiled and then fed to a vibrating feeder and jig plant (rated capacity 136 mt). The coal is hauled by truck to a rail siding

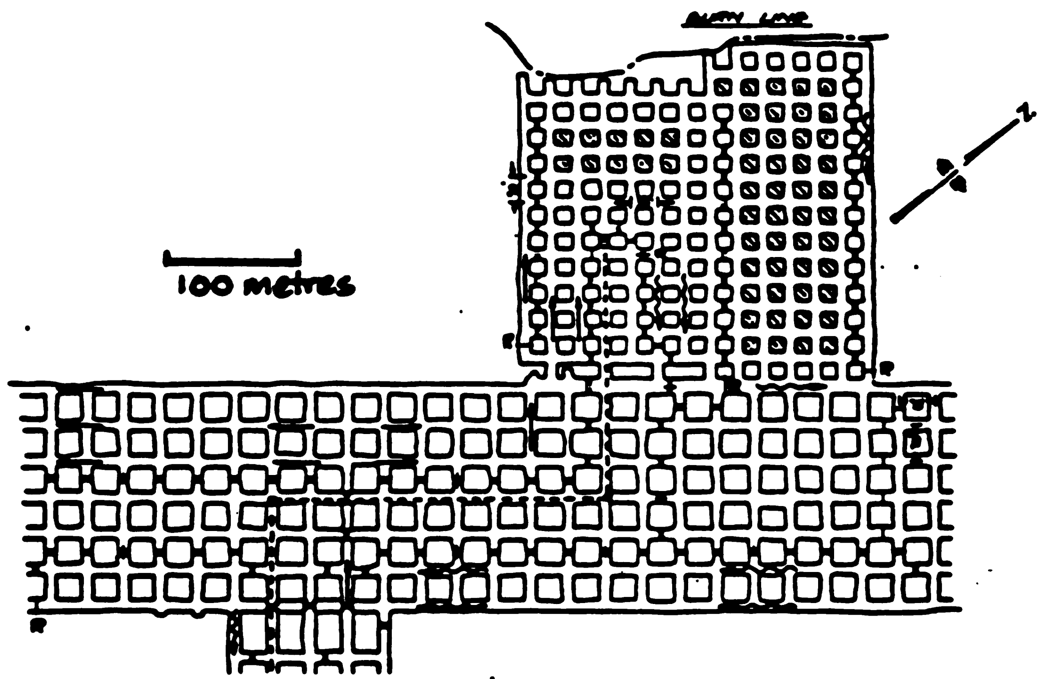


Figure 11

MINE B. CONTINUOUS MINING AND SHUTTLE CAR HAULAGE

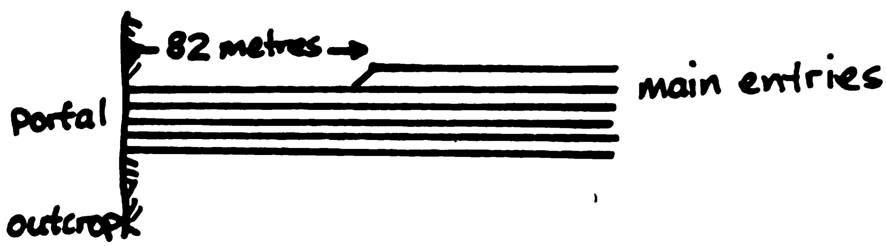
Location: Eastern Kentucky
Topography: Mountains
Overburden:
- Shale and sandstone
- Varying depth

Coal Seam:
- Bituminous
- 1 to 1.3 metres thick
- Undulates; no severe grades

Roof Bolting:
- Mechanical bolts (in shale)
- 0.9 metres long
- Spacing 1.2 metres

Floor:
- Fireclay (dry)

Mine Access: Five (5) drift (in-seam) entries are developed from the outcrop. At 82 metres an additional entry (6) is developed.



These main entries are advanced a further 472 metres before sub-mains are developed at right angles. Production room and pillar operations are developed inbye from these sub-mains.

Entry Width:
- 5.5 metres
- Centres 18.3 metres
- Pillar size = 18.3 - 5.5 = 12.8 m

A 30.5 metre barrier is left between the production section. See Figure 12.

Continuous Mining Equipment
1 Jeffrey 170L, or Lee Norse 265 continuous miner
2 Joy 21SC Shuttle cars
1 Galis 300 roof bolter
1 Stamler feeder
1 Elkhorn battery-powered scoop
1 Power center
36 inch (0.9m) panel conveyor belt

Coal Production:
- 420 mt (raw) per shift
- 260 mt (cean) per shift

Unit Personnel: 10 miners

Coal Haulage: Coal is hauled from the miner to the feeder breaker a maximum haul distance of 128 metres. The belt conveyor is advanced every two to three crosscuts (36 to 54 metres) coal, produced on 2 shifts per day (1 shift maintenance and utility work), is conveyed out of the mine to a 155 mt truck bin, outside the portal (entrance). Coal is then hauled away by 25 mt trucks.

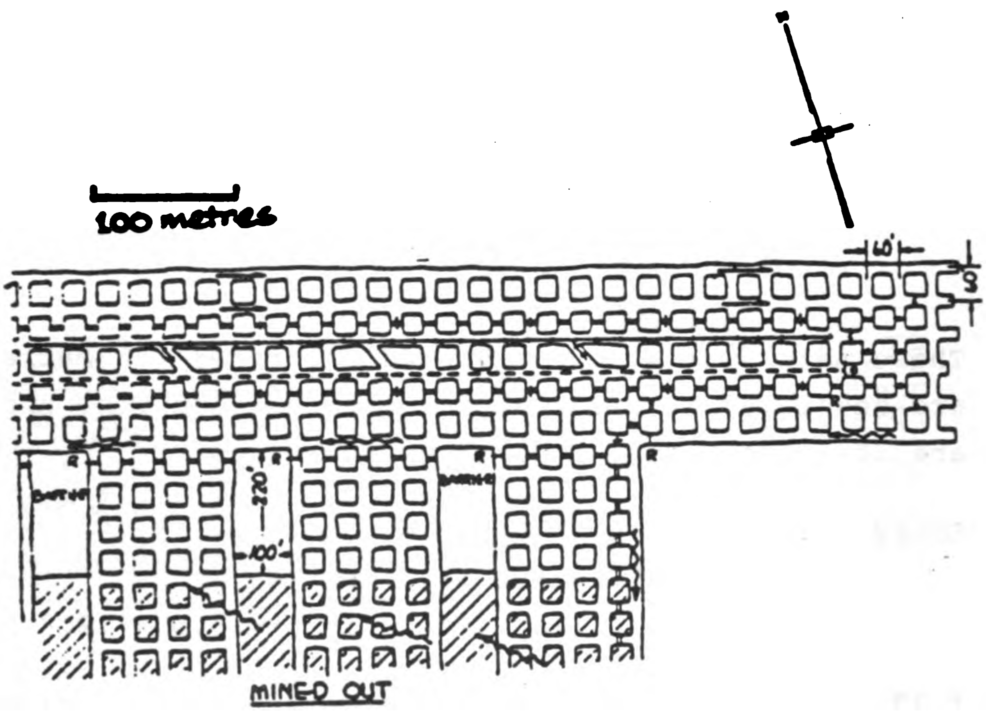


Figure 12

MINE C: CONVENTIONAL MINING: 'SHOOTING OFF THE SOLID'

Location: Eastern Kentucky

Topography: Mountainous

Overburden:
- Shales, sandstones
- Varying depth, up to 275 metres

Coal Seam:
- Bituminous
- 1.62 to 2.79 metres in thickness
- Shale parting, 0.3 metres thick in lower half of seam.
- Inclination up to 2.5 percent
- Metallurgical grade

Roof Bolting:
- Mechanical bolts, shale roof
- Length 1.8 metres

Floor:
- Hard Shale (dry)

Mine Access: Four (4) entries are developed from the coal outcrop. 61 metres inby, an additional two entries are developed, for a total of 6. The six (6) entries are advance 1,000 metres. At about the 500 metre point, rooms and pillar operations are branched off in 7 entries on 21 metre centres. (see figure 13).

Entry width:
- 5.5 metres
- Centres 21 metres
- Pillar size = 21-5.5 = 15.5 metres

Conventional Mining Equipment
(Shooting from the SOLID)
1 Schroader coal drill
4 Elkhorn AR-75 scoops
2 ACME roof bolters
1 S&S feeder breaker
1 MSA rock duster
2 Rectifiers, 480 v.
36 inch (0.9m) panel belt conveyor

Coal Production:
- 910 mt (raw) per shift
- 580 mt (clean) per shift

Unit Personnel: 11 miners

Coal Haulage: Battery-powered scoops transport coal from the miner to the feeder breaker, to a maximum distance of 122 metres. The panel belt conveyor is advanced over 3 cross-cuts (64 metres). The coal is conveyed to a 273 mt bin, outside the portal, and then by truck to a cleaning plant.

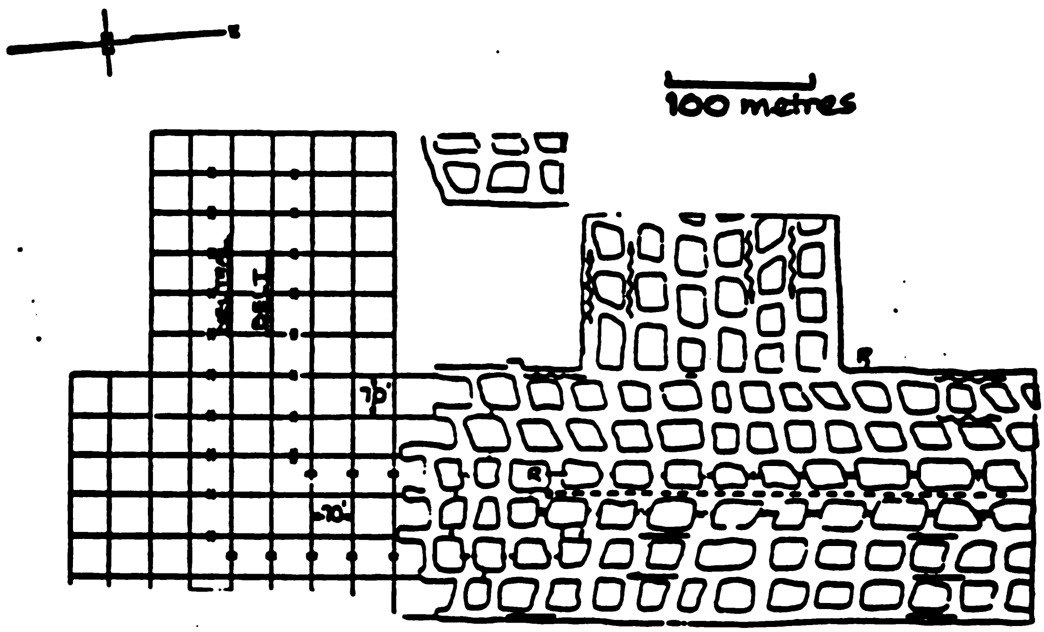


Figure 13

MINE D. CONVENTIONAL MINING USING BATTERY OPERATED SCOOP

LOCATION: WEST VIRGINIA

TOPOGRAPHY: Mountains

COAL SEAM:
- 1.5 to 1.7 metres
- Bituminous
- Grindability No. 38
- Inclination (grade) 1½%

Floor: Fireclay

Entry Width: 6.1 metres (all entries)

Mains entry centres: 18m x 18m

Production room and pillar centres: 15m x 15m; 12m x 12m

Equipment:

3 x S&S 488 Battery Scoop
Joy 15 RU cutting machine
320 Galis Roof Bolter
Hand held hydraulic (2700 litres/min) drills

Cost of Equipment (in U.S.)

Battery Scoop = $105,000
3 sets of batteries = $20,000
TOTAL = $125,000

Coal Production: 1310 mt per shift

Unit Personnel: 12 miners (including forman)

Mining System: This conventional system is unique and highly productive. The coal (hard) is drilled by hand-held hydraulic drills. The cut or advance is 3.4 metres (average 3 metres), drilling 5 holes: 3 in a centre wedge and one on each of the sides on 100 ms delay.

3 scoops are used; 2 for transport to the feeder breaker, 1 for clean up. The scoops tend to spill a lot of coal and West Virginia law requires a clean working area. The scoop hauled a maximum distance of 200 metres. 3 scoops would cost 3 x $125,000=$375,000. Three batteries are required due to time required for charging and cooling.

Although this mine had a maximum inclination of 1½%, the scoops have been used successfully up to 25%.

Two unit scoop sections was used in another mine. The mine was older and had been previously worked, also the general geological conditions were worse than the very successfull one-unit scoop operation. The productivity for this two unit operation averaged 50 mt per man shift, mining on two shifts.

The hand held drills were about to be replaced by drills mounted on the scoop, to make the hard drilling work easier.

Best Productivity seems to be attained by working:

- ONE UNIT OPERATION
- ONE SHIFT PER DAY
- ONE TEAM OF MINERS

CHAPTER IV

ANTHRACITE MINING IN APPALACHIAN MOUNTAINS

The principal system of mining the steep anthracite deposits is room (gallery) and pillar. Most of the mining is carried out on a small scale and relies on traditional methods that have not changed much over 100 years. The following gives a summary of the anthracite mining:

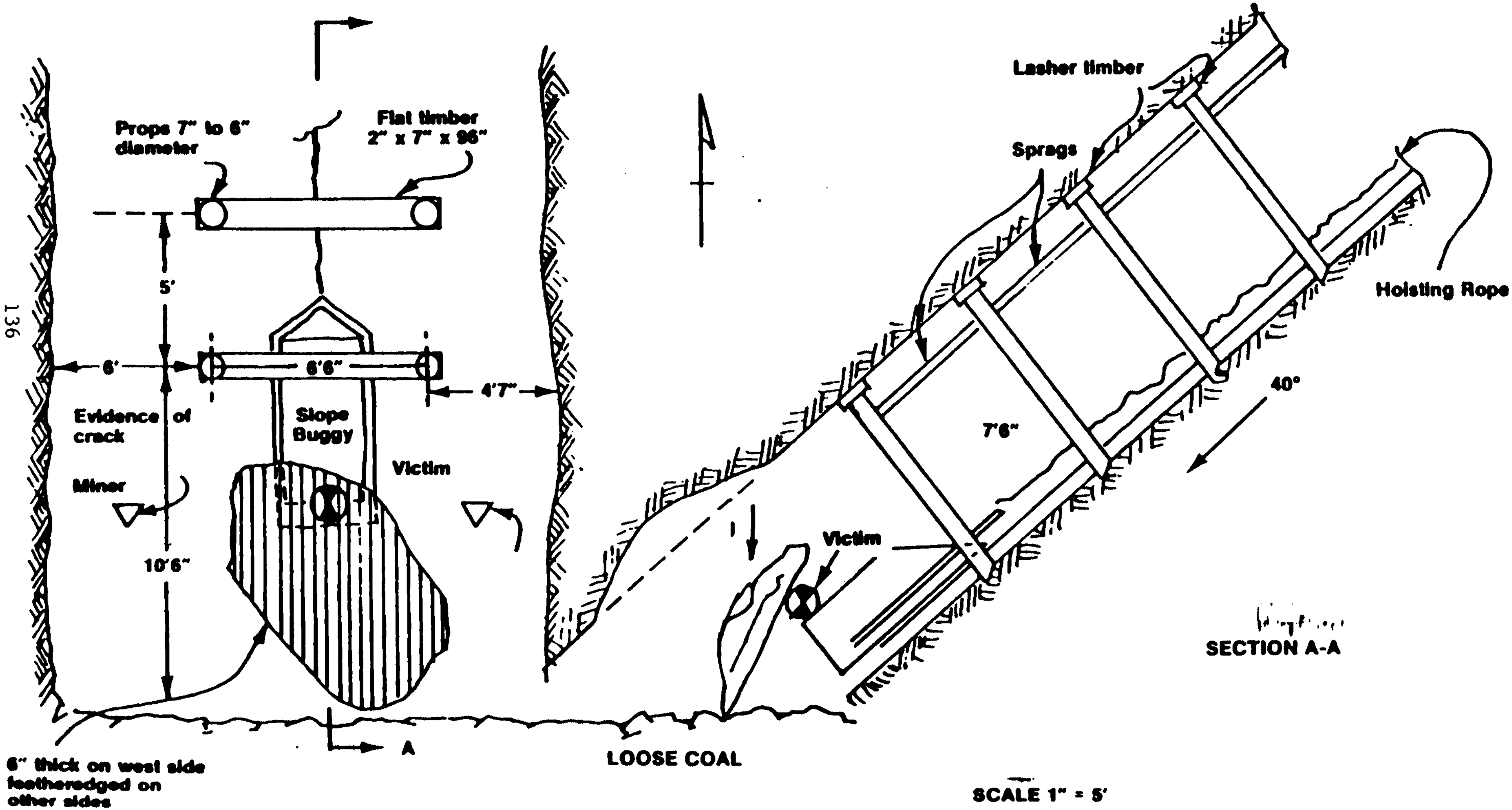
Depth of mining: 61 to 305 metres
Thickness of seam: 0.6 to 6.1 metres
Width of entry (gallery): 2.4 to 3 metres
Depth of cut (blast): 2.4 to 3 metres
Production: 50 to 250 mt per shift
Mine Personnel: 3 to 4
Support: Timbers (no bolting)

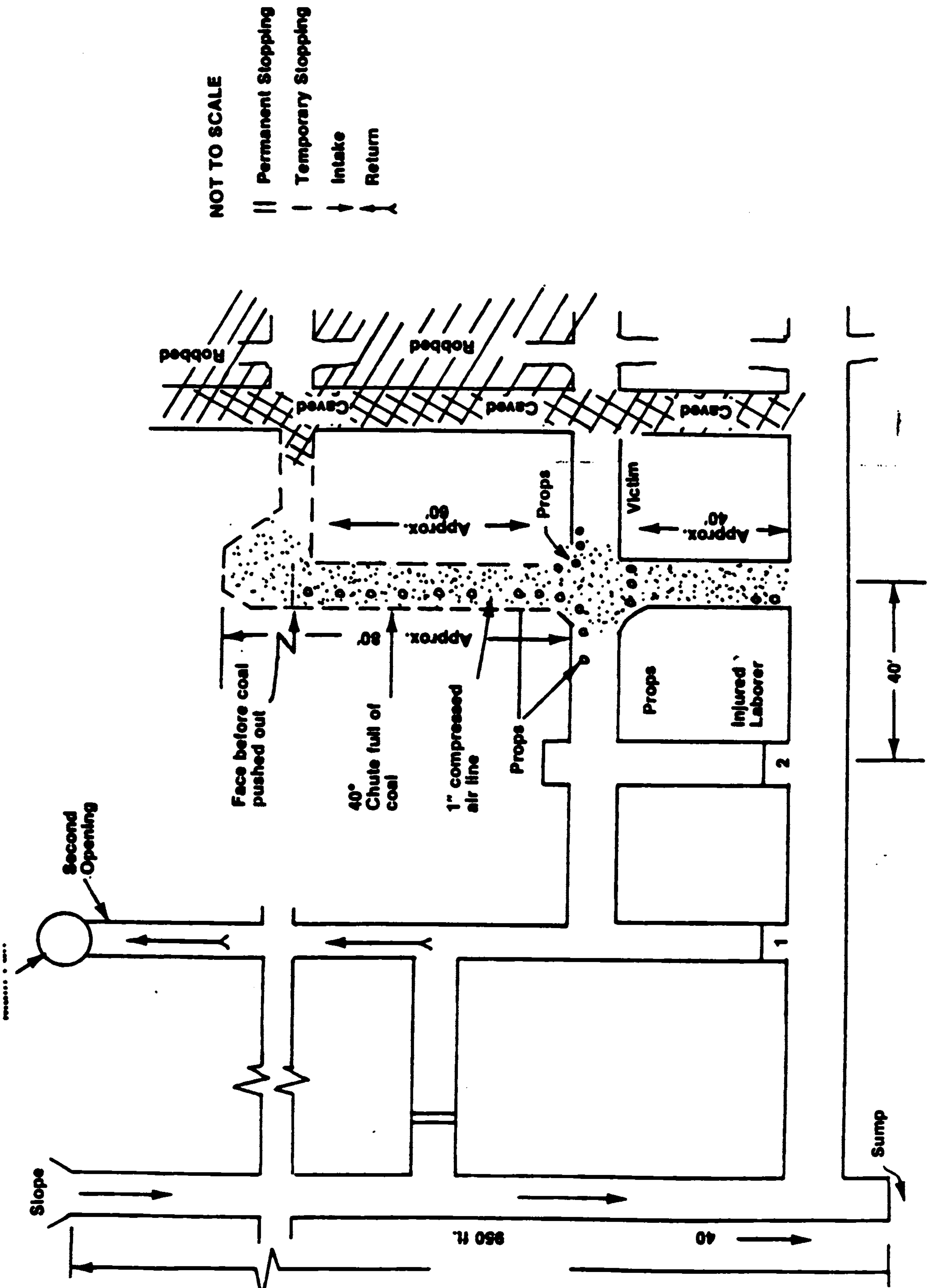
General Comments: The principal mining procedure is that of forming rooms by drilling and blasting from the solid coal. Productivity of the mines depends on:

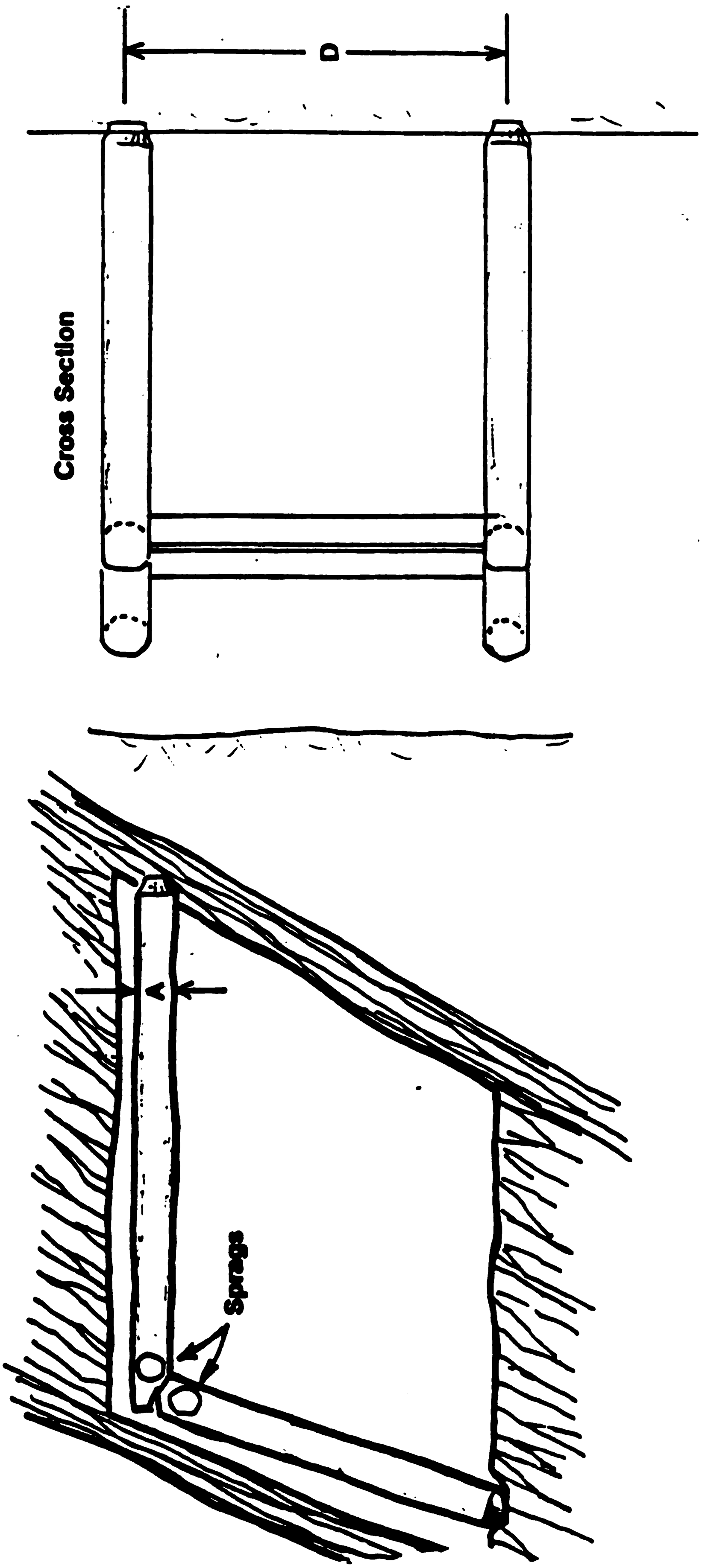
- Coal reserves and availability
- Mining conditions: thickness of coal seam
- Skill and motivation of miners

Typically 3 to 4 miners will work one shift per day. The lowest and highest productivity has been recorded at about 50 and 250 mt respectively. The thickness of coal seams (veins) tend to change ie in the same seam. Where the anthracite coal is more friable, and the coal reserves justify it, sub-level caving has been tried.

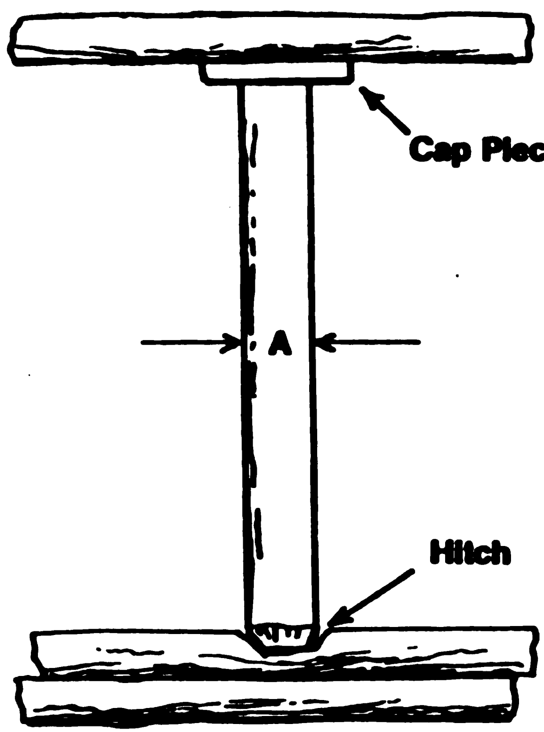
FATAL ROOF FALL ACCIDENT
GOODSPRING, SCHUYLKILL COUNTY, PENNSYLVANIA



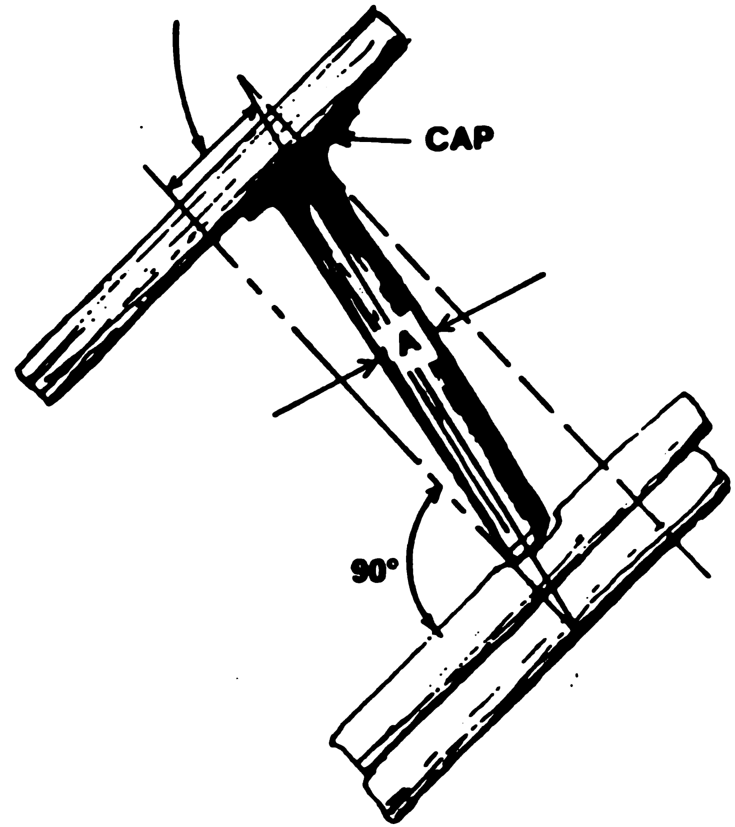

NOT TO SCALE
Permanent Stopping
Temporary Stopping
Intake
Return
Robbed
Robbed
Caved
Caved
Caved
Approx. 60'
Props
Victim
Approx. 40'
Approx. 80'
Face before coal pushed out
40° Chute full of coal
1" compressed air line
Props
Props
Injured Laborer
40'
2
1
Second Opening
Slope
Sump
950 ft.
40

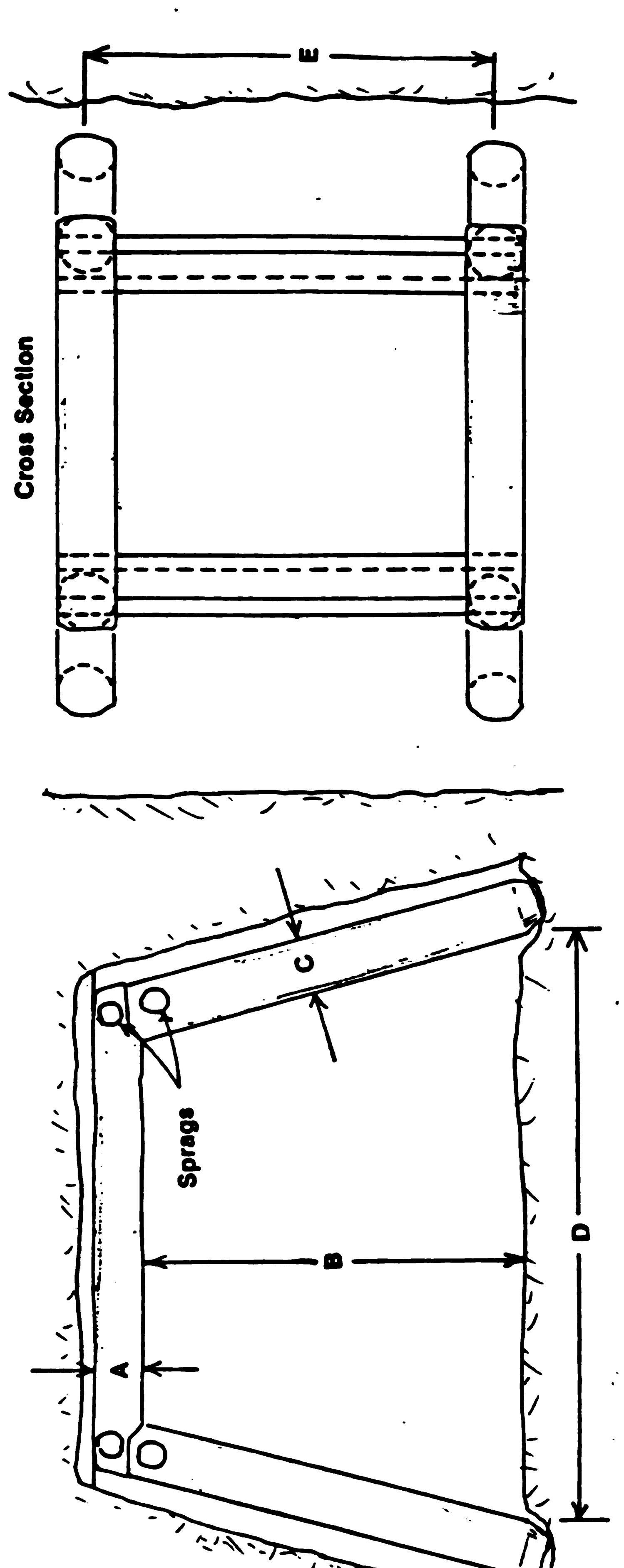

D
Cross Section
A
Sprags

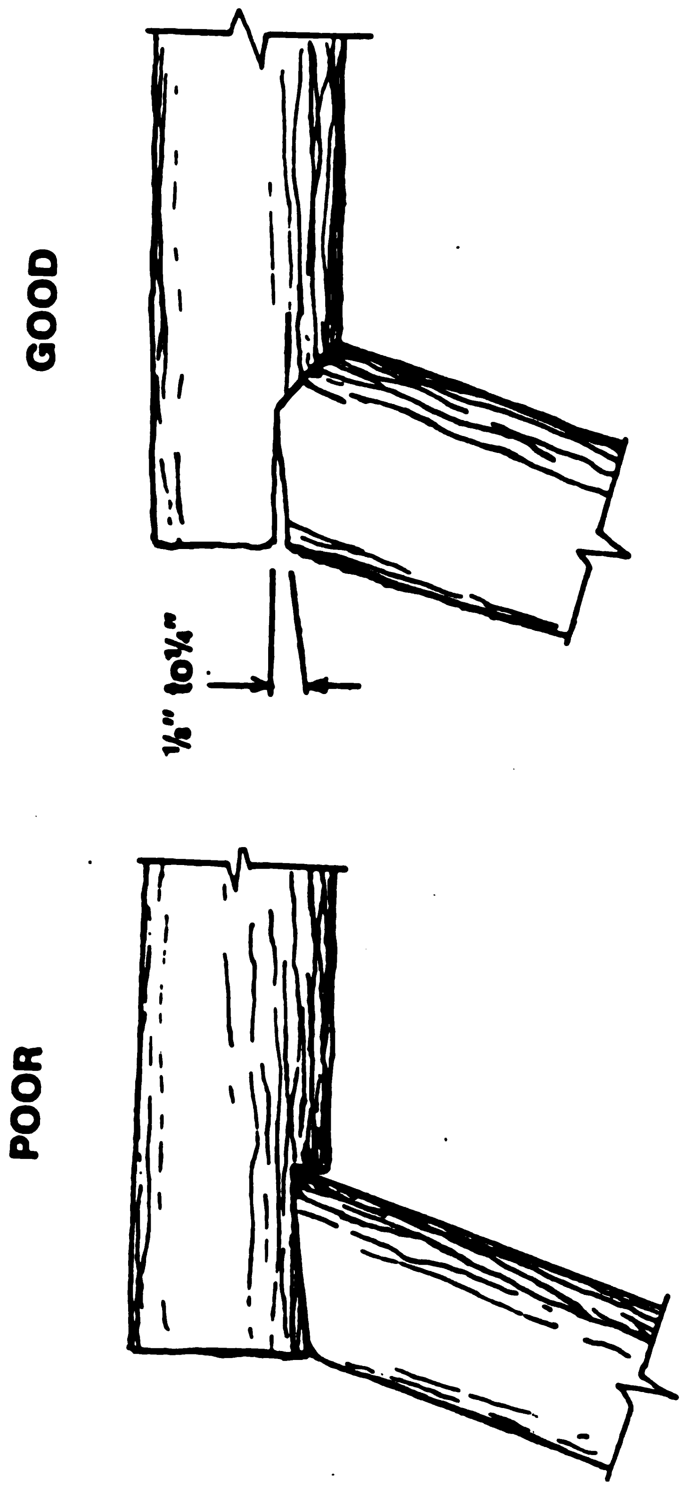
PROP SETTING IN FLAT BEDS

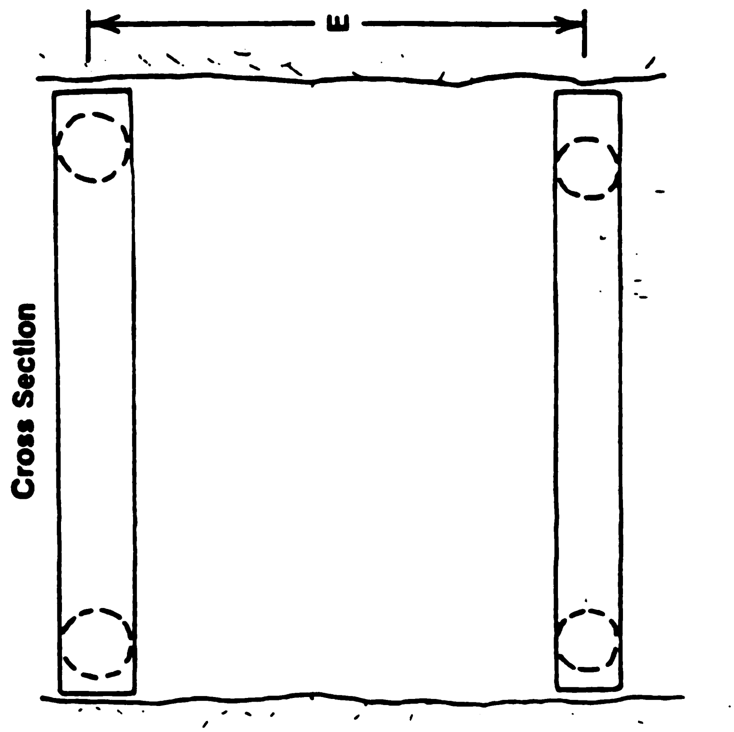


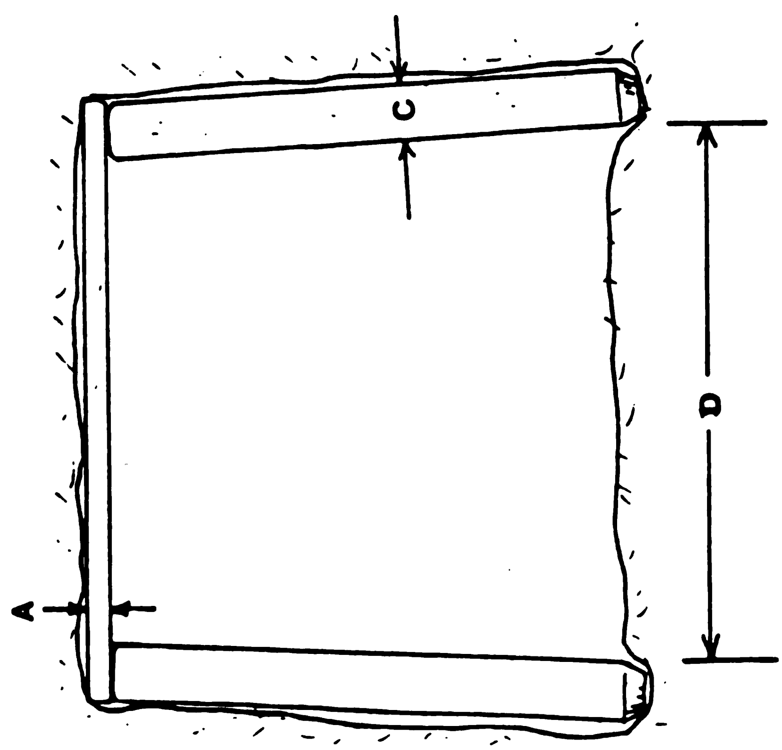
PROP SETTING IN PITCHING SEAMS




E
Cross Section
C
Sprags
B
D
A

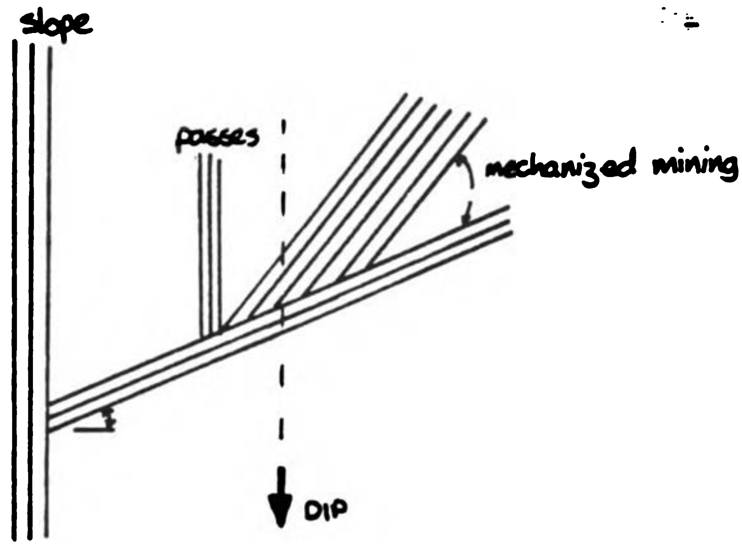

GOOD
1/8" to 1/4"
POOR


E
Cross Section

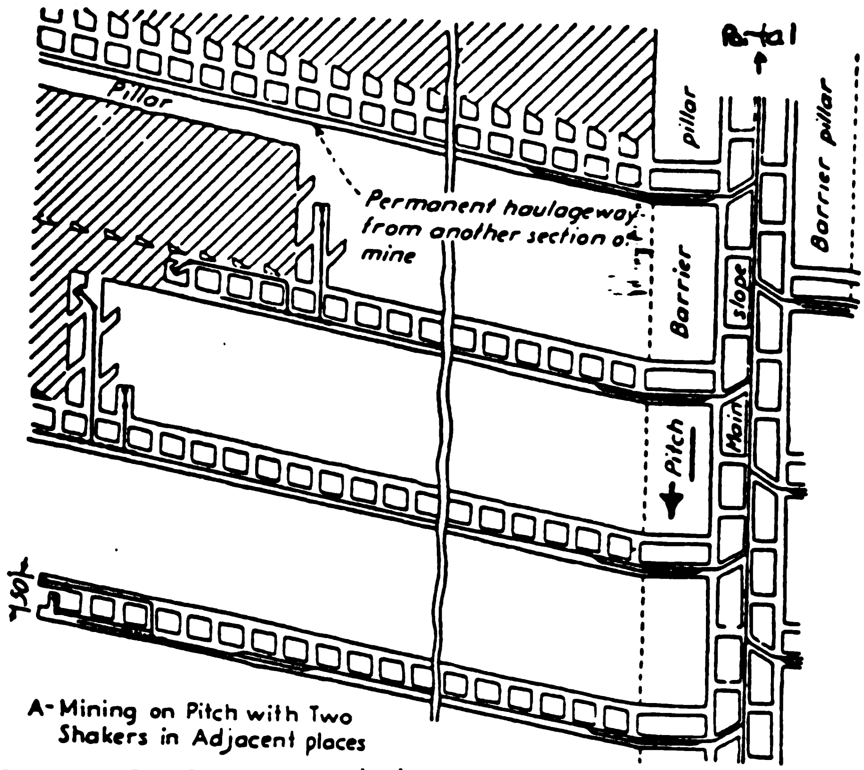

C
D
A

STEEP SEAM MINING

For moderately dipping seams mechanized mining can be carried out by turning off production workings at an apparant dip.



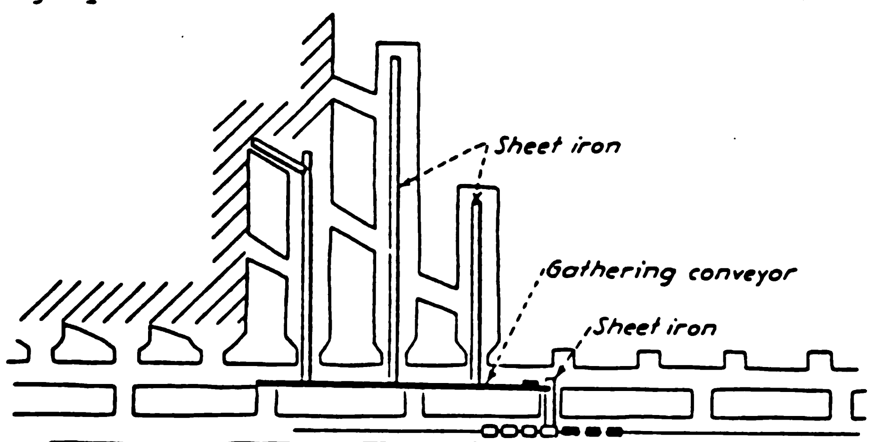
For Steeper Coal Seams.
The face transport is basically by gravity via sheet iron. The main entries are driven along or near strike in order to minimize the angle of dip.
For most of the mining systems, in steep coal seams, the coal is either hand-loaded or organized such that the majority of the coal falls down the chute, immediately upon blasting from the solid.

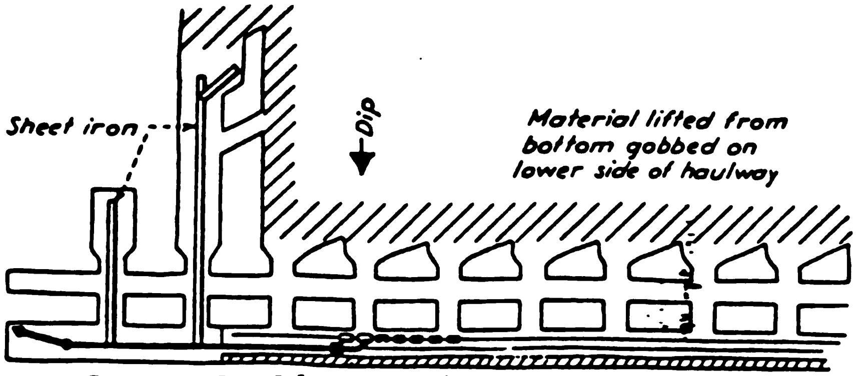


System A. Retreat Mining

The System A is very similar to the longwall retreat mining layout, which may be an attractive option for mining in the deeper coal seams. However, the main drawback is the stability of multiple entries in deep seams. Single entry development would be a better proposition. This system may also lend itself to backfilling; to avoid subsidence.

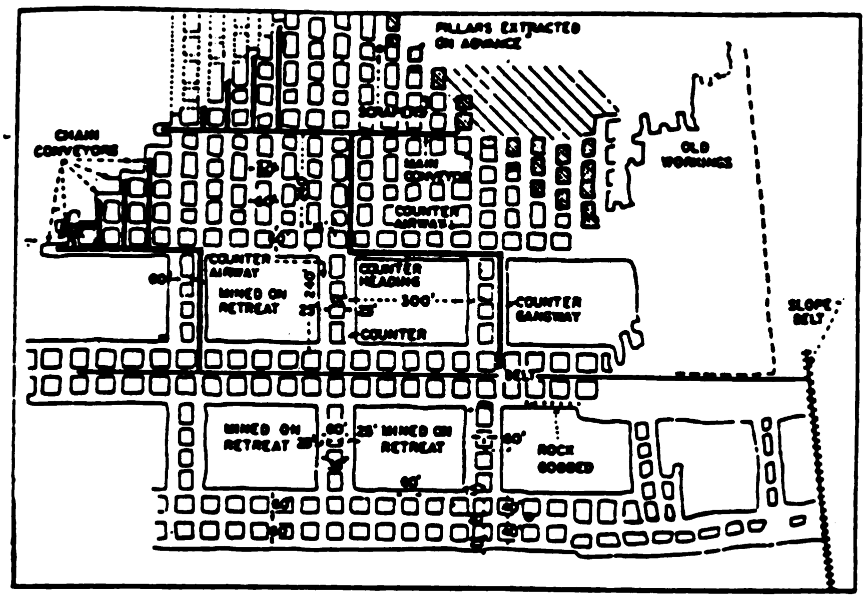
Face transport system
for a Retreat Mining System





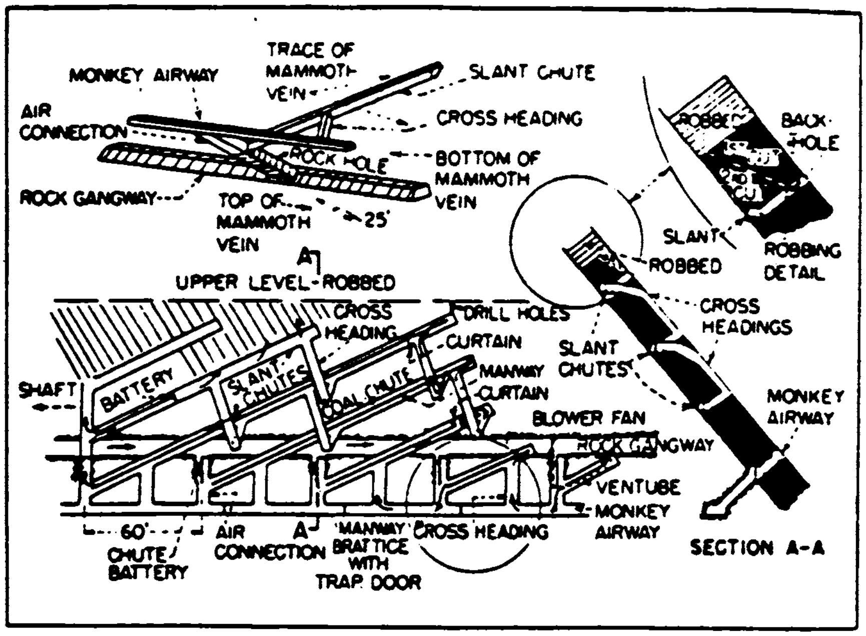
System B. Advance Mining

System B shows the entry development and production layout for an advance system. This system would probably be a better choice than System A (retreat) for DEEP COAL SEAMS. That is, in deep mines efforts are usually made to minimize entry development (ahead of production) when mined in-seam because there are likely to be more unstable in time. Advance mining is also better for CASH FLOW.



System C. Room and Pillar Mining

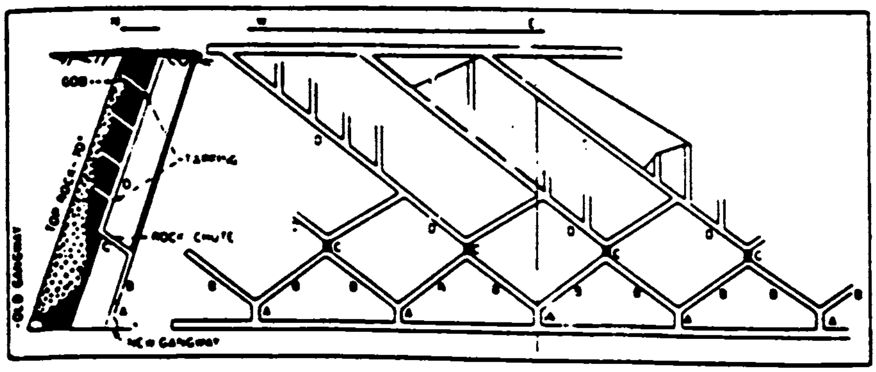
System C shows a Room and Pillar system that relies on hand-filled loading and chain conveyor face haulage.



System D. Slant-Chute

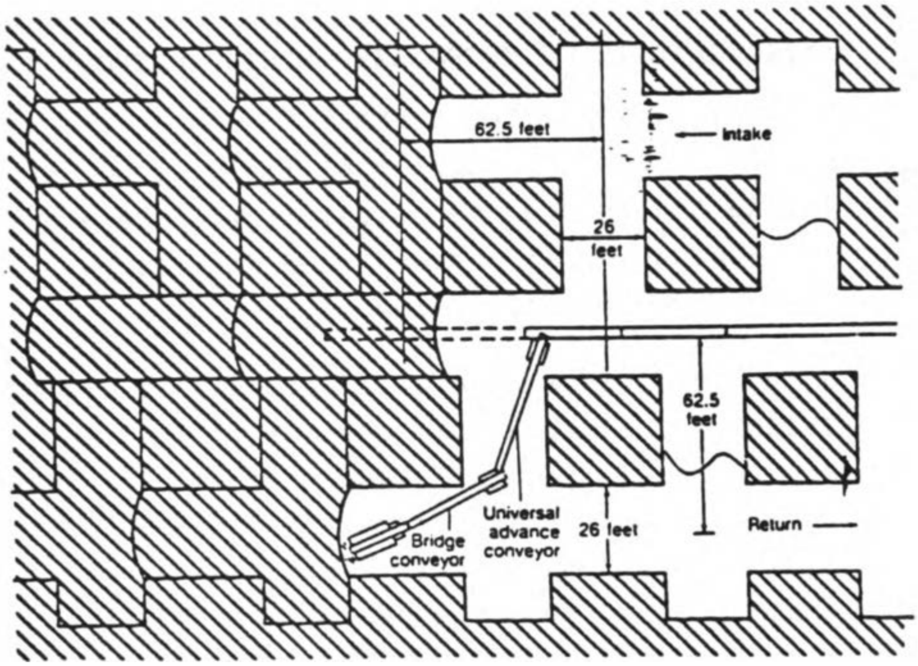
System D outline a slant-chute system that has been used for thick coal seams.

Other Systems



Tapping Mining System

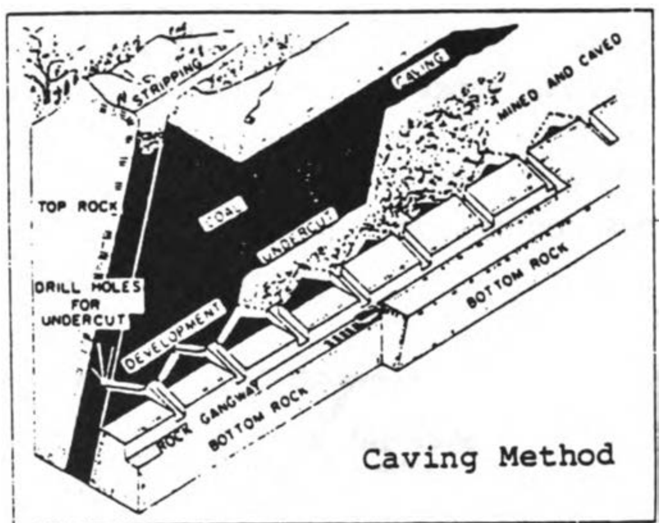
Thin Seam Mining-Continuous Mining with a Bridge Conveyor



Production : 250 mt per shift

Coal Thickness: 0.64 to 1.02 metres

Seam Dip : 5° (up to)



Caving Method

CHAPTER V

APPLICABILITY OF MECHANIZED MINING METHODS TO THE ANDEAN REGION

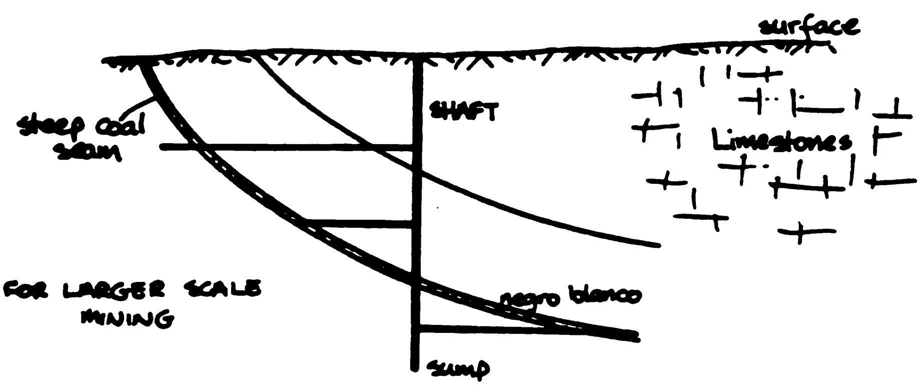
● JATUNHUASI COAL FIELD (PERU)

Although the Jatunhuasi coal field is not necessarily typical of the Andean Region coal deposits, it will be a useful exercise to describe the mining conditions and then discuss possible applications of various mechanized mining methods.

A report [1] gives a detailed account of the mining conditions of JATUNHUASI and possible methods of coal extraction. The centre of the Junhuasi cynclinal basin consists of a series of sandy shales, fine grained sandstones and limestones (up to 300m thick). Below lies 50m to 75m of massive sandstones often including thick red shale and one/two interbedded sandstones.

Mining Variables

OVERBURDEN	:• Up to 1100m limestones; 75m sandstones
COAL SEAMS	:• Thickness 0.5 to 0.95m (av 0.7m)
	• Subbituminous
	• 6,000-7,000 KCAL/Kg
	• Ash 9 to 16%; Sulfur 0.6 to 2.5%
	• Inclination 24° to 33° (Av 30°)
ROOF CONDITIONS	:• Thick sandstones (xy seam)
	• Sandstones indulates displacing the top coal
	• Competent (hard)
FLOOR CONDITIONS	:• Similar to roof, grading to sandy-shale in places.
	• Competent (hard)



[1] Report on Jatunhuasi Mining Methods Investigation by Cerro Corporation 1970.

THE SELECTION OF MINING METHOD will depend on:

- Scale of mining (coal demand)
- Mechanization vs Non-mechanization
- Caving vs Non-caving

This discussion will focus on the latter two points ie the supply rather than the Demand characteristic.

Mechanization vs Non-Mechanization

The factors to consider are:

- Ability of machines to perform in mining conditions
- Productivity: machines/labor intensity

The principal mining variables for the Jatunhuasi coal field are:

- Inclined shallow coal beds
- Level (or near) deeper beds
- Soft coal
- Good roof

Mobile mining machines such as shuttle cars, scoops require a grade of not greater than 20% (12°).

The actual continuous miner and loading machine can mine on grades up to about 25°, although a limit of 15° is more practical. As the Jatunhuasi coal seams incline up to 33° it is quite feasible to mine on an apparant dip. The main entries being developed along strike.

However, considering the LIMITED RESOURCES and generally ample SKILLED LABOR, and probably small seale mining, the Andean Region will probably not be preoccupied with mechanizing the mines. This would call for high initial capital, replacement parts and maintenance programs.

Caving vs Non-Caving methods.

As quoted in the Cerro de Pasco report, caving may NOT be an attractive proposition due to:

- Hard roof
- Possibility of fracturing water bearing MACHAY LIMESTONES.

ROOM and PILLAR mining may then be a suitable method. Assuming CONVENTIONAL MINING (higher labor intensive) the following limits apply:

- Depth ≯ 700 metres
- Dip ≯ 15°
- Coal thickness 1.0 to 6 metres
  (Jatunhuasi 0.5 to 0.95m)
  Probably the limiting factor.

Unfortunately, as in many coalfields, the shallow seams are steep and the deep coal is more level.

Also, the coal being soft/friable (subbituminous) will not produce strong coal pillars in the deeper coal. Thus, if backfilling is not used (to prevent caving) coal recovery (percentage) will be low. Mines in Eastern Kentucky mine coal, with the Room and Pillar system, in level and 2 metre coal seams to 800 metres under the ridge of the mountain. The coal pillars are generally retreated.

LONGWALL MINING was suggested in the Cerro de Pasco report as being an attractive alternative: However, backfilling, to PREVENT CAVING, would be used. The longwall system would be suitable in the deeper and inclined coal seams. A fully mechanized longwall unit, of face length 150 metres would cost in the order of $6 million. This scale of investment would require:

- large seale (high production/mining)
- large, continuous coal reserves
- high capital investment
- coal seam thickness greater than 1.0 metre .

Subsequently, mechanized longwall will NOT BE SUITABLE FOR Jatunhuasi specifically and probably in the Andean Region in general.

However, there may be a case for a less mechanized mining system. Similar to Longwall Mining, especially in the deeper deposits.

MINING IN DEEP COAL DEPOSITS

The principal problem is the decreasing stability of the main entries over time. The U.S. system of MULTIPLE ENTRIES has a significant disadvantage in deeper coal, whereas a SINGLE (or even two entries) system would be far more stable. Also, developing multiple main entries is usually costly.

THE SHORTWALL MINING SYSTEM uses a combination of:

- Longwall layout; length 50 to 60m
- Continuous cutting machine

The shortwall system requires better roof conditions than the longwall mining system.

Therefore, single entry, labor intensive, shortwall system may be suitable for the deeper, more level coal seams. Mining the coal with HYDRAULIC PICKS is another alternative.

HYDRAULIC MINING is a possibility for:

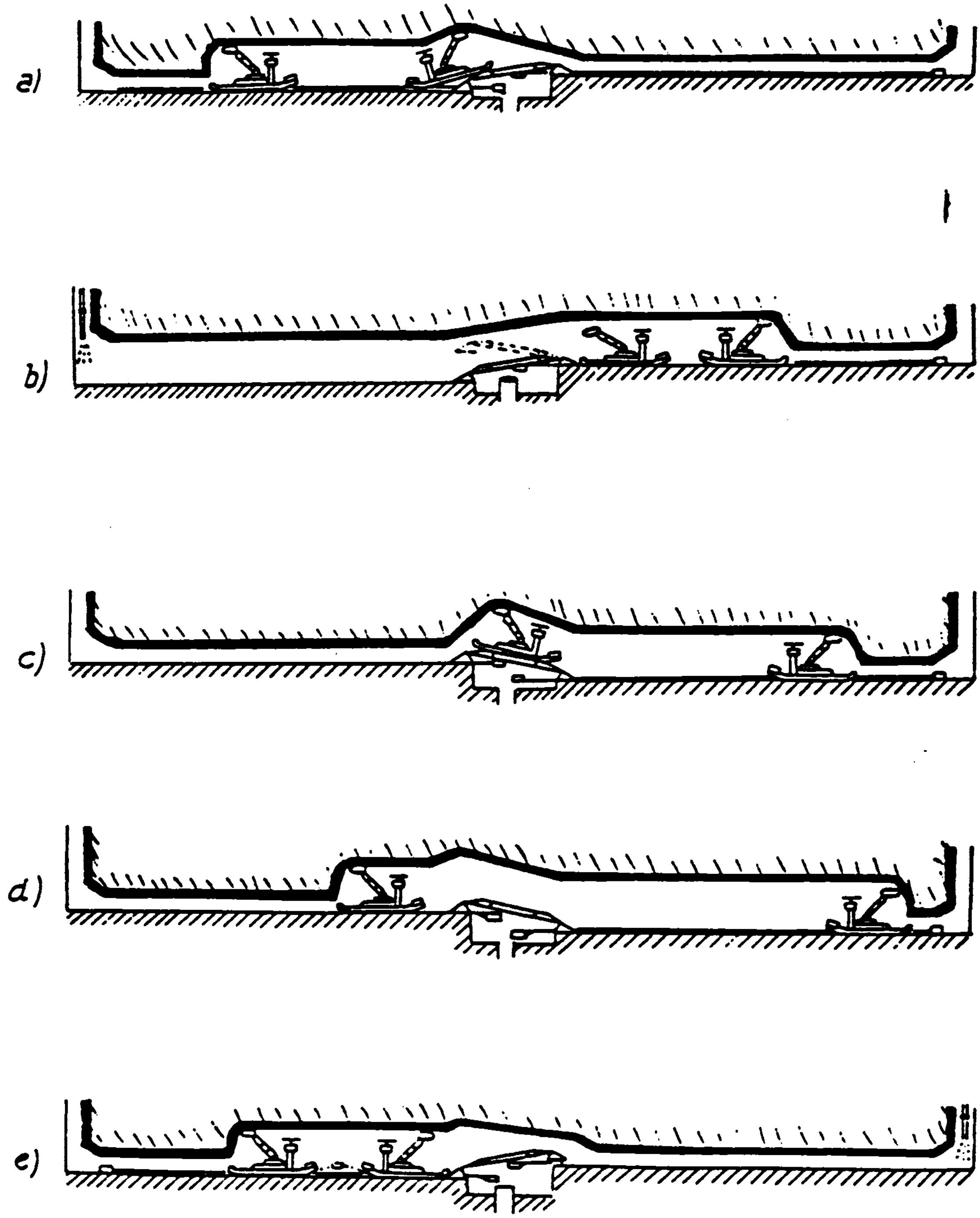
- Coal seam dips 8° to 90°
- Soft-Medium hard coal
- Thickness, generally 2.5 metres plus

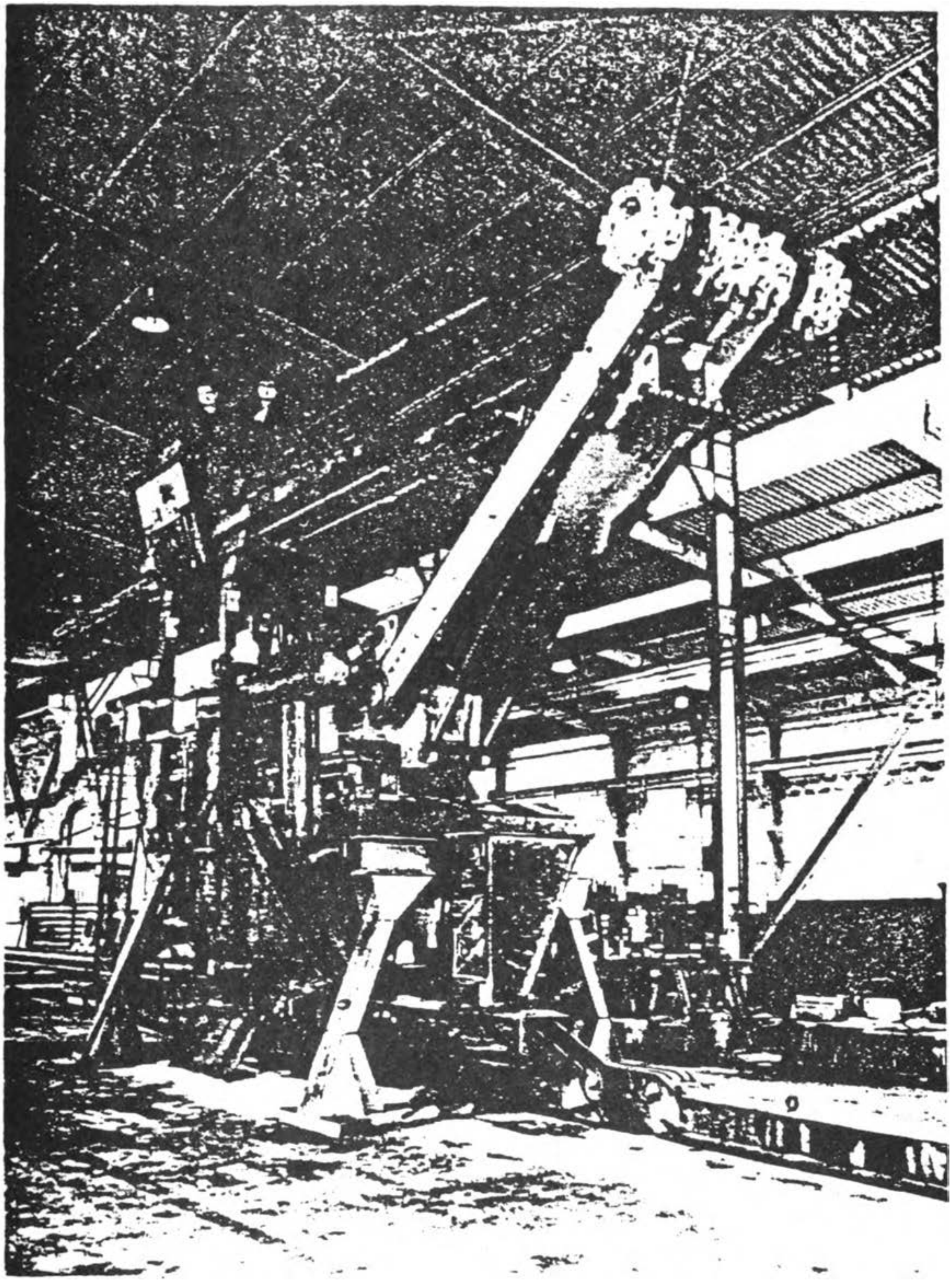
The Jatunhuasi coal field has good roof and floor conditions, but, probably the coal is too thin. Also, most hydraulic methods involve caving. (see Appendix C)

UNDERGROUND AUGERING is probably more suitable for the thicker, steep, anthracite deposits of the Andean Region. Also, there is a lack of actual case studies of full scale underground auger mining, to be able to draw any definite conclusions on applicability of auger mining (see Appendix B).

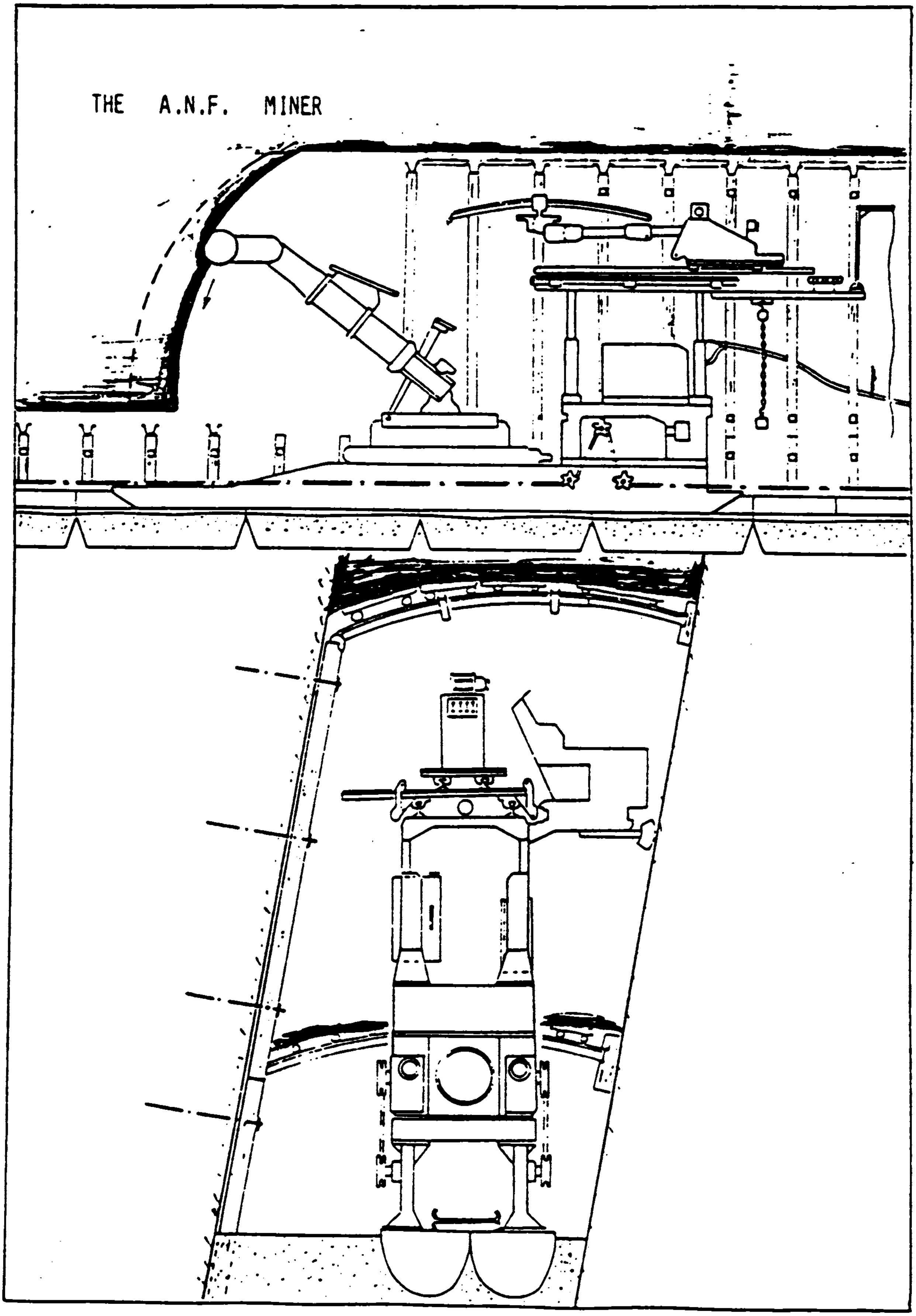
APPENDIX A: FRENCH METHOD OF MINING VERTICAL COAL SEAMS

STARTING A NEW SLICE WITH VERTICAL MINERS

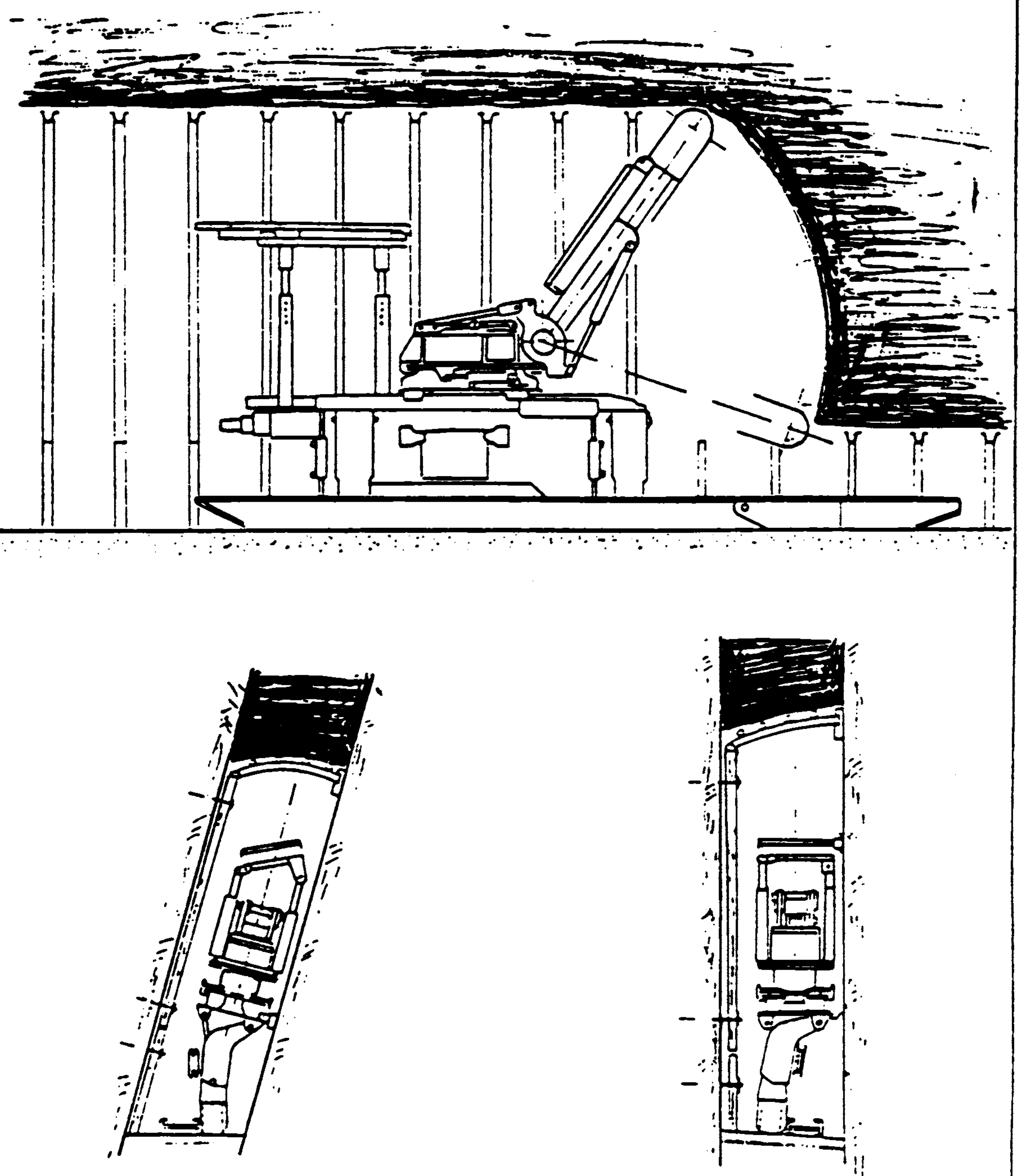




THE DRESSMATIC MINER


THE A.N.F. MINER

"DRESMATIC" MINER FOR THINNER VERTICAL SEAMS



APPENDIX B. UNDERGROUND AUGERING OF STEEP COAL SEAMS

I. CONTINUOUS BORING MACHINE AND 0.61 METRE AUGERS IN STEEP ANTHRACITE COAL

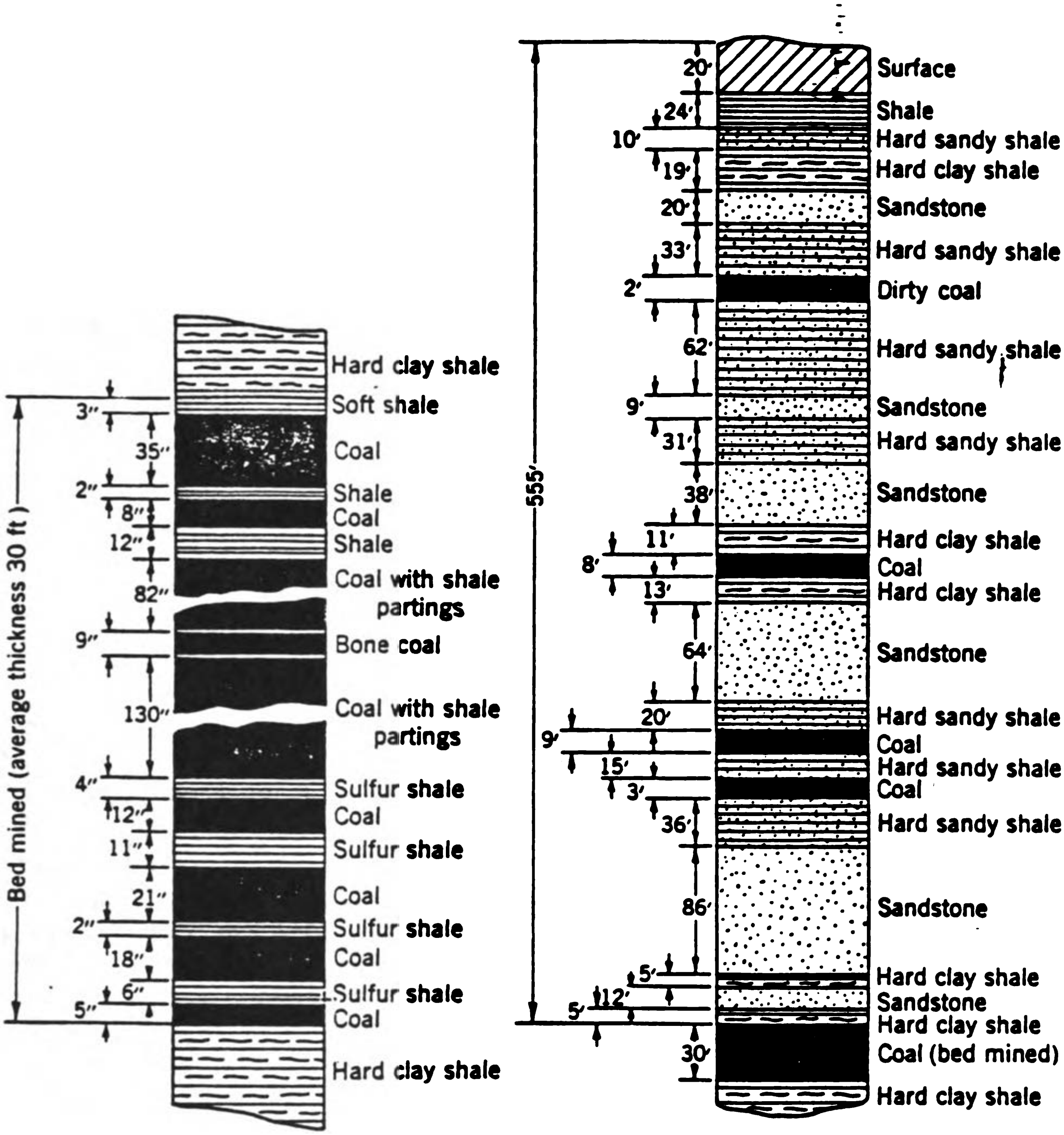
The United States Bureau of Mines produced a report (No. 6759) in 1966 on the use of a boring machine in a 10 metre thick Anthracite coal seam; inclined 15° to 45°. However, the boring machine could not mine on an inclination greater than 15° (27%).

Entries (gangway) were driven with the continuous borer. Ventilation openings between the entries were developed by a large (0.61m) diameter auger (described later). The blocks of coal between the entries were mined by the long-hole (blasting) method. Conveyors were used to transport the mined coal.
See the Figure .

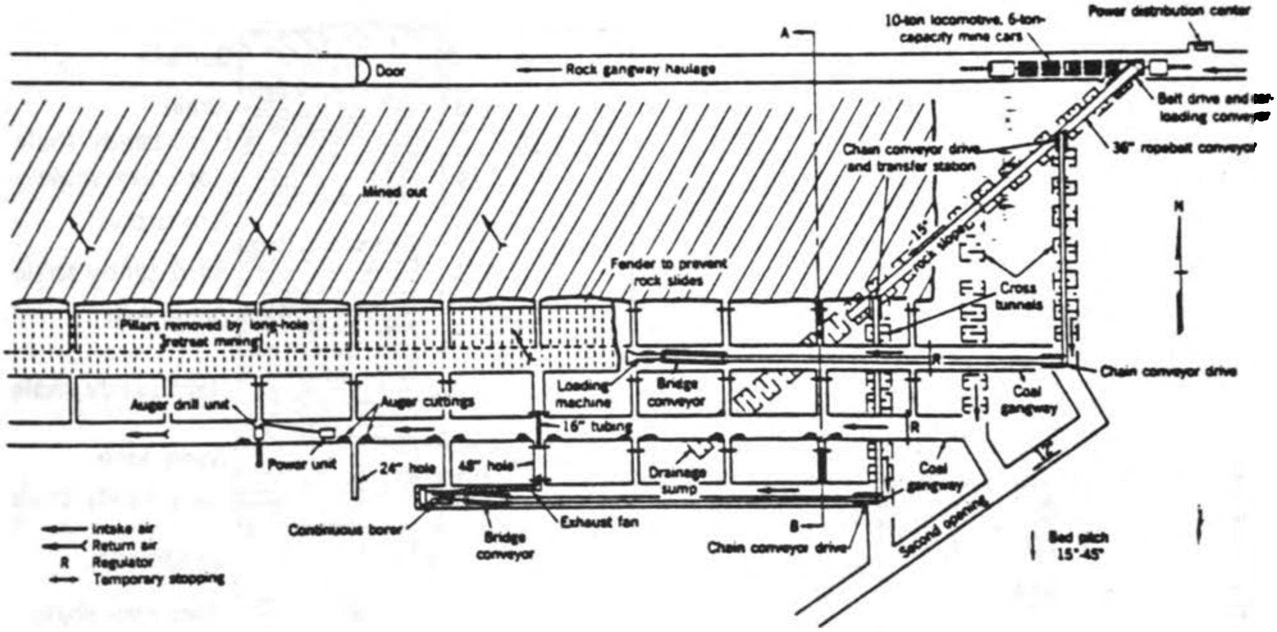
As the boring machine competely filled the circular entry advance support could not be used. As such, a lot of ground control difficulties were encountered.

- Average Productivity Rate = 18 mt per man-shift

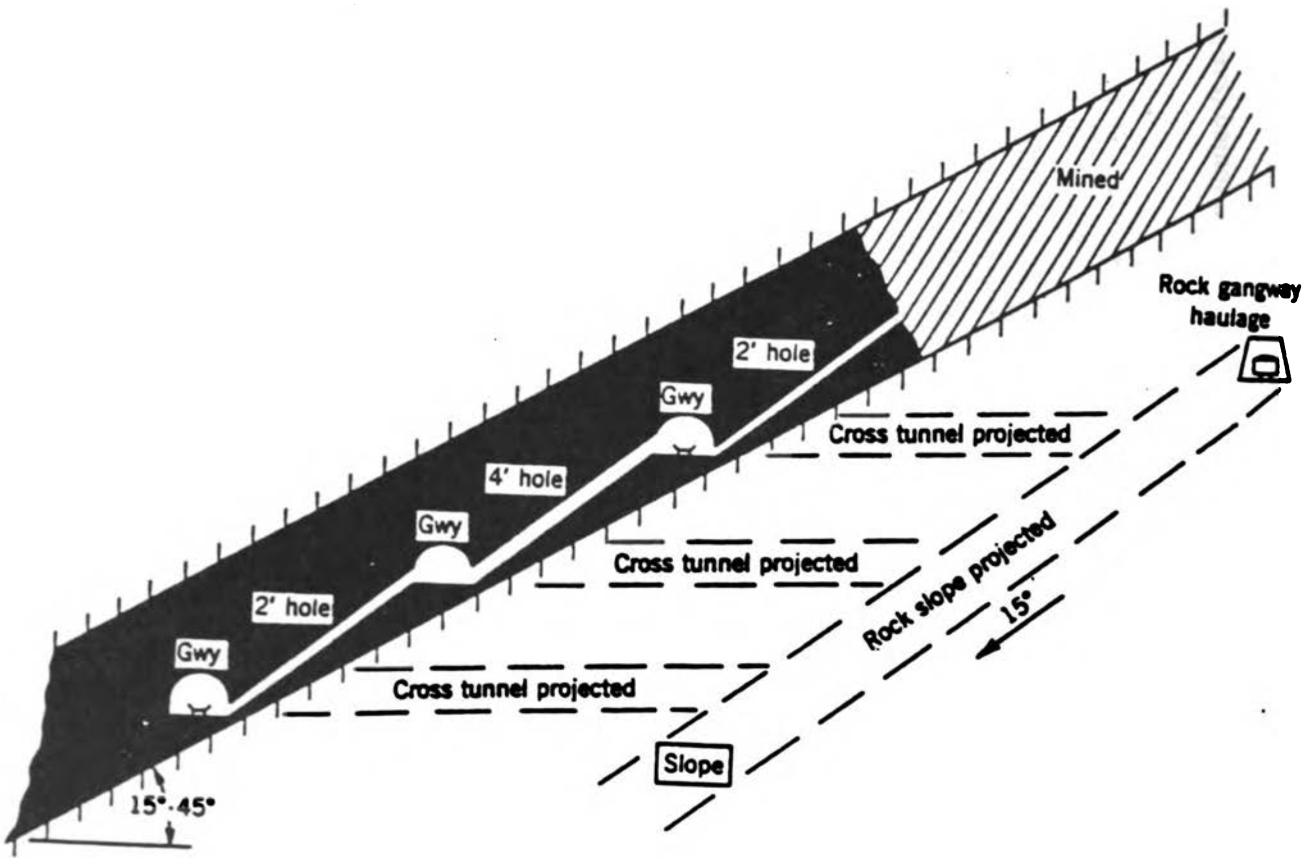
The boring machine is prototype equipment and would be too unreliable for the needs of the Andean Region.



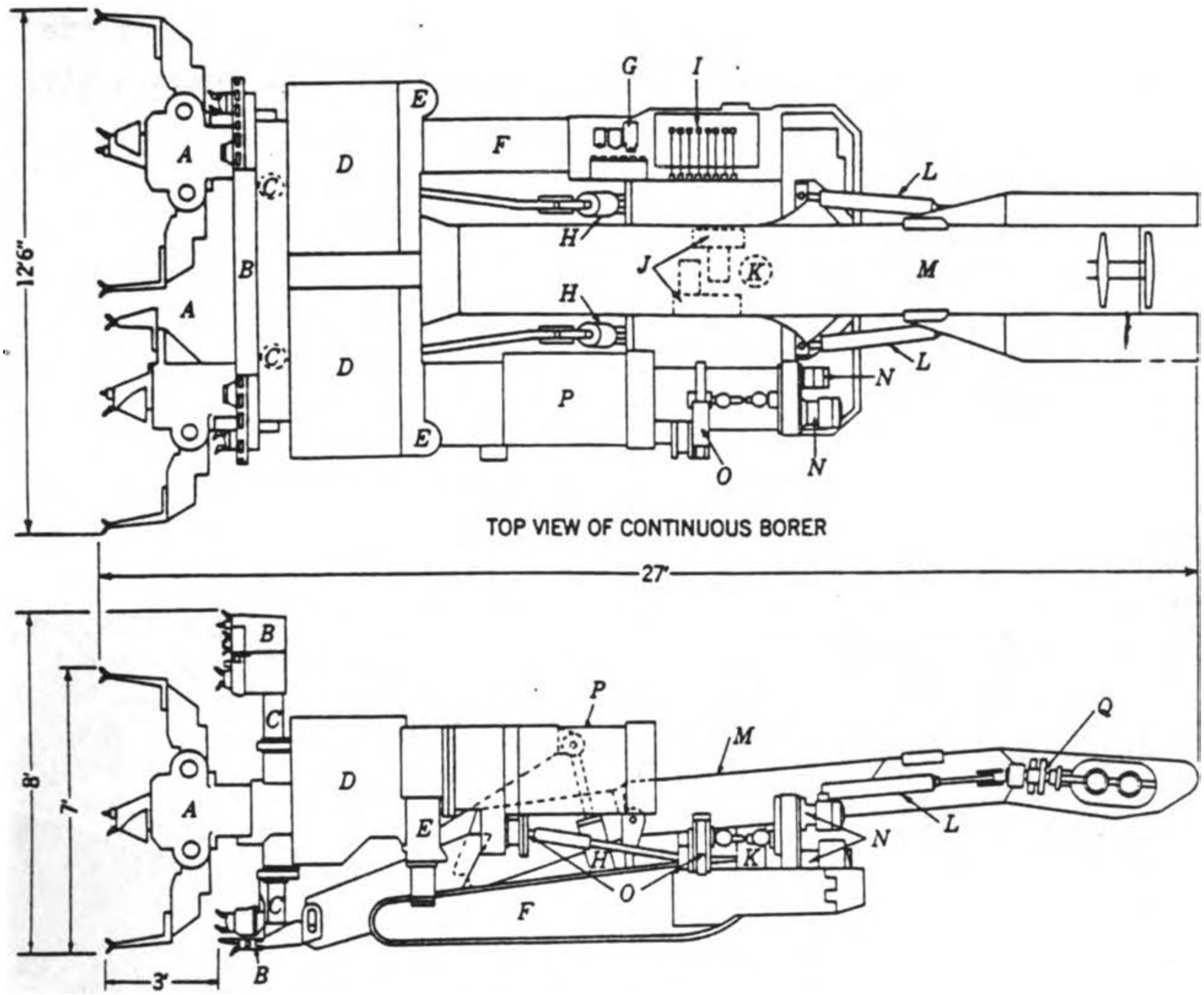
Columnar Sections of Coalbed and Overburden.



Development, Method of Mining and Deploying Equipment.



Cross Section A-B of Figure 2, Showing Coalbed and Relative Position of Rock Gangway Haulage, Rock Slope, Cross Tunnels, Coal Gangways, and Auger Holes.



A Rotating boring elements
B Cutter chain
C Chain-bar elevating jacks
D Gear case
E Head elevating jacks
F Crawler treads
G Hydraulic motor, water spray pump
H Head tilting jacks
I Control panel
J Hydraulic tramming motors
K Boom elevating jack
L Boom swing jacks
M Discharge conveyor
N Hydraulic pumps
O Power takeoff
P Main motor
Q Hydraulic conveyor motor

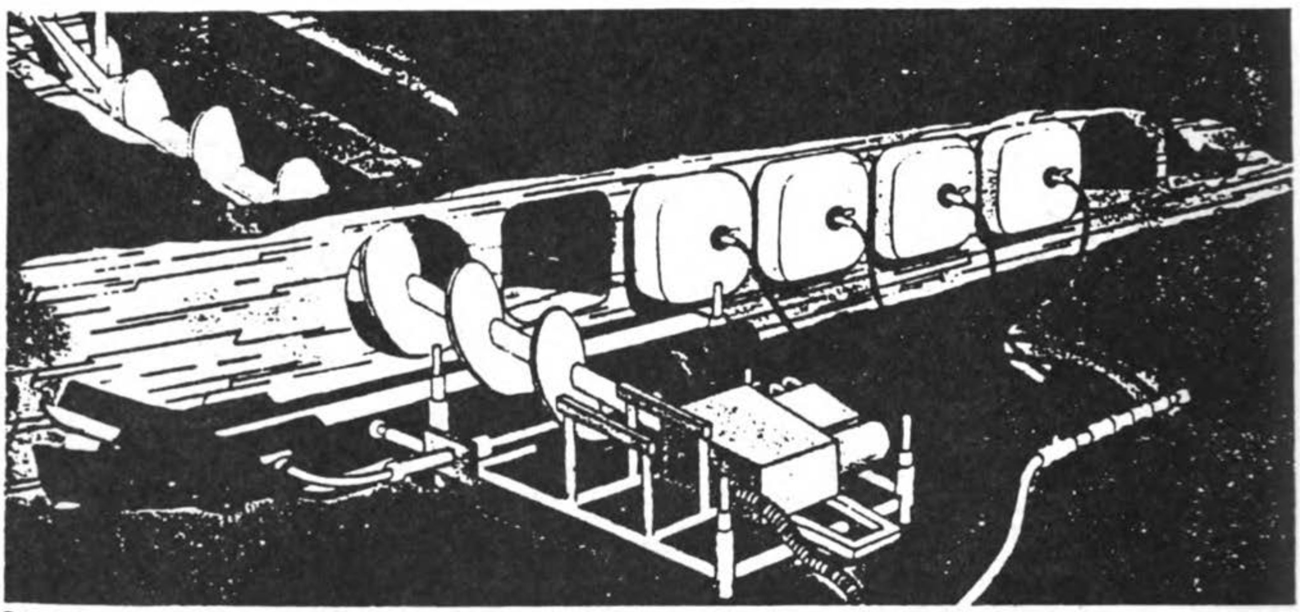
Continuous Borer Assembly.

II. HI-REAM AUGER SYSTEM

A more recent mining development (by USBM) involves the use of the surface mining auger technology to underground coal seams. The two principal uses are:

- Mine out prepared panels of coal at low cost and high recovery rates.
- Secondary mining or to excavate coal from remnant pillars.

This system is very promising and involves relatively simple mining technology.



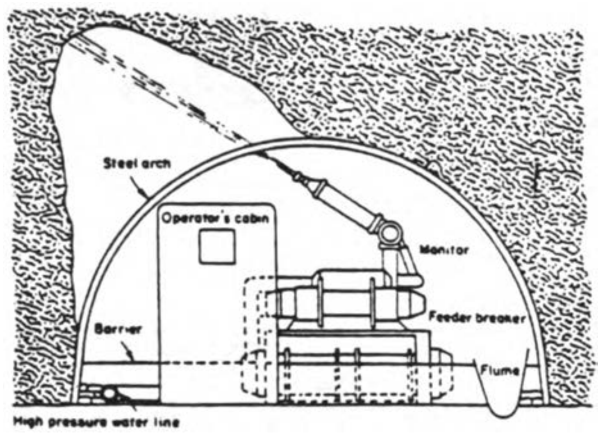
Removing more coal per hole is purpose of back-reaming square-hole auger. Auger bores round holes, then head flight expands hydraulically before withdrawing. Bags inflated by air pressure help support roof weakened by the extra removal.

APPENDIX C: HYDRAULIC MINING OF THICK AND STEEP COAL SEAMS

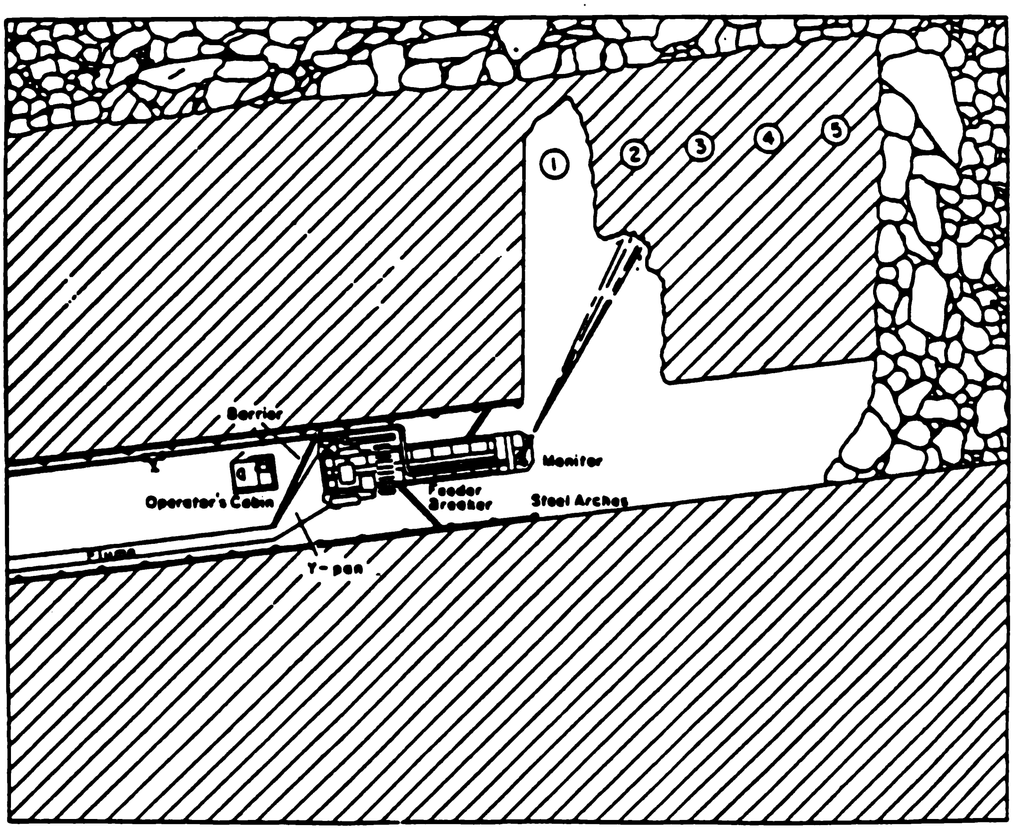
HYDRAULIC MINING

Hydraulic Mining has been used extensively in the Rock Mountains, British Columbia, Canada; USSR and China.
A hydraulic jet (monitor) of water is impacted against the coal. The coal/water mixture then passes (by gravity) down a flume, see diagram.
The water jet is produced at 13.8 MPa, by a 1864 KW centrifugal pump.

Productivity: 13mt per minute
1000 mt per shift
Unit Personnel: 7 miners
Coal Seam: well jointed, not hard
Floor: needs to be hard and inclined

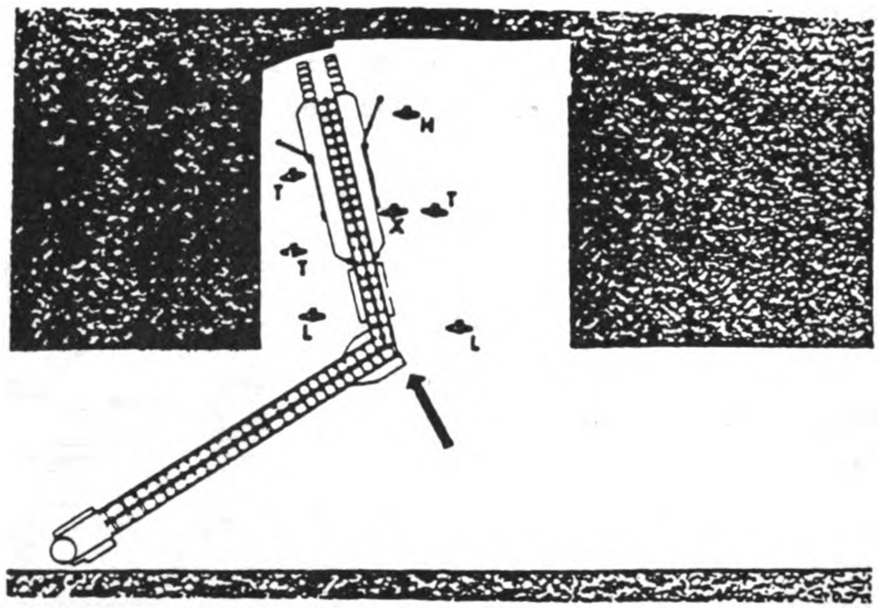


End view of a retreating face area

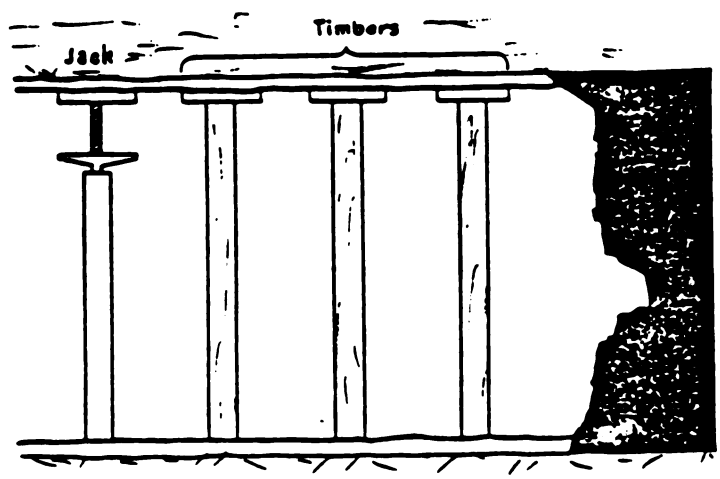


Plan view of a retreating face area in the Hydraulic mine

APPENDIX D: A THIN SEAM MINING MACHINE (AUGER HEAD)



Another continuous mining method is continuous auger mining. A series of both chain and belt conveyors will carry the coal to the surface. In the following series of sketches, you will see the location of the auger and its attached conveyor only. Look at the large number of workers and how close to each other, to the face and to the equipment they must work. On the diagram "X" represents the equipment operator, "H" represents his helper, "T" represents timbermen and "L" represents hand loaders.



The helpers must constantly set up jacks to "winch" or move the auger from position to position.

AUGER MINING METHOD

In a typical face operation, the wire ropes pull the miner forward into the coal at one side of the coal face (fig. 3). This is called sumping. After the augers are fully into the coal, the wire ropes are moved to the front sheaves and anchored at each side of the machine to pull it sideways to cut the coal across the face.

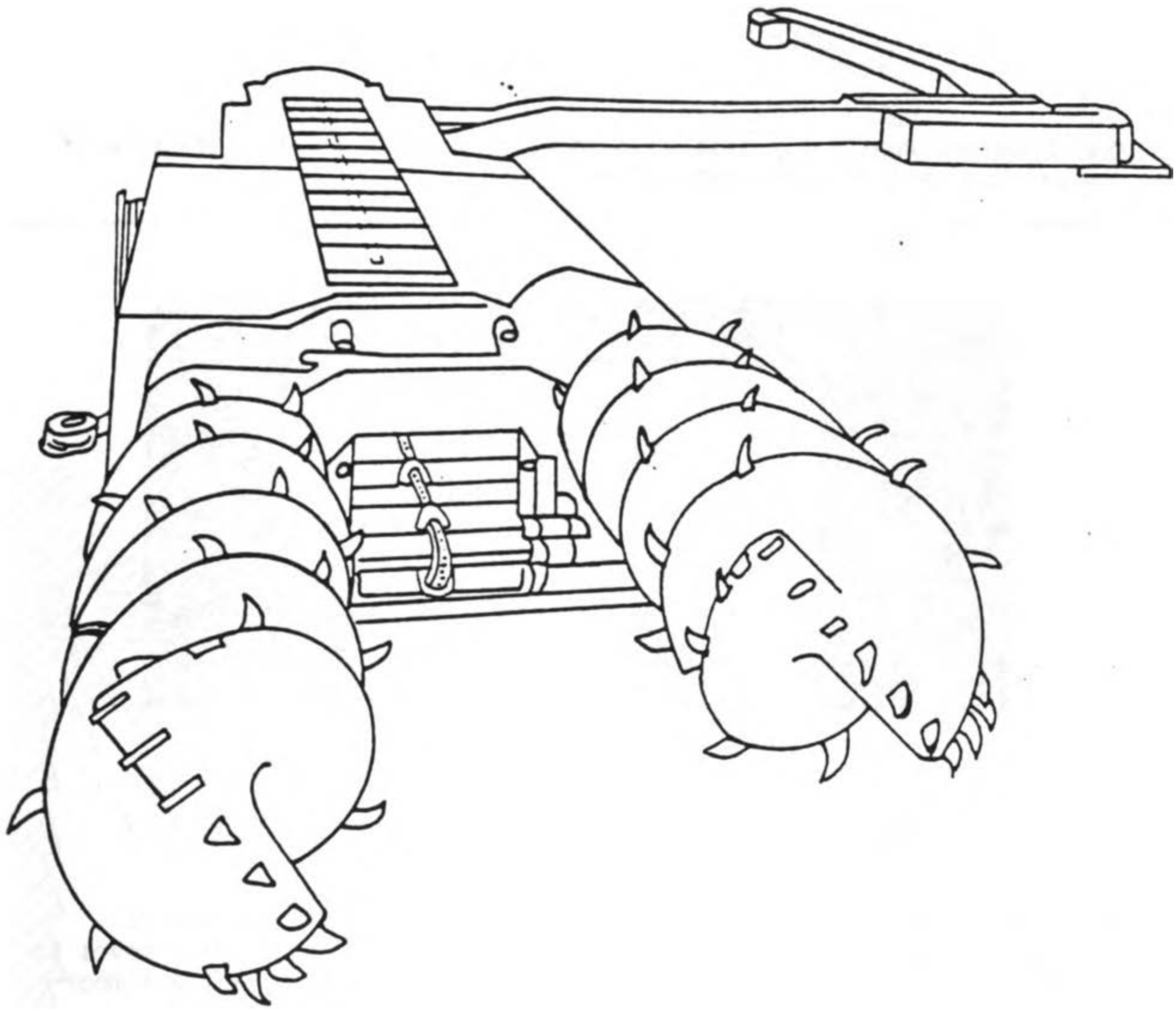
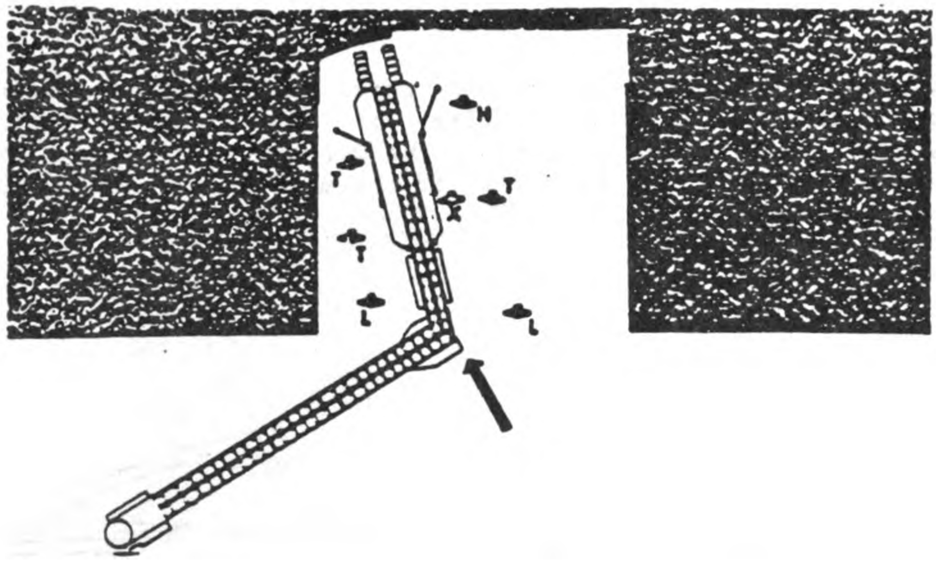
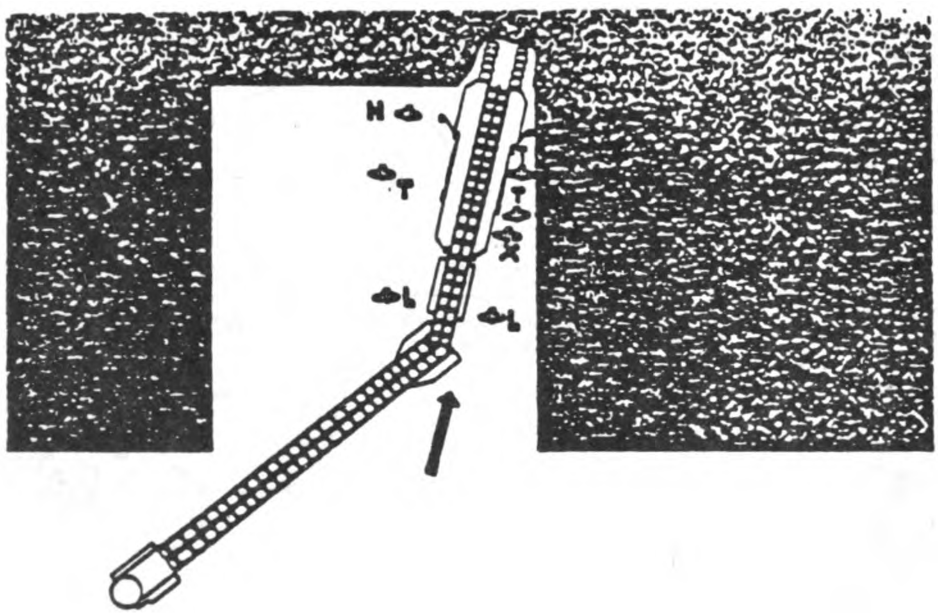


FIGURE 1. - Auger-type continuous miner.



One timberman constantly sets up temporary supports on the left side of the machine as the auger moves to the right.



At the same time the timberman on the right side of the machine is removing the supports. This process is reversed as the machine moves to the left. The loaders in continuous auger mining also move the timber supports and shovel the loose coal onto the conveyor.

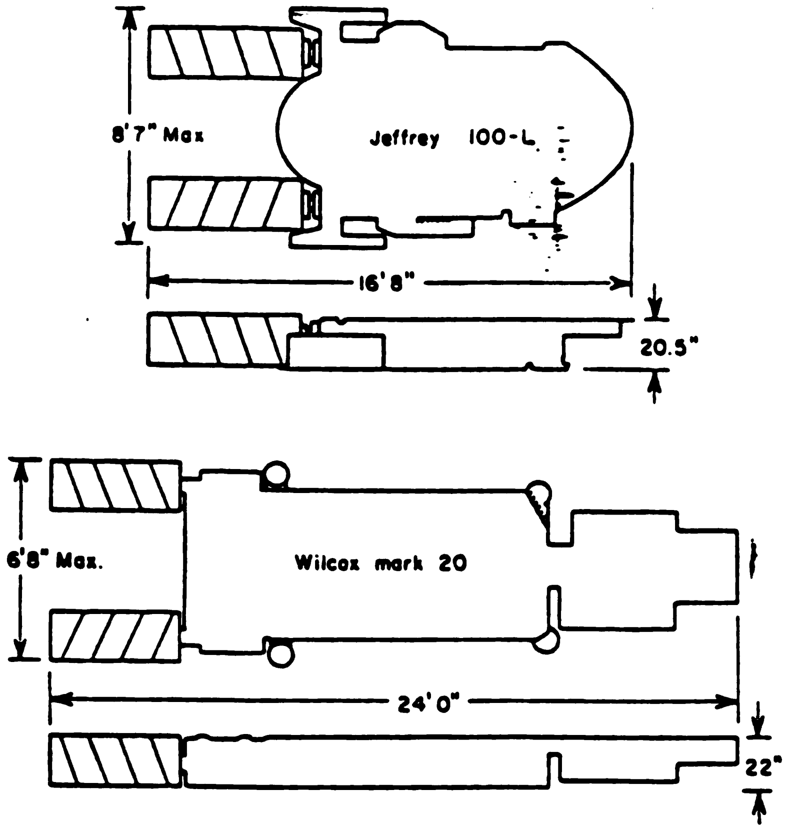


FIGURE 2. - Plan view of Jeffrey and Wilcox auger miners.

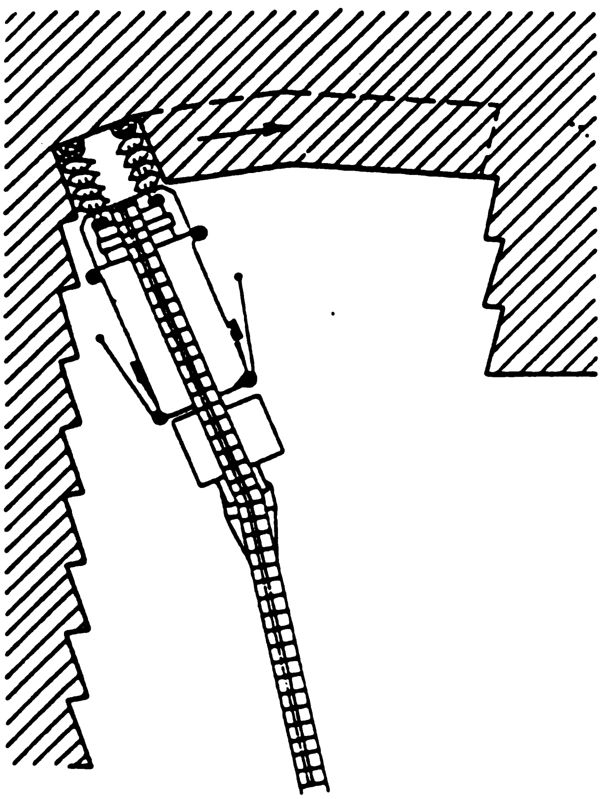


FIGURE 3. - Auger miner sumping into coal face.

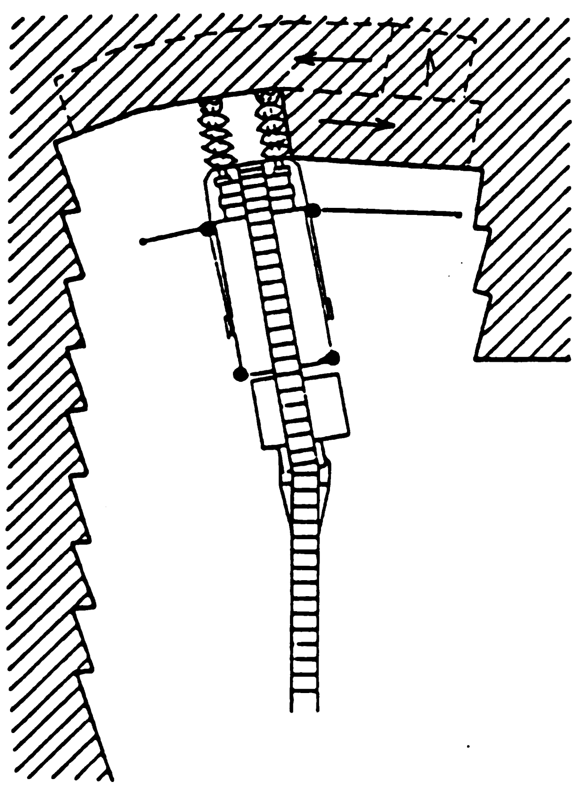


FIGURE 4. - Auger machine mining face cut.

The Mark 20 PJ eliminates sumping, the mining step that puts the jack setters forward of the pull ropes and near the rotating augers. Instead of sumping and then cutting across the face, the arc miner progressively cuts a series of arcs (figs. 5-7). Pivot jacks at the rear corners of the Mark 20 PJ make it self advancing. Extending one jack to the floor and the roof creates a pivot point. As the miner is pulled by a rope on the pivoting side, it

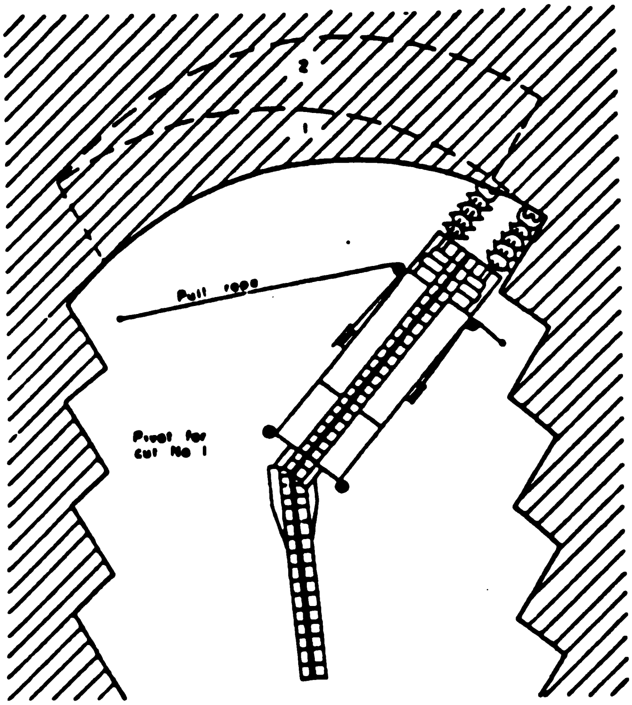


FIGURE 5. - Wilcox Mark 20 PJ auger miner starting arc.

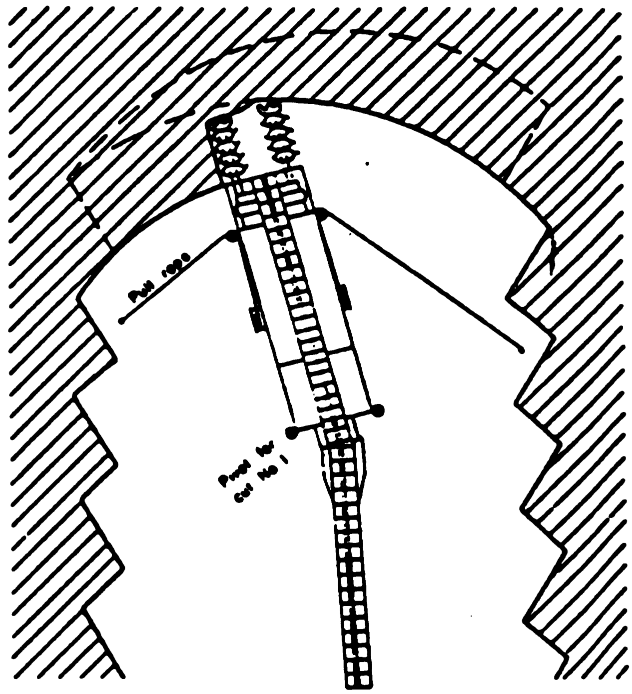


FIGURE 6. - Wilcox Mark 20 PJ auger miner midway in arc.

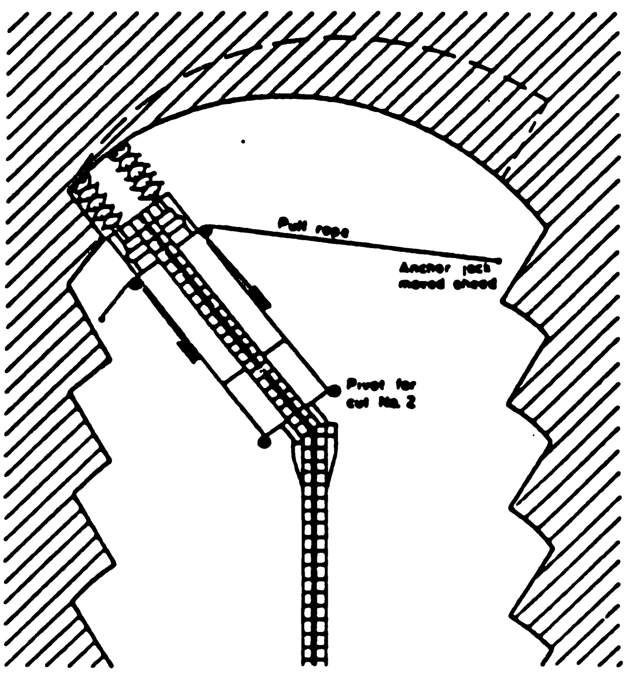
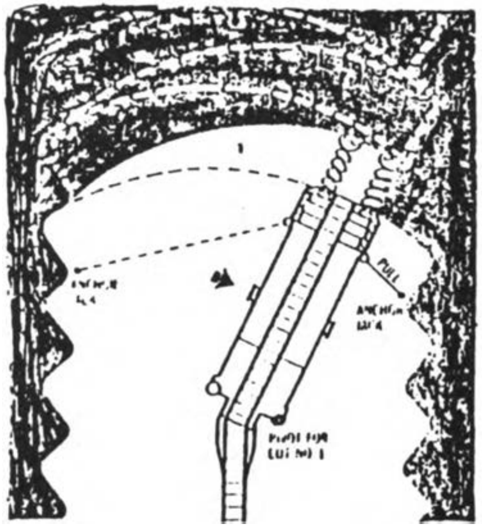
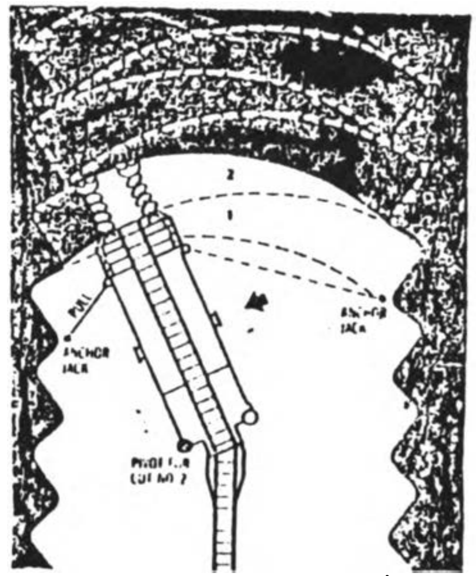


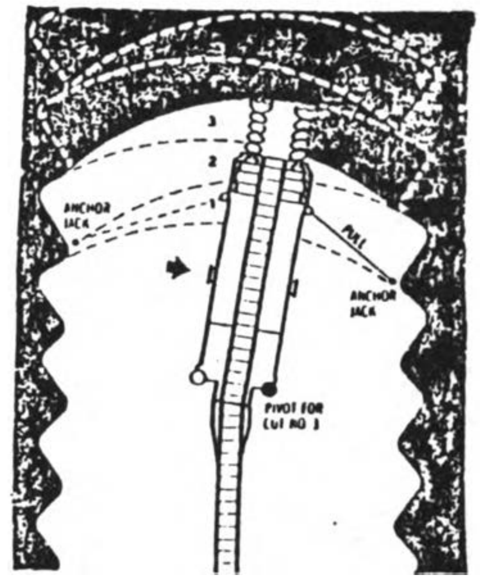
FIGURE 7. - Wilcox Mark 20 PJ auger miner ready for next arc.



1. Miner pivots on extended right pivot jack as it swings to right making cut no. 1. Retracted left pivot jack swings forward toward no. 2 pivot point.



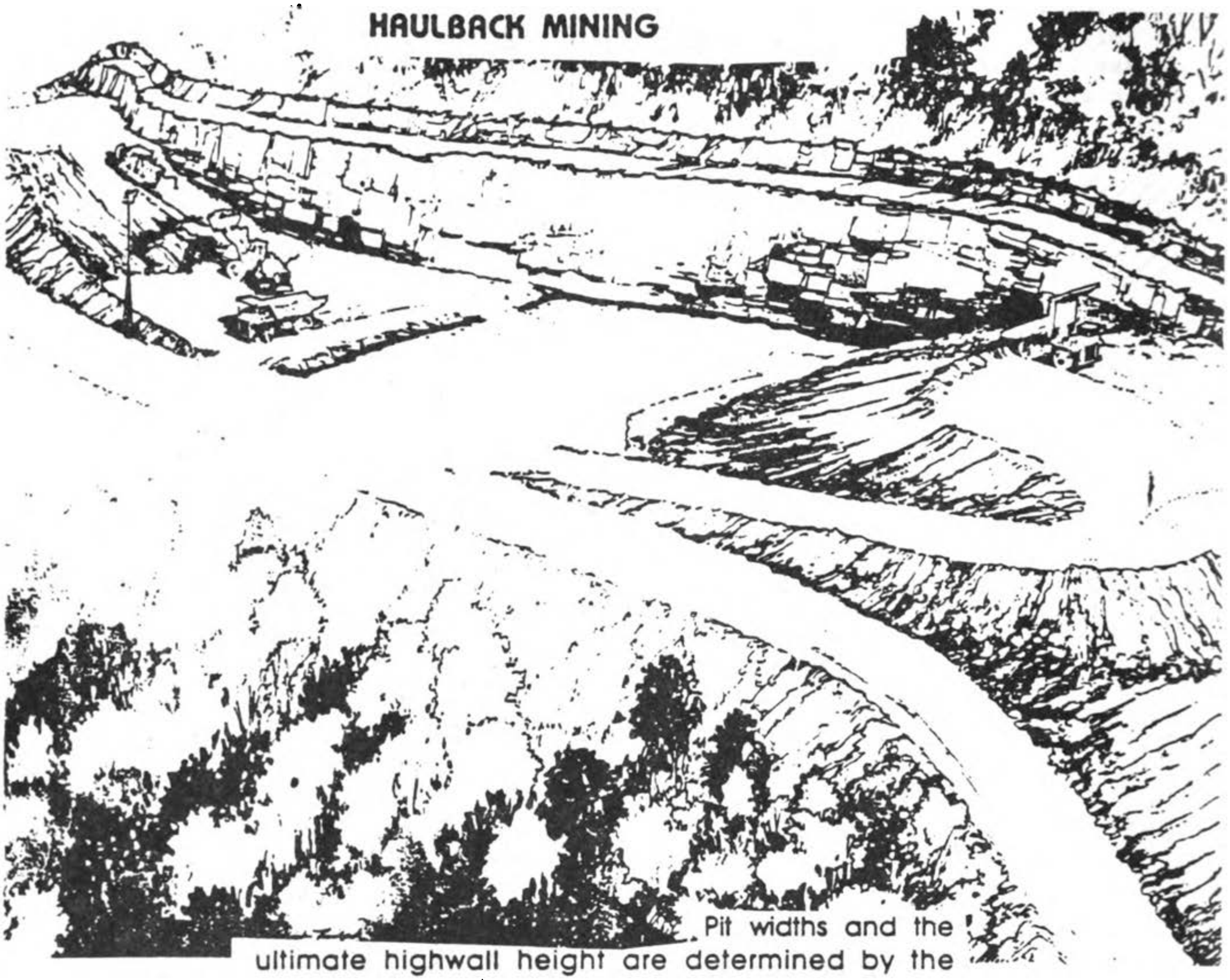
2. Pivoting on extended left pivot jack, miner swings to left through cut no. 2. Retracted right pivot jack advances toward no. 3 pivot point.



3. Again pivoting on extended right pivot jack, miner swings right, making cut no 3. Retracted left pivot jack moves ahead toward no. 4 pivot point

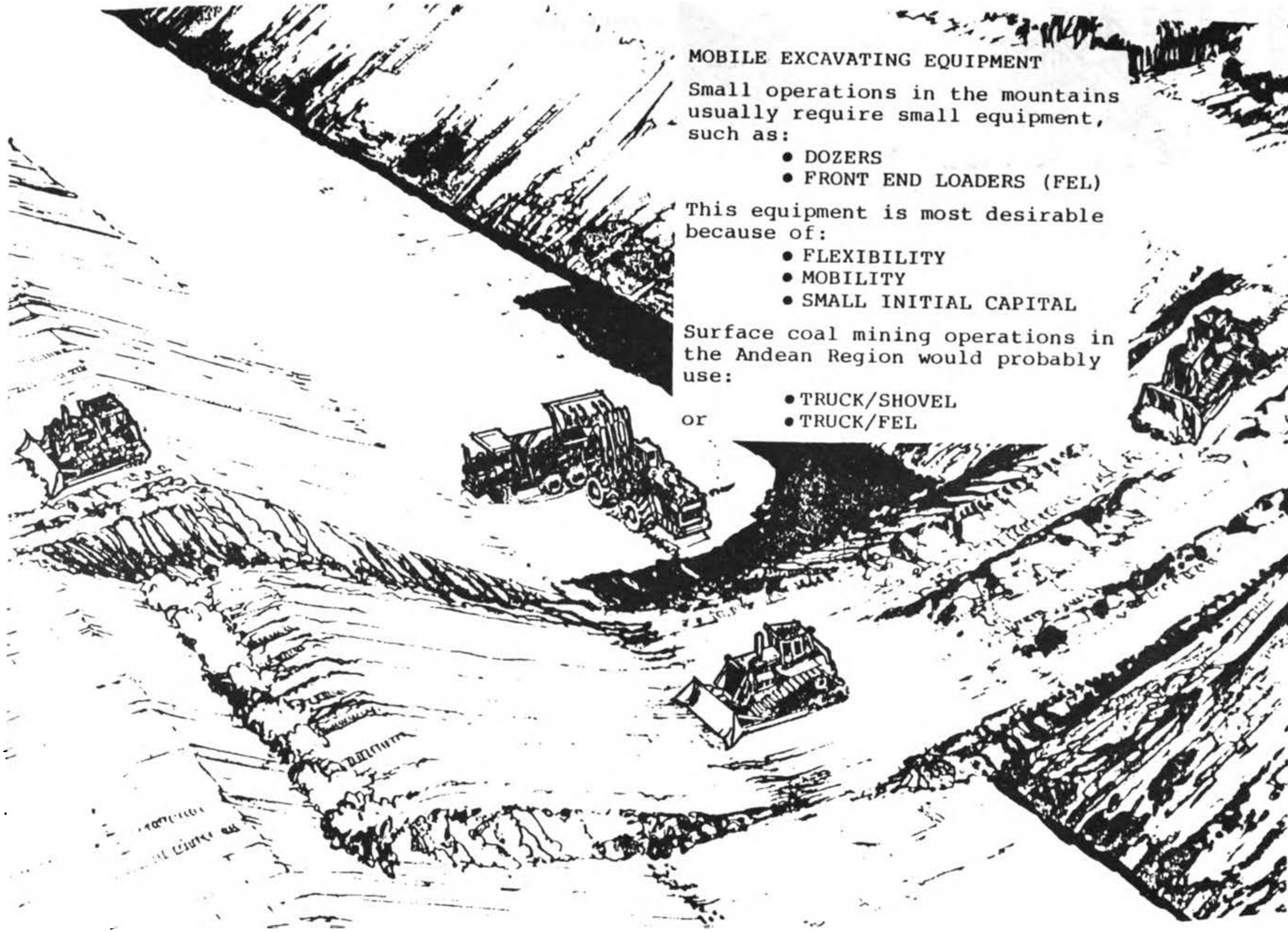
PIVOT AUGER TYPE MINER

CONVENTIONAL CONTOUR TRUCK HAULBACK MINING



Pit widths and the ultimate highwall height are determined by the topography, stripping ratio, and operating capabilities of the excavating equipment. Initial cut spoil is excavated using bulldozers and front-end loaders and hauled by rock trucks to valley fills or ridges.

At a typical haulback mine site today, unit operations begin with site preparation. After the virgin area immediately ahead of the mine has been cleared and grubbed, drill benches are constructed by dozers. Overburden is then drilled with rotary drills and blasted using an Ammonium Nitrate - Fuel Oil product. Dozers equipped with "U" blades and often fitted with rippers push the blasted rock to a front-end loader. The loader then loads the overburden haul trucks for transport to the deposition site. Once in place in the deposition site, dozers will regrade the spoil and prepare it for reclamation.



MOBILE EXCAVATING EQUIPMENT

Small operations in the mountains usually require small equipment, such as:

- DOZERS
- FRONT END LOADERS (FEL)

This equipment is most desirable because of:

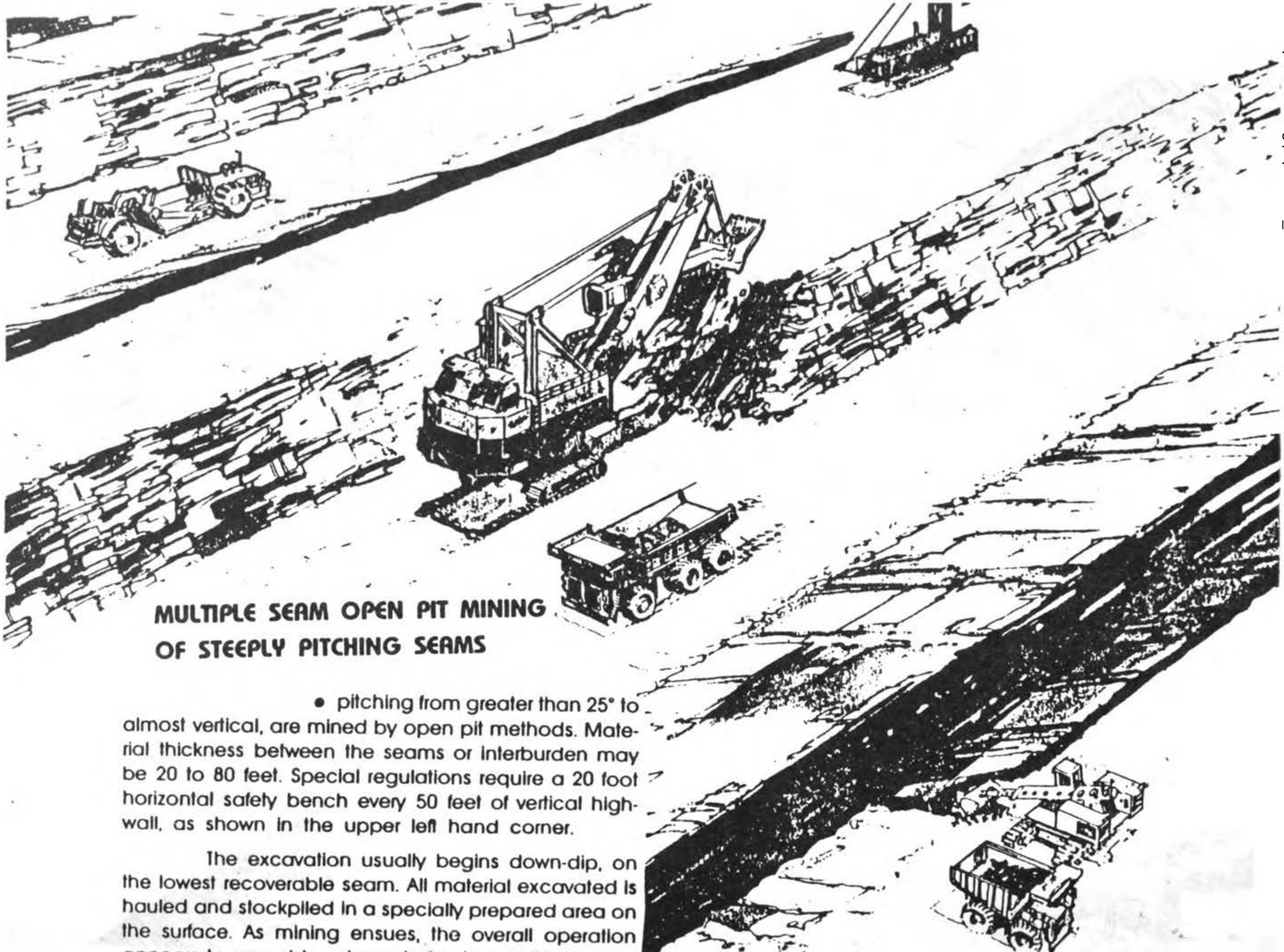
- FLEXIBILITY
- MOBILITY
- SMALL INITIAL CAPITAL

Surface coal mining operations in the Andean Region would probably use:

- TRUCK/SHOVEL

or

- TRUCK/FEL



MULTIPLE SEAM OPEN PIT MINING OF STEEPLY PITCHING SEAMS

• pitching from greater than 25° to almost vertical, are mined by open pit methods. Material thickness between the seams or interburden may be 20 to 80 feet. Special regulations require a 20 foot horizontal safety bench every 50 feet of vertical highwall, as shown in the upper left hand corner.

The excavation usually begins down-dip, on the lowest recoverable seam. All material excavated is hauled and stockpiled in a specially prepared area on the surface. As mining ensues, the overall operation appears to resemble a huge hole - hence the name - open pit. Interburden consists of consolidated material.

DRAGLINES

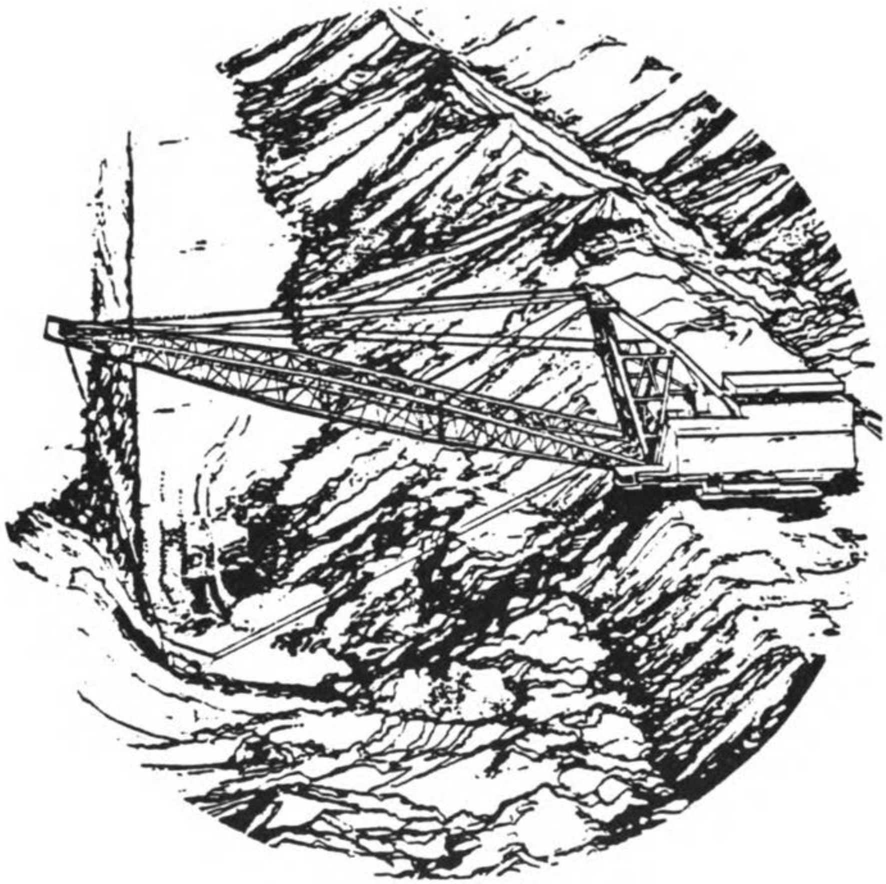
Dragline and stripping shovels are very popular in Area Mining, where the topography is flat.

A large amount of reserves are required to justify such large equipment.

Typically for a large dragline:

- Cost + Transport + Erection = $25 million

These large machines would probably not be feasible for the Andean region.



Dames & Moore

COAL TRANSPORT: CONVENTIONAL AND SLURRY

(Technical and Economic Factors in the Transport of Coal)

For

Cooperative Workshop on the Utilization of Coal as

an Alternative to Petroleum Fuels in the Andean Region

Lima, Peru -- June 24-28, 1985

By

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COAL TRANSPORT: CONVENTIONAL AND SLURRY

(Technical and Economic Factors in the Transport of Coal)

I. INTRODUCTION

Among the Andean nations of South America, the distribution of known coal reserves varies widely. Colombia and Venezuela have large reserves, Chile's are modest, while those of Peru, Ecuador, and Bolivia are relatively small. Colombia will be the largest producer, but almost all, initially, for export. Chile has long produced its deposits near Concepcion for the steel manufacturing plant at Talcahuano. Venezuela is developing its large potential, but has yet to reach its neighbor Colombia's scale of operation. Among the three central Andean countries, Peru has the longest history of coal production, with modest amounts of anthracite and bituminous coal being produced for the metals and minerals industries in La Oroya and Chimbote. Ecuador has relatively low-rank coal deposits, which has discouraged their exploitation in view of the greater abundance of petroleum. Bolivia, similarly lacking a domestic steel industry, and having sparse reserves of coal, has oriented its thermal energy requirements to oil and gas.

The current resurgence of interest in coal is directly attributable to the Arab oil embargo of 1973 and subsequent escalation of oil prices by the Middle Eastern OPEC producers. Countries with ample reserves of oil (whether OPEC members or not) have generally benefited from the price increases. But those with limited domestic supplies have been obliged to face the dilemma of dedicating their production to exports, in order to earn foreign exchange for other necessities, while penalizing the pace of their economic development with inadequate supplies of energy. Alternatives to oil have been sought: conservation (already carried to the maximum), hydroelectric power (for those fortunate enough to have favorable climatic conditions), and such combustibles as coal, wood, bagasse, and other bio-mass materials. The latter have provided only a small part of total requirements, however.

For those countries with coal deposits, the primary concern is how to get it from the ground to the point of use as cheaply and efficiently as possible. Depending on distance and terrain between the deposits and the points of use, the cost of moving the coal can approach or even greatly exceed the costs of mining. And, finally, the delivered cost of the energy content of the coal has to be compared with the energy value of competing fuels (including oil and gas as well as imported coal), to ensure that allocating resources to coal utilization will not jeopardize achievement of other goals having higher real economic and social returns.

Coal utilization requires capital-intensive processes which cannot easily be converted to other uses if the coal activity turns out to be non-economic. Of the various factors determinig coal economics--reserve size, deposit characteristics, demand requirements, heat content, impurities, cost, availability of alternative energy forms and requirements for handling and transportation--the latter probably have the greatest impact on total cost of utilization. We shall now look at the specific technical and economic factors that characterize coal transportation. Once these details are presented, we can then look at the Andean countries' situations and assess the problems and opportunities associated with moving their coal to market.

II. TECHNICAL AND ECONOMIC FACTORS IN THE TRANSPORT OF COAL

Coal Transport Modes: Capabilities and Costs

For coal to be a useful source of energy, it must be supplied in large quantities with little variation in the rate of delivery or the quality of the fuel. An electric power generating station of 300,000 kilowatts (KW) capacity, which would supply the electrical energy needs of a city of around 300,000 residents, would require approximately 750,000 tons of coal per year. For steel making, depending on the technology involved, anywhere from 0.5 to 0.8 ton of coke is needed to produce one ton of steel. The coke, in turn, comes from a larger quantity of bituminous coal (the coking coal is reduced by 15 to 30 percent in volume in being converted, depending on the content of volatile substances). Thus, a steel mill of 300,000 tons per year capacity would require approximately 150,000 tons per year of coke, if a high-efficiency basic oxygen or electric arc furnace is used. Assuming the mill has its own coke ovens, it would require upwards of 180,000 to 200,000 tons per year of coking coal. Smaller but still significant amounts of coal would be consumed by such industrial activities as cement manufacture, ceramics (stone, clay and glass), and sugar refining.

In the major industrialized economies, the quantities of coal being transported attain very high levels. Electric power plants serving cities of several million population consume upwards of 5 million tons per year. Unit trains made up of 100-ton-capacity hopper cars of 90 to 110 cars per train operate on a shuttle basis from mines hundreds of miles away. A 10-inch (25-cm) slurry pipeline in the state of Arizona, USA, moves 5 million tons per year of pulverized coal over a distance of 273 miles (439 km) to a single power plant in southern Nevada that supplies power to Southern California. Major coal exporting countries, such as Canada, Australia, South Africa, Poland, the United States, and soon Colombia, have coal ports capable of loading ships at the rate of 5,000 tons per hour, and some can accommodate ships in excess of 150,000 DWT.

These transport systems require large investments of capital in order to gain economies of scale and yield very low unit costs of movement. But even for smaller volumes, such as were cited earlier for smaller-sized power plants and steel mills, costs of transportation can be minimized by developing transport systems that are sized to the operation. The objective is to identify which combination of handling and transportation facilities will yield the least total cost of delivery. Of necessity, consideration must be given to the specific characteristics of each coal supply situation: volume, terrain, distance, and condition of the existing transport infrastructure are the most important, with the delivered cost of the next best fuel alternative setting the upper limit on the costs of developing the coal supply.

Rail Systems

Railroads are the primary mode of transportation of coal. In the United States, more than 60 percent of total coal production is moved by rail (about 500 million tons out of a total production of more than 800 million tons), and the commodity is the railroads' single largest source of revenue.

Rail shipment of coal is attractive because of several factors:

1. The marginal cost of rail transport tends to drop as the size and distance of the haul increase, and facilities are dedicated to the coal traffic (or other major bulk commodity);

2. The fixed costs of the railroad are shared among all types of traffic;

3. Cars can be added to a train in whatever numbers are necessary to move the scheduled shipment;

4. It is relatively easy to load and unload dry bulk commodities like coal in open-top hopper cars with suitable equipment.

5. The coal can be shipped in the form it comes from the mine.

There are, however, some disadvantages in using rail transport of coal:

1. Possible lack of transport alternatives leaves shippers vulnerable to monopoly tariffs;

2. Railroad operating costs are mostly variable (fuel, labor, maintenance materials) and therefore are difficult to control in an inflationary economic environment;

3. Shippers may have to supply their own hopper cars to assure availability of service; and

4. Existing railroad track and equipment may be inadequate to provide desired levels of service, thus necessitating major improvements and investments.

Rail tariffs and costs vary widely with the conditions of service. For example, the tariff per ton of coal shipped only a few cars at a time, such as occurs with the production of a small mine, is much higher than the tariff for large shipments covered by guaranteed minimum annual volumes and specified maximum periods of time for loading and unloading. This latter situation--typical of a unit train operation for a million tons per year or more--would have a tariff of $US 0.015 to 0.025 per ton-mile ($0.010-0.017 per MT-km). The lower volume case would have tariffs two to three times higher than the unit train rate.

The unit train tariff cited above would apply to an existing rail service with adequate track and equipment to handle 100-car trains moving 50 miles per hour (80 km/hr). In a region where either a new rail system had to be constructed to gain access to a coal deposit, or the existing system would require extensive upgrading to handle the loads, then the costs of the improvements would have to be borne largely by the coal traffic. In such a case, the tariff could be several times higher. Some recent studies have estimated that a new railroad service constructed for development of newly discovered coal deposits in Indonesia would have costs of service totaling $US 0.05-0.08 per MT-km). This new line would involve construction of a line through rough jungle terrain.

Table 1 summarizes three estimates. Those for a newly constructed or upgraded line are speculative, owing to wide differences that may exist with respect to construction conditions and costs of finance. The major difference between the rates for existing versus new lines is due to the capital recovery costs, to amortize new debt and generate equivalent return on equity funds invested in the improvements. For existing routes, often much of the original investment in track and right-of-way has been recovered.

For purposes of reference, cost of improvements in route and equipment are typified by the following values:

- New right-of-way, grading, track and control facilities: US $1 million per mile ($621,500 per km)
- Diesel locomotives (3,000 HP): US $1.3 million (C.I.F.)
- Hopper (self-unloading) coal cars, 1000-ton capacity: US $100,000 (C.I.F.)

These figures are for high capacity operations, and are based on a variety of sources. Smaller-size operations could use less powerful locomotives and smaller-capacity coal cars, and the carrying capacity of the rail line could be reduced by using lighter rail than the 100-pounds per foot (and higher) rail used for unit train lines. Also, the rail route could be designed for lower operating speeds (i.e., tighter curves and steeper grades); thus, allowing for greater flexibility in selecting the most direct route from mine to market.

Truck

Trucks are used for hauling coal over relatively short distances--typically between mines and rail loading terminals (where terrain prevents extension of the railroad to the mine), or to power plants or factories within 10 to 20 miles (16 to 32 km) of the mine. The vehicles used for commercial hauling of coal typically have a capacity of 20 to 26 short tons (18 to 24 metric tons) and cost about $US 130,000 (C.I.F.). Total costs of operation (including capital recovery) run 10 to 15 cents per ton-mile (6 to 10 cents/MT-km).

Trucks have the advantages of high operating speeds, ability to handle steeper grades than railroads, and flexibility of scheduling. These advantages have a cost, of course, because a truck requires more power per ton of payload to accomplish its speed changes and climb steeper grades. Labor cost per ton of payload is also higher for the truck vis-a-vis the railroad. (The 25-ton truckload requires one driver, while a trainload of coal requires only four or five crew members.)

TABLE 1

ESTIMATED RAIL TARIFFS FOR TRANSPORTING COAL
(In U.S. cents per short ton-mile and metric ton-km)

	Level of Service	
Status of Route	Unit Train (>1,000,000 TPY) 10,000 tons/train	Single Car (<100,000 TPY)
Existing Line		
per ST-mile	1.5 - 2.5	3.0 - 5.0
per MT-km	1.0 - 1.7	2.1 - 3.4
Newly Constructed or Upgraded Line		
per ST-mile	8.0 -11.0	15.0-25.0?
per MT-km	5.5 - 7.5	10.3-17.1?

Note: ST = short ton (2,000 lbs)
MT = metric ton (2,205 lbs)

Sources: Unit train, existing route: Mining Engineering, 1982
Unit train, new route: Dames & Moore, 1984
Single car, existing route: Dames & Moore, 1976, Mining Engineering, 1982
Single car, new route: Dames & Moore projection

Costs of truck operation vary widely with differences in road conditions. The smoother, flatter, and straighter a road surface is, the more time a truck can operate at its most efficient speed. Hills, curves, and rough road surface markedly reduce a truck's performance. The following table illustrates the variations in operating (variable) costs for a Volvo N-12 medium truck of 16 MT capacity, as a function of road conditions.

TABLE 2

16-TON TRUCK: VARIABLE OPERATING COSTS
(in U.S. cents per metric ton-km)

Terrain	Type of Road Surface: Paved	Gravel	Dirt (Rough)
Flat	3.1	4.1	7.2
Rolling	3.2	4.4	7.3
Steep	3.5	5.8	7.4

Source: CONREVIAL, 1981.

The data are for 1981 and are based on surveys of vehicle operating costs in Peru by CONREVIAL (Consorcio de Rehabilitacion Vial). Capital costs and taxes are not included.

In a developing country, trucks often are the only way of transporting minerals from smaller mines, because the volume of production does not justify the up-front investment costs of rail, conveyor belt, or slurry pipeline systems. The versatility of truck transport compensates for its higher unit costs of operation. The higher operating costs are somewhat mitigated, however, by the generally low cost of using public roads in developing countries. User charges in the form of tolls and fuel taxes rarely cover the real costs of maintaining the highways. Thus, the motoring public, including truck operators, receives a subsidy to the extent that highway maintenance work is funded from general revenues.

Ship

Shipment of coal by water is the least costly mode of transport. Unit costs of barge or ocean-going bulk carrier run typically between 0.5 and 1.0 US cents per ton-mile (0.3 to 0.7 cents/MT-km), exclusive of terminal costs. Figure 1 illustrates the full range of operating costs for different sizes of vessels.

Waterborne transport of coal offers the greatest advantages when both the origin and the destination of the shipment are located near deep water and the volume of coal to be shipped is large. These conditions imply that there is a minimum of rehandling of the coal and that the fixed costs of the system can be spread over a long service life and a large volume of throughput.

Ships have low costs of operation because their carrying capacity increases by a multiple of their displacement. The power requirements do not increase in proportion to increases in displacement because resistance to movement through the water increases fractionally (at lower speeds). The trade-off, however, is with port costs. Large ships are energy-efficient and have low running costs, but they need deep harbors and expensive cargo handling equipment to load and unload quickly.

Smaller coal ships and barges can be used for shorter distance, shallower water, and lower volume operations, but there is the penalty of reduced economies of scale (upwards of an additional 1 cent per ton-mile). On the other hand, port costs are lower because of less need for dredging and high volume loading/unloading systems.

In recent years, self-discharging bulk carriers have been built to provide service to users at ports which lacked deep water, or whose volumes of consumption did not justify installation of large shore-based unloading facilities. These self-unloading ships (see Figure 2) have an extendable boom that can reach over the wharf to receiving facilities (storage areas or conveyor systems). They are capable of discharge rates of upwards of 4,500 short tons (4,082 MT) per hour. The cost of operation of such ships is higher than for a ship without unloading gear (there is a penalty for the carrying capacity lost to the weight of the unloading gear), but that is made up by the ability of the ship to serve

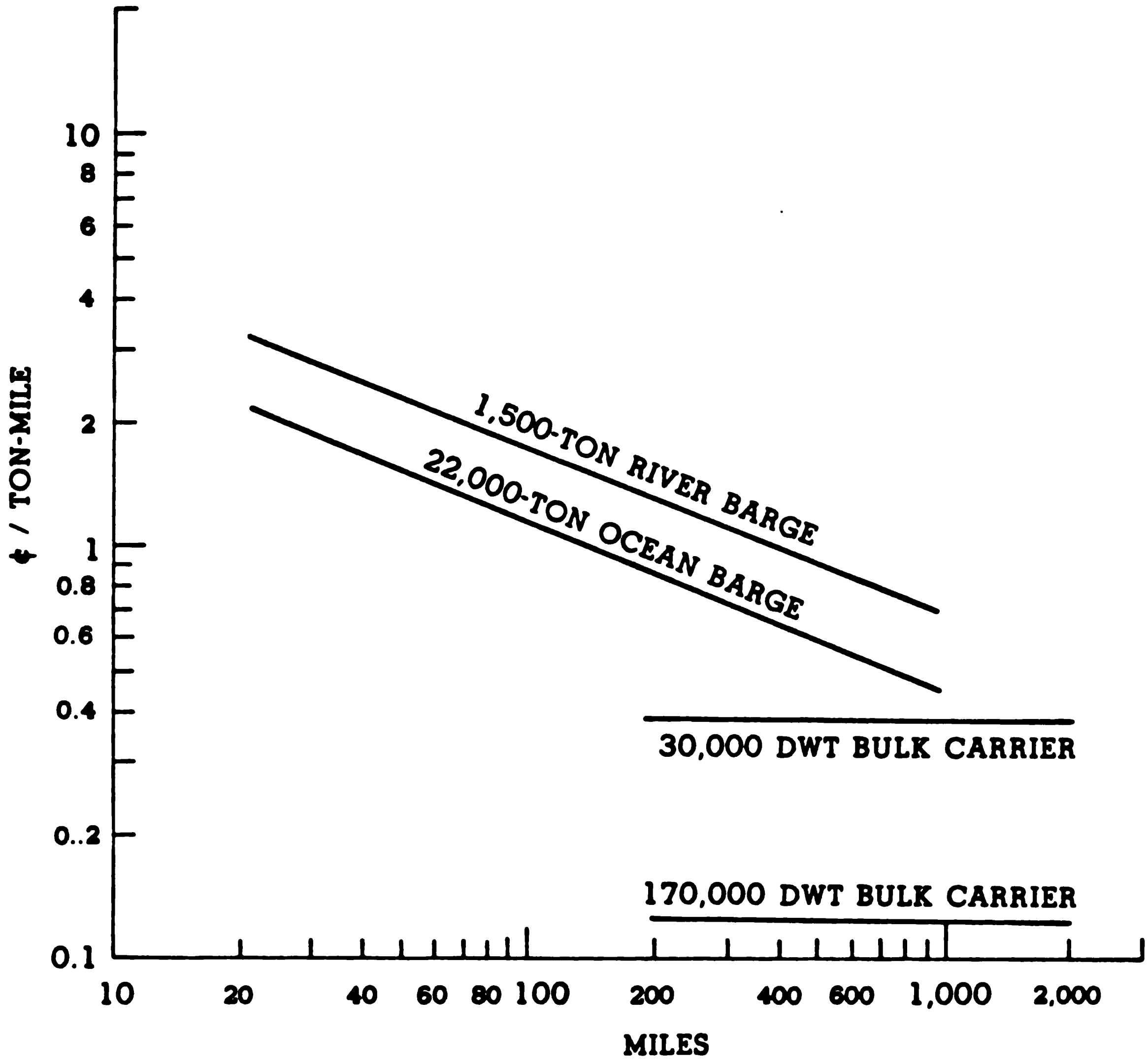


Figure 1 COAL TRANSPORT COSTS WATER MODES

Sources: Dames & Moore, 1976. BPPT/Bechtel 1981.
Port of Los Angeles, 1979

customers who otherwise would have to incur greater expense to bring bulk commodities overland from more distant, deeper draft ports.

A major consideration in planning of waterborne bulk materials transport operations is the depth of water available for navigation over the intended routes. The deeper the navigable water, the larger the ship and its carrying capacity can be. And, as size and volume increase, unit costs of movement decline. Table 3, below, illustrates the relationships. The data assume one-way movement of cargo (i.e., no backhaul) and no excessive downtime due to port delays and unscheduled maintenance. The required freight rate includes fixed costs (notably capital recovery charges for 20-year economic life with 10 percent interest), fuel, crew maintenance, and port charges. The freight rate data are from a 1979 study and have not been corrected for price changes. Of principal interest is not the exact values, but the inverse relationship between vessel size, draft, and unit cost operation and ownership.

Slurry Pipeline

The coal slurry pipeline offers the lowest cost per ton-mile for transporting coal overland (see Figure 3) provided a number of conditions are met.

1. The user requires a continuous supply of a relatively constant, large volume of coal for many years;

2. The length of transport is relatively long (several hundreds of miles). Alternatively, if the pipeline route is significantly shorter than an alternative rail or highway route, the slurry pipeline may be more economical over short distances; and

3. There is an adequate supply of water (up to 100 percent equivalent of the weight of coal to be moved).

Slurry pipelines are highly capital-intensive, costing several millions of dollars per mile, including equipment for coal preparation, water supply, pumping stations, dewatering at destination, and disposal of transport water. To cover these costs, there must be a large, uninterrupted flow for many years.

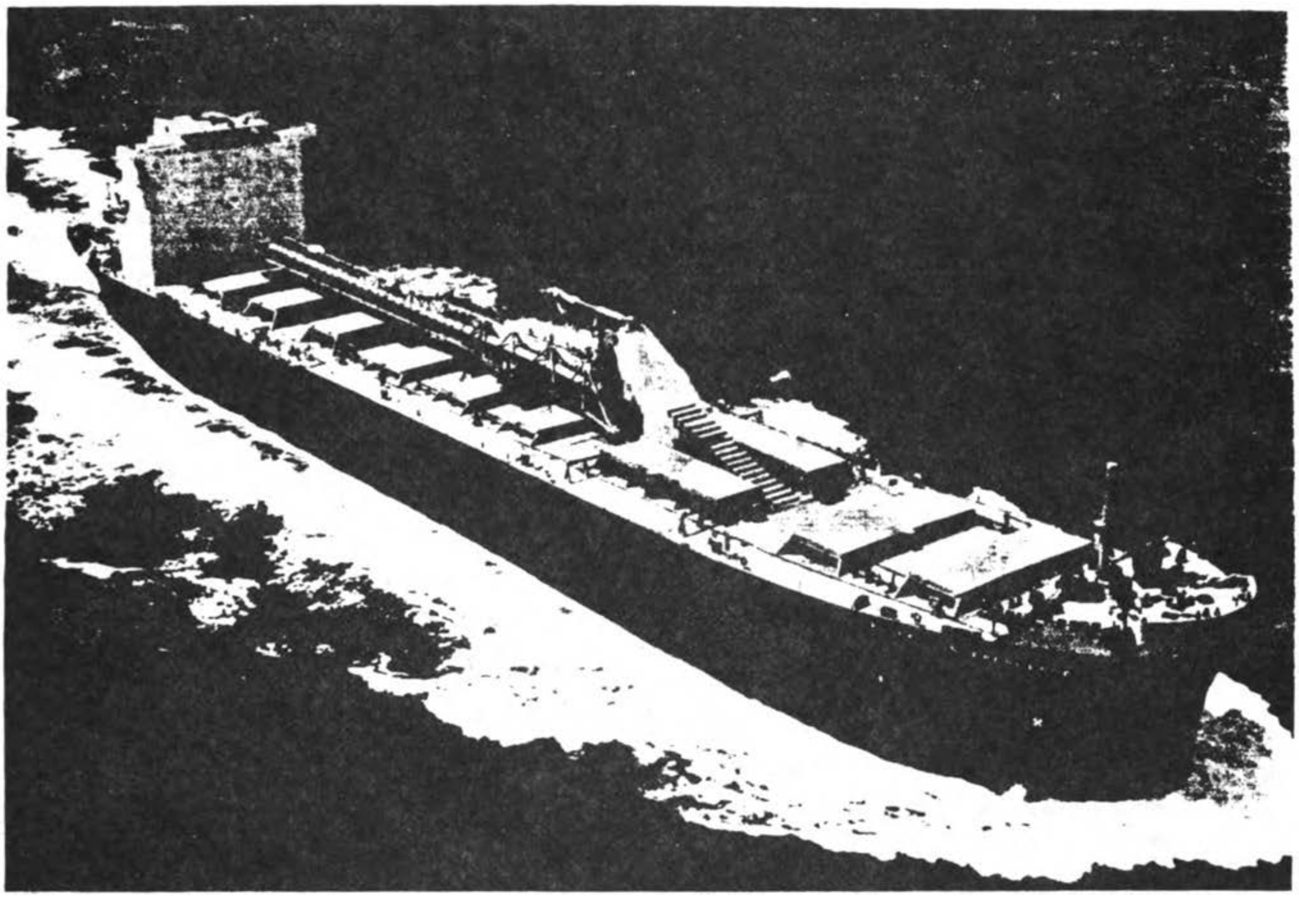


Photo credit: General Dynamics, Inc.

In 1983 this U.S.-flag coastal coal-carrier was built to use its own cargo as fuel

Figure 2

TABLE 3

COMPARISON OF OPERATING CHARACTERISTICS AND COSTS OF BULK CARRYING VESSELS

Type of Vessel	Capacity Cargo DWT (short tons)	Draft (feet)	Draft (meters)	Required Freight Rate (US cents)[1] (ST-mile)	Required Freight Rate (US cents)[1] (MT-km)
River barge[2]	1,500	9	2.7	0.150	0.102
Ocean-going barges[2]	30,000	22	6.7	0.100	0.068
Self-unloading collier[3]	60,000	40	12.2	0.022	0.015
Conventional bulk carriers[3]					
Medium	60,000	40	12.2	0.019	0.013
Large	50,000	55	16.8	0.012	0.008

Notes:

[1] Includes allowance for fixed costs.

[2] Propelled by separate pusher-type tugboat; average one-way distance of 200 miles (324 km).

[3] Self-propelled; one-way distance greater than 200 miles (324 km).

Sources: Minerals Transportation, 1979
Dames & Moore, 1984

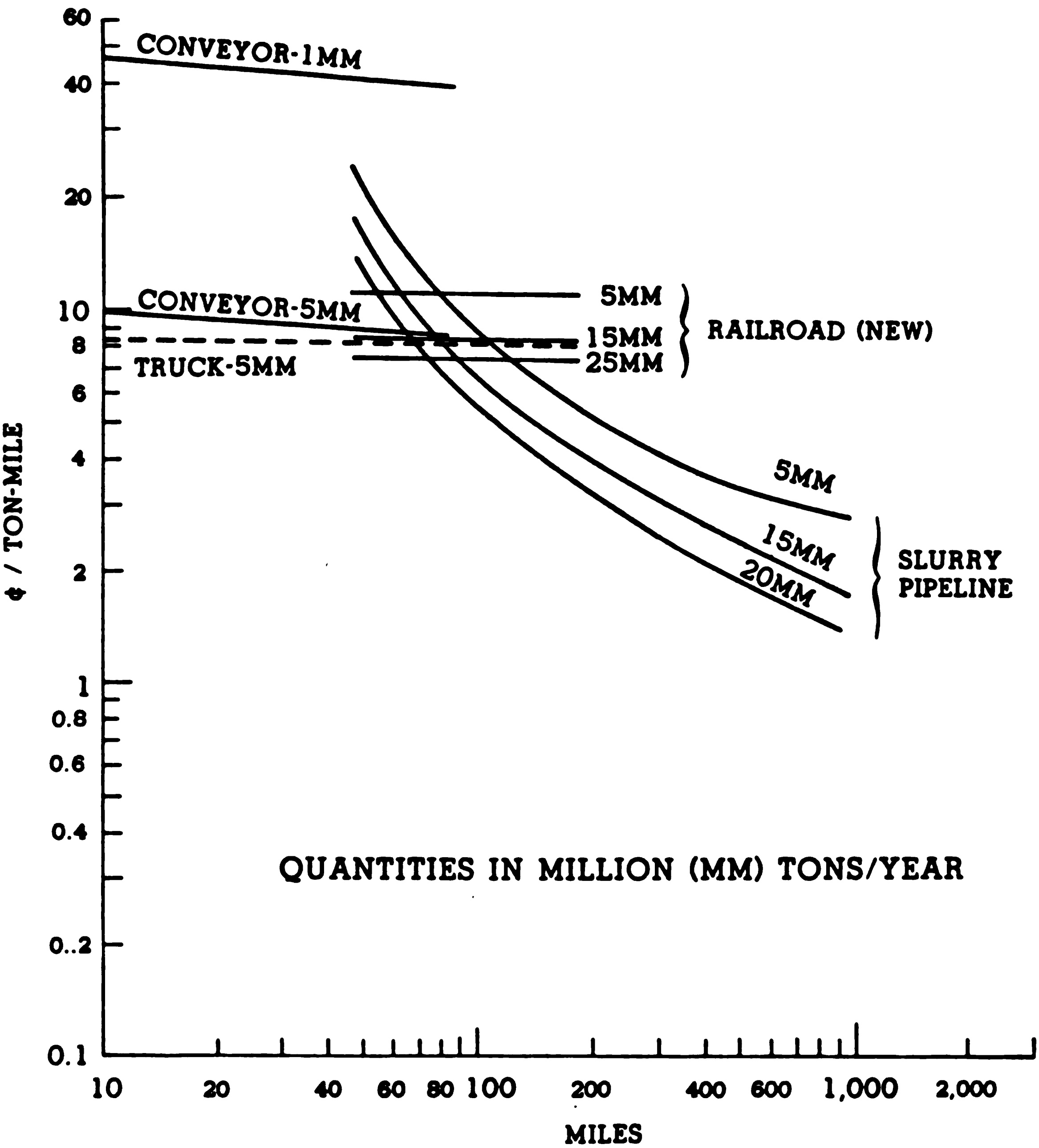


Figure 3. **COAL TRANSPORT COSTS LAND MODES**

Sources: Aude, 1981: Reiber, 1977

Distribution of slurried coal to multiple destinations is possible, and it is possible to move different qualities of coal to different customers, by separating shipments with "slugs" of water and controlling off-take valving at distribution points.

Considerable research and development have gone into the technology of moving coarse coal and reducing the amount of water in the slurry (through addition of substances that keep the coal particles in suspension). But the only operating coal slurry pipeline (Black Mesa in Arizona in the United States) operates with finely pulverized coal in a 50 percent (by weight) water slurry. The slurry is centrifuged at the Mojave Power Station and dewatered coal is fed directly to the boilers. The line has been operating for over 10 years and has a reliability factor in excess of 98 percent.

A number of new coal slurry lines have been planned in the United States, but none have started construction. These would involve annual volumes ranging upwards of 25 million tons per year. Opposition from railroads, fearful of losing profitable traffic, and from environmental interests concerned about the impact on regional water supplies have prevented the pipeline developers from acquiring routes and permits. Also, the decline in the rate of expansion of demand for electric power and the decline in inflation rates has reduced some of the economic advantages pipelines have over railroads. Under current economic conditions, slurry pipelines appear to be economically superior to railroads when there is either no existing railroad to serve the traffic, or an existing line would need very substantial upgrading to carry the amount of coal involved.

The economic minimum for the size of a coal slurry pipeline appears to be about 5 million tons per year over a distance of at least 200 miles (324 km). At volumes and distances greater than these values, the unit cost of slurry transport drops rapidly. This is due largely to the volumetric economies of scale and lower unit power requirements of larger diameter pipelines. Also, pipelines require few operating personnel. Thus, upwards of 70 percent of unit costs are non-escalating capital-related costs, which remain fixed over the life of the facility regardless of inflationary trends. This is in contrast to railroads, whose ratio of variable to fixed costs is typically on the order of

80:20. As a result, unit costs of rail transport tend to flatten out beyond haul distances of around 200 miles, while those of slurry pipelines continue to decline.

Despite these long-term cost advantages, the slurry pipeline entails considerable risk because of its dependence on large continuous volumes. Financial support depends on guarantees of debt service whether or not the line stays in operation (lenders prefer "take or pay" contracts to support the project financing). In a developing country, the foreign exchange requirements are considerable, unless the domestic steel pipe manufacturing enterprises can meet strict specifications for large diameter, high-pressure pipe.

In summary, a coal slurry pipeline can yield significant economic benefits if it is designed to move a specific volume of coal between two fixed points over a long period of time. Its flexibility to accommodate fluctuations in use are very limited, and the fixed costs of the system can quickly erode the profitability of the operation if throughput volumes and revenues are not maintained at design levels.

Coal by Wire

An alternative to transporting coal is to transmit its energy over high voltage power lines from mine-mouth power plants to population centers or major industrial installations. In this sense, a coal-fired power plant is analagous to a hydroelectric plant, which uses long distance transmission lines to transport the kinetic energy of falling water. If coal reserves are large, consideration should be given to locating the power generation facilities at the mine, thus avoiding the necessity of developing high-volume coal transportation facilities.

On the basis of cost-per-kilowatt hour of electrical energy delivered to the power distribution grid, high voltage transmission lines can have total costs in the same range as railroads and highways. In very mountainous terrain the transmission line can be the most economical because it does not require a routing that is transitable by wheeled vehicles. Therefore, the line is likely to be considerably shorter than a vehicular route.

Siting conditions will play a major role in determining the feasibility of a mine-mouth power plant: suitable geotechnical conditions, adequate supplies of water for boiler feed and condenser cooling, suitable facilities for personnel housing, ash disposal, plant security, and adequate access for transport of construction materials and plant machinery.

Coal Handling and Storage Facilities: Capabilities and Costs

Wherever it is necessary to transfer coal from one mode of transport to another in its journey from mine to user, facilities must be provided to physically move the coal from one conveyance to the other. Also, space and equipment must be provided to store coal that may accumulate when the capacities and frequencies of the various modes are not synchronized. In other words, buffer stock or surge storage facilities must be provided.

For high volume operations, where throughputs measure in the millions of tons per year, transfer and storage facilities are large and complex. Such facilities are primarily located at power plants, ports, and major industrial complexes. Large coal storage and loading terminals are also located in the coal mining areas where it is necessary to consolidate the production of many small mines and to blend various qualities of coal to meet buyers' specifications.

The scale of operations of a coal terminal depends, of course, on the throughput requirements. There needs to be sufficient ground space to contain several weeks' supply of stored coal (suitably segregated by quality), so that loading out operations can continue in the event of a suspension of supply from the mines (e.g., due to a work stoppage, or closing of a rail link). Figure 4 depicts a major coal terminal at Charleston, South Carolina, which has a coal storage area of about 25 acres (10 Ha). Equipment for stacking and reclaiming coal is necessary. Examples of some of the types of equipment for these activities are shown in Figures 5 and 6.

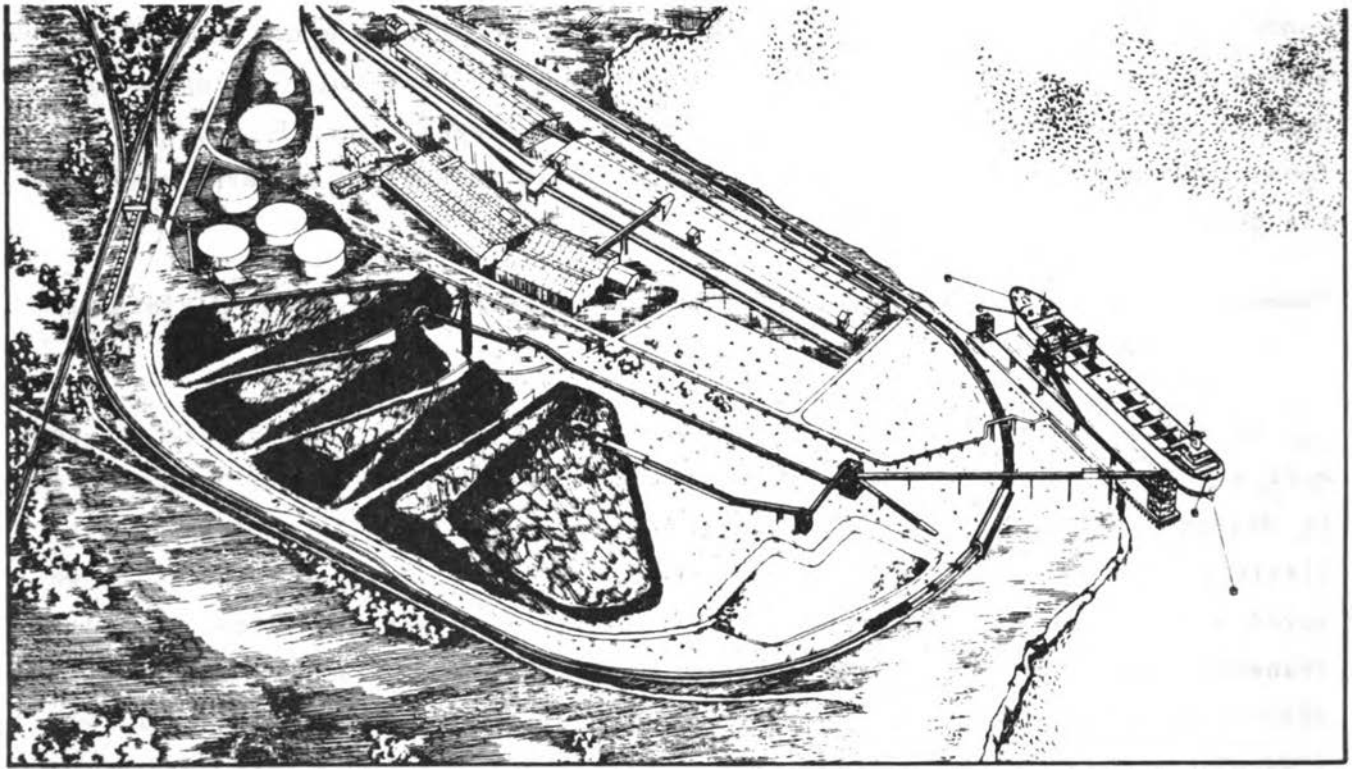
Terminals with a throughput capacity of several million tons per year have capital costs on the orders of US $7 to $12 per ton of annual capacity. Variations in the average cost of construction are due to differences in site preparation and dredging requirements. Operating costs for such a facility run on the order of $2.50 to $3.50 per short ton ($2.75-$3.85 per metric ton), including capital charges. Thus, a coal export terminal capable of handling 1 million short tons per year would cost about US $10 million to build and would have gross operating costs of perhaps US $3 million per year.

Terminal costs make up a significant part of the total expense of moving coal from mine to market. Unless the terminals' capacities are adequate to handle the transfer and storage requirements, substantial extra expense can accrue to shippers because of delays. A 60,000 DWT coal ship has an in-port cost of perhaps US $1,500-$2,000 per day for crew wages, electricity, and port fees, plus another $5,000 per day in capital charges. Delays in cargo handling can quickly erase profits.

Summary: Integrated Coal Transport Systems: Capabilities and Performance Trade-Offs

If a transportation system can be built for a single purpose--that is, to move a known quantity of material from Point A to Point B--then it is possible to design and construct a very cost-effective system that is configured precisely to the requirements of the movement. However, if the quantities to be moved and the users to be served are not known with any precision, then the transport system must have some flexibility to deal with fluctuations in traffic. These considerations influence the choice of equipment, routes, and financing arrangements.

As a general proposition, the larger the quantities of material to be moved per unit of time, the more capital-intensive and less flexible the transport infrastructure will be, in order to be able to capture economies of scale. Thus, one of the first things that must be done is to forecast the volume of material to be moved and then evaluate the alternative transport technologies that are available. For example, for a coal movement of less than 100,000 tons per year, the transportation could be accomplished in 4,000 25-ton truckloads (12 to 15 per day), 2,000 50-ton rail hopper cars or, if water shipment were possible, 67 1,500-ton river barges. If, however, the annual volume was 1,000,000 tons, then trucks would probably not serve because of congestion, and



Railed-in coal is stockpiled and reclaimed by gravity through a tunnel conveyor at Massey Coal's Shipyard River Terminal in Charleston, SC. Four grades of coal can be separately stockpiled for blending over the tunnel conveyor.

Figure 4

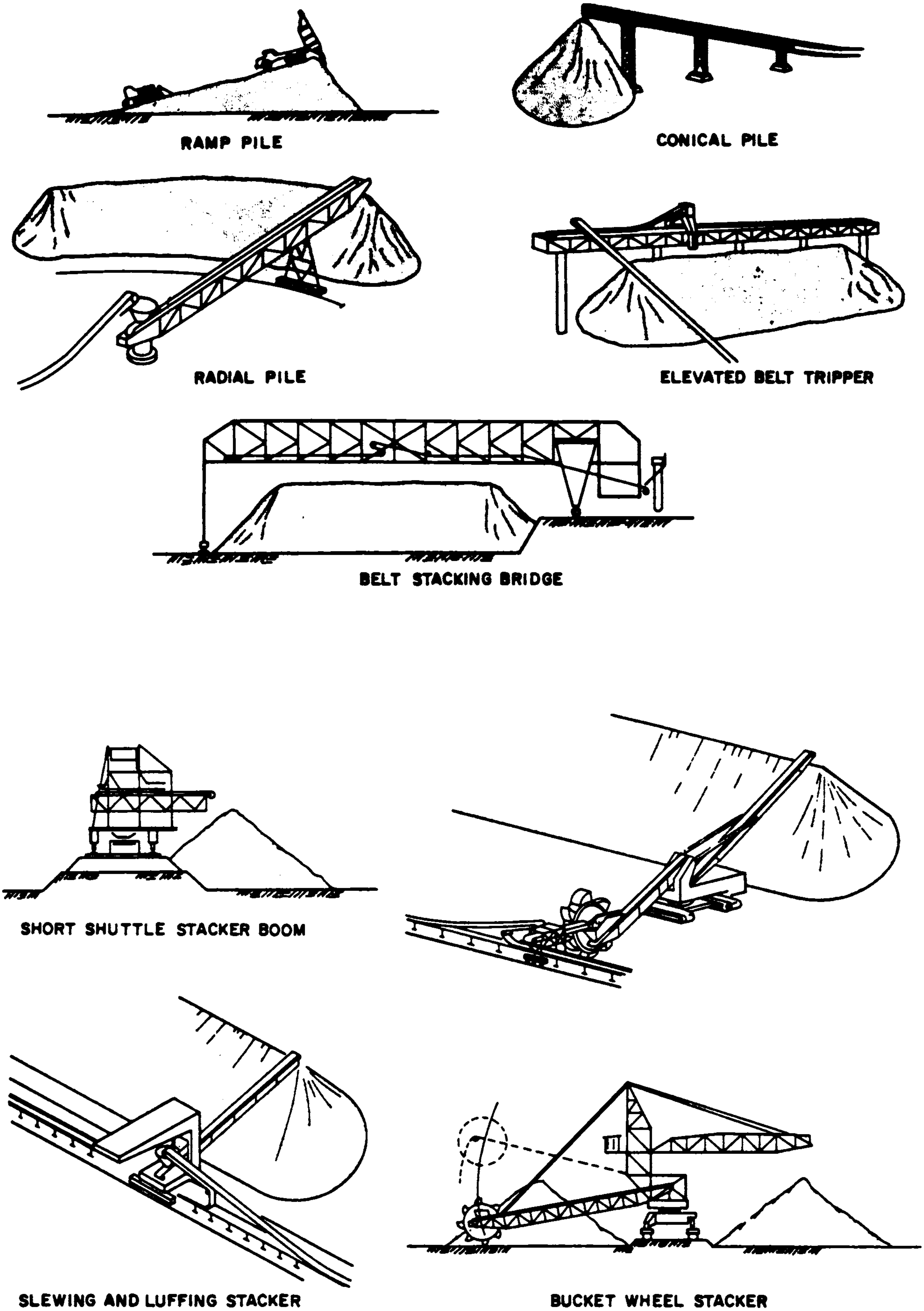


Figure 5 VARIOUS STOCKPILING METHODS

TYPES OF OPEN GROUND STORAGE FACILITIES.

Many types of facilities are in use today for storage and reclaim of solid bulk materials. The handling methods preferred for a given situation will depend on numerous factors, such as quantities to be stored and reclaimed in a given time period, space available, desirable rates of stocking and reclaiming, time during which material remains in storage, and material characteristics. Certain reclaim and storage methods are compatible with each other, while others should not be used together for best advantage.

The most common type is "open-ground-storage", whereby the materials are placed in piles on relatively level piece of real estate. Placing the materials in the piles is called "stockpiling" and removing them is called "reclaiming".

Stockpiling Methods.

Stockpiles can be built using various means. Since we are concerned only with building or placing of piles, the difference between active or passive piles (live and dead storage) is not being considered here. The method of reclaiming determines what portion of the total pile will be active.

The most common methods for stockpiling of bulk solids are illustrated in figures 1 and 2. For each of these methods some practical ranges of storage volumes are given in figure 3 as a function of pile height. The angle of repose is assumed to be 40 degrees. Since the size, shape and volume of ramped piles built by mobile equipment can vary so much, no values are listed for this type.

In order to give an approximate range of required real estate for various types of stockpiling methods, the lower table in figure 3 shows the area in square feet per net ton of 100# material. This value includes the area utilization factor, which allows for the additional land needed to locate the stacking equipment.

Conventional stacker-booms range in length from 50 to 150 ft. On occasion, stacker-booms have been designed up to 250 ft in length, but they are not too common in the industry.

Several means of increasing pile sizes with a given stacker-boom are available, such as raising the stacker rails on a berm or trestle; providing a retaining wall at the foot of the pile; or locating partitions between piles in multiple-pile storage systems.

The methods listed in figure 3 should be considered only basic and illustrative. Many combinations and variations are available. For instance, the cone-pile stacker may be combined with a bull-dozer to distribute the material over a wider area, which is often done in coal storage. The rail-mounted, single or double wing stacker is many times combined with another self-propelled tracked stacker (bandwagon) to extend the stacking range and increase the pile width.

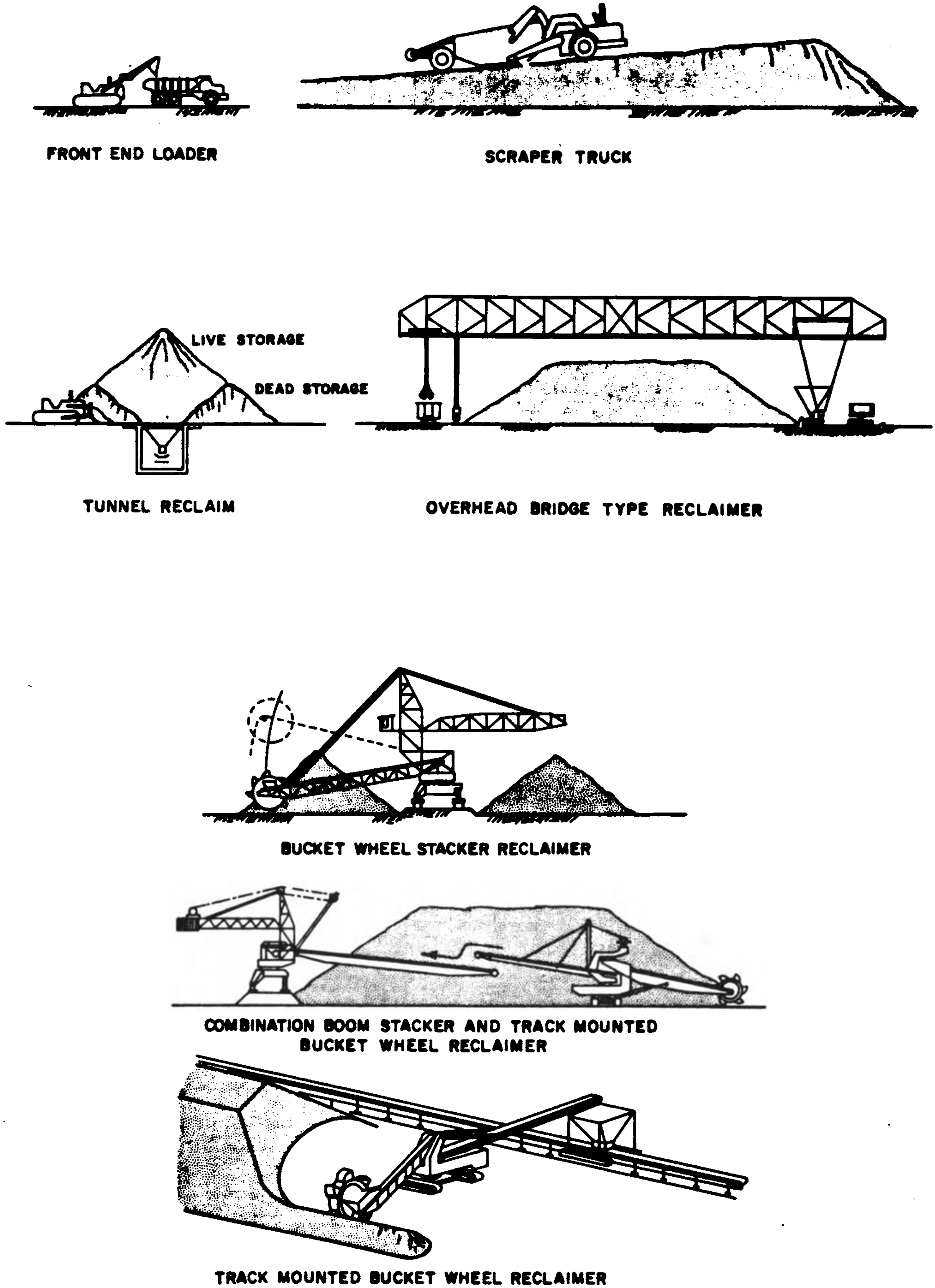
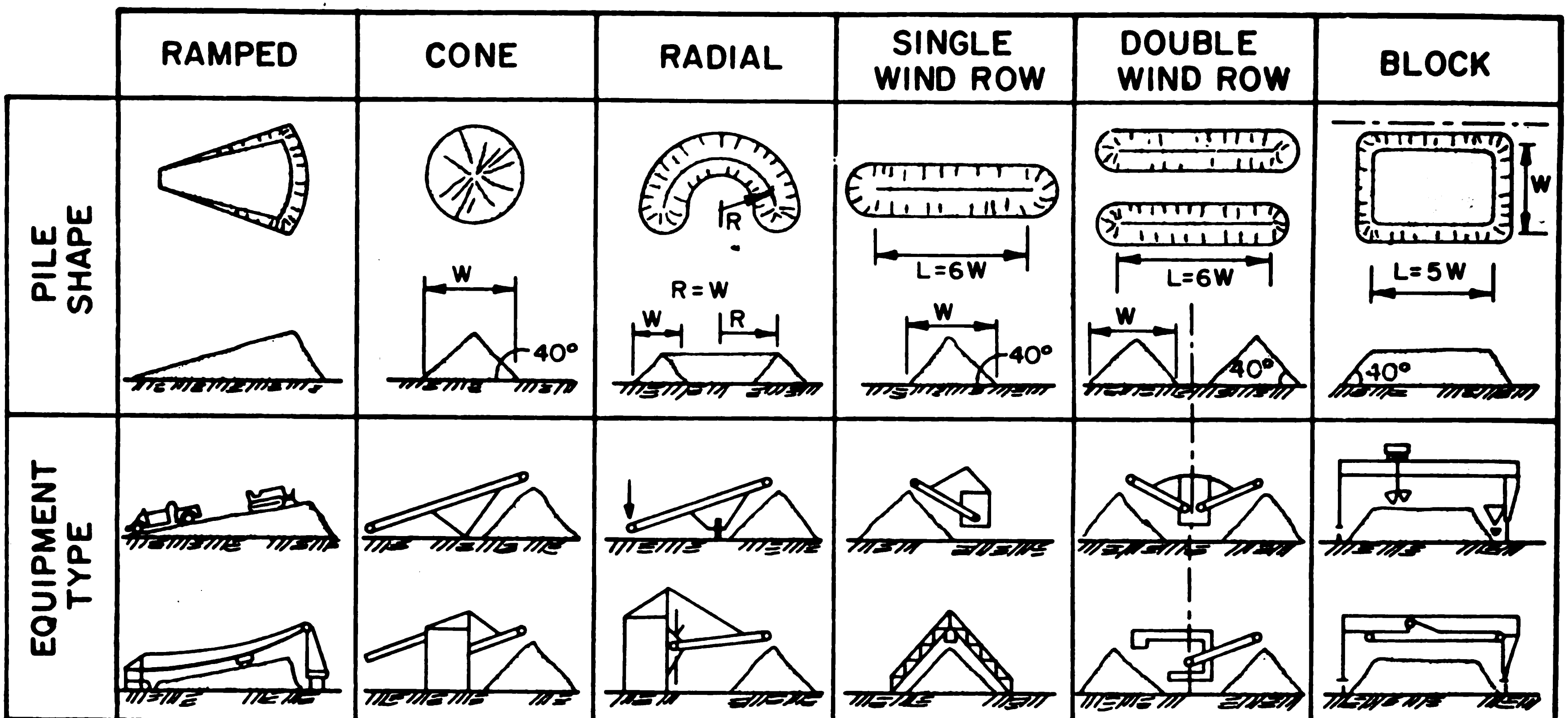


Figure 6 VARIOUS RECLAIM METHODS



	CONE				RADIAL				SINGLE WIND ROW				DOUBLE WIND ROW				BLOCK			
PILE HEIGHT IN FEET	25	50	75	100	25	50	75	100	25	50	75	100	25	50	75	100	25	50	75	100
BASE WIDTH IN FEET (W)	60	120	180	240	60	120	180	240	60	120	180	240	2X 60	2X 120	2X 180	2X 240	100	200	300	400
VOLUME IN 10^3 CU. YD	.85	6.8	23.5	55	5.8	48	164	385	10.5	85	294	685	21	170	588	1370	46	370	1250	2950
AREA UTILIZATION FACTOR	75%				90%				80%				90%				80%			
FT^2/TON (100# MAT'L)	3.1	1.6	1.07	.78	1.7	.87	.58	.43	2.1	1.05	.70	.51	1.9	.94	.62	.45	1.0	0.5	.33	.25

VARIOUS STOCKPILING METHODS

FIGURE 3.

larger hopper cars in long trains would have to be used in order to avoid congestion of rail movements. Depending on distance and terrain, a slurry pipeline might be economically preferable.

For a 1-million ton-per-year or larger coal operation over a distance of several hundred miles, the choice of systems would very much depend on the condition of the existing railroad, if any, or, in the case of waterborne movements, the locations and capacities of ports. For the overland haul, the additional coal traffic might overwhelm the existing rail facility; a study would have to be made between upgrading the existing line, building a new route, or building a slurry pipeline. Alternatively, if the primary use of the coal was to fuel power plants, consideration would need to be given to building a mine-mouth power plant and a high voltage transmission line to the demand center.

In a developing country with the potential to expand production and domestic consumption of its coal resources, the emphasis in planning for transportation of the fuel should be on the side of flexibility. Because the levels of demand and patterns of industrial development are changing dynamically, it is important to maintain flexibility, perhaps even at some loss of economies of scale in transport facilities. Ideally, facilities can be developed in stages or modularly, so that as demand increases, additional transport units can be added to the system without disrupting existing operations. Only in cases where a single user of coal, such as a steel plant or power plant, has a long-term level of production that will absorb all of the output of a mine or group of mines in one locality would it make sense to develop a dedicated transport system that operated independently of the rest of the region's transport infrastructure. Where there are multiple users of the coal--factories, cement producers, sugar refineries--then the coal supply system must be able to accommodate fluctuations in demand with storage areas, mobile handling equipment, and the ability to vary the rate of speed of operation of facilities without excessive risk of breakdowns.

The trade-off is generally one of exchanging very low operating costs, with high volume, fixed rate of operation-type equipment, for somewhat higher unit cost operations that can be varied with demand. By using systems that do not involve large up-front investment costs, the shippers and operators reduce the risks of fixed costs becoming a problem during periods of low demands.

III. PROSPECTS FOR EXPANDED USE OF COAL IN THE ANDEAN REGION: THE ROLE OF TRANSPORTATION DEVELOPMENT

The Andean nations now run primarily on the energy from petroleum, natural gas, hydroelectric and forest resources. A recent survey of the energy sources and uses of several Latin American countries (see Table 4) showed that for Bolivia, Ecuador and Peru these energy sources accounted for virtually 100 percent of requirements, with coal represented only fractionally (with the exception of Chile) in the total. In Chile consumption of coal has remained fairly high because of the coking coal needs of the iron and steel industry located near Concepcion.

Referring to Table 4, at the bottom the data indicate that in terms of total energy, Bolivia and Ecuador are completely self-sufficient and Peru is almost self-sufficient, but Chile is more dependent on imports. Ignoring balance of payments problems for the moment, from a purely physical standpoint, Chile and Peru would appear to have the best prospects for coal-substitution while Bolivia and Ecuador could remain dependent on their oil and gas resources. However, balance of payments concerns cannot be ignored, nor can the high proportion of total energy consumption supplied by firewood. The oil and gas as well as the forest resources of all the Andean countries should have higher and better uses than to boil water.

The rapid growth of urban centers, mineral processing industries and intercity transportation has been fueled primarily by liquid hydrocarbons and hydroelectric power, because (1) these resources were originally relatively cheap, and (2) they are much cleaner and easier to use than coal. However, the recent explosive rises in the real costs of oil and of money to invest in energy development have shifted the scales somewhat in favor of coal in instances where local supplies are available. Coal is a very attractive alternative fuel in applications requiring high, constant volumes of fuel, such as electric power generation, steel making, and cement manufacture. Electrification of transportation within as well as between cities can greatly improve the quality of service and the cleanliness of the environment. Also, coal in briquettes can substitute for kerosene and firewood as cooking fuel. These areas offer the greatest opportunities for coal in the Andean countries.

TABLE 4

DISTRIBUTION OF PRIMARY ENERGY CONSUMPTION IN ANDEAN COUNTRIES 1981 (In percent)

	Bolivia	Chile	Ecuador	Peru
Oil	48.2	51.1	71.0	60.0
Gas	10.0	11.2	-	5.2
Hydroelectric	6.0	6.8	8.0	7.1
Coal	0.7	12.5	-	0.7
Firewood, etc.	35.1	18.4	21.0	27.0
Total	100.0	100.0	100.0	100.0
Percent Requirements Imported:				
Petroleum	0	60	0	0
Coal/coke	0	30	0	67

Source: Bundesstelle fur Aussenhandelsinformation, 1984.

The role of transportation in this process is more than just complementary. Transport facilities must be improved or developed in order that domestic coal resources may be used. Without transportation, the coal has no utility or value. If transportation facilities can be developed that will deliver coal to major users at costs per unit of heat value that are close to what oil now costs, then a case probably can be made for adding new coal-fired production capability to serve future demand growth. If, on the other hand, it can be shown that the delivered costs of the coal energy would be below those of the oil-fired capacity now in use, then a strong case might be made to convert existing production facilities to coal. Costs of extraction of the coal from the ground must be considered, of course, but because transportation costs can comprise the major part of total delivered costs, the transportation component can make or break the venture.

A clear example of the possibilities for coal substitution is in the conversion from oil to coal of the two electric power stations at Tocopilla, Chile, which supply electricity to the Chuquicamata copper mines. The discovery of large surface coal deposits in Punta Arenas assured an adequate supply, which large coal-carrying ships will transport at low cost. CODELCO, the Chilean state-owned copper company that operates the large mines, plans to convert all its smelting operations to coal-fired energy. When this is done, Chile's total coal consumption will rise from its present level of about one million MT/years (mainly metallurgical coal from Concepcion for the iron and steel industry) to more than three million MT/year.

The Tocopilla conversions are expected to produce savings on petroleum imports of US $40 million per year, starting in 1987. These plants will consume about one million MT/year of Punta Arenas coal. Conversion of the other major mines' power supplies (Andina, El Teniente and El Salvador) would add another one million MT/year of coal consumption and oil import savings of another US $40 million.

In Peru, because the coal deposits are inland, underground, and high in the Andes, they are more expensive to produce and deliver than the Chilean coals of Concepcion and Punta Arenas. The economics are less favorable because (1) the major demand centers are considerable distances overland from the mines, and (2) low cost water transportation is not possible. Under these circumstances, it would appear that the more viable policy for developing Peru's coal potentials would be to follow an incremental program of gradually adding coal-fired power plants and industrial processes to meet the growth of demand, rather than to embark on a program of rapid conversion of existing facilities. This program would permit the gradual upgrading of existing transport facilities, such as straightening and widening of roads in the coal regions, and upgrading the tracks, control systems and rolling stock on the Central Railroad.

Converting burners from oil or gas to coal is very expensive, because coal, as a solid, is more difficult to handle than liquids or gases. Even as a slurry, coal requires considerable preparation and handling, whereas liquids or gases can be stored in tanks and pumped through pipelines at very low cost. Therefore, a decision to convert a burner from oil or gas to coal can only be made if it is evident that the coal will not cost more (after preparation, transportation and handling) than the oil or gas it is replacing. In Peru, as noted earlier, the circumstances of the location of the coal would appear to favor an approach where coal-fired processes were developed gradually, to replace obsolescent boilers and to meet new demand.

In 1980 Peru produced 145,051 MT of bituminous and anthracite coal from the following coal fields:

Coal Field	Province	MT	Percent
Goyllarisquizqa	Cerro de Pasco	73,831	50.9
Alto Chicama	La Libertad	19,727	13.6
Oyon/Gazuna	Lima	32,201	22.2
Santa	Ancash	18,567	12.8
Santa	Huanuco	725	0.5
	Total	145,051	100.0

Sources: INGEMMET, PROCARBON

Virtually all production went to CENTROMIN's smelters at La Oroya and to SIDERPERU's coking mill at Chimbote for the steel plant. Chimbote was supplied by truck while La Oroya was supplied by rail. Both entities also imported coking coal and coke, which is estimated to have run about 173,800 MT per year in the late 1970s (Min. de Energia y Minas, 1980). The data for the tabulation above did not mention the mines at Jatunhansi, in Huancayo Province, which now are supplying metallurgical coal by rail to CENTROMIN's La Oroya smelters.

There is a great deal of disagreement and speculation among analysts about the scale and timing of development of Peru's coal reserves. Estimates for 1990 range from a low of 0.5 million MT to a high 1.85 million MT, and for the year 2000 the range is between 0.7 million and 3.05 million, according to the survey of Andean countries' energy supply and demand situations cited earlier (Bundesstelle fur Aussenhandelsinformation, 1984). Some Peruvian analysts have projected effective demand for coal to exceed 7.5 million MT/year by 1995, after estimating the extent that conversion of boilers and heaters from oil or gas to coal could be economically accomplished. It is difficult, therefore, to estimate precise patterns of coal shipments: the origins, destinations, volumes, routes and modes that would be involved. We do know, however, that one major opportunity for increased coal utilization lies with the Lima area, for its many factories producing cement, bricks, ceramics, fish meal and chemicals and for its electric power generating plants. Coal would be shipped by rail from the mines in Cerro de Pasco, Huanuco and Huancayo Departments (the Oyon, Gollarisquizga and Jatunhuasi fields) which are served by the Central Railroad. The Lima area would also receive coal from the Alto Chicama coal fields in northern Peru; collier ships or ocean-going barges could be loaded at Salaverry, near Trujillo for the 560 km voyage to Callao. Trucks or, if the volume were significant, a slurry pipeline could bring the Alto Chicama anthracite coal the 160 km from central La Libertad Department to the port.

A second major opportunity for coal would be the Trujillo area itself, for its sugar, fertilizer and cement manufacturing industries, and for electric power generation. The Alto Chicama anthracites would be the principal source of fuel.

A third opportunity is the SIDERPERU steel plant at Chimbote. Its small supply of domestic coking coal is brought in by truck at considerable expense because of the poor condition of roads descending to the coast of Ancash Department from the Cordillera. Chimbote also has a substantial fish meal sector that uses much fuel.

A fourth opportunity would occur with coal delivered by ship to the iron ore concentrating (pelletizing) operation at the Port of San Nicolas, in southern Ica Department (for electric power and heating), and to the copper smelting and refining operations at Ilo, in Moquegua Department. These ports could be served by colliers loading out of Salaverry, Chimbote or Callao.

There are two sets of problems to be solved to increase the transport capability for coal in Peru. For the Alto Chicama and Santa region coal deposits, the roads from the coast to the coal areas are paved only in the coastal plains and lower foothills of La Libertad and Ancash Departments. In the highlands, however, the roads are gravel or dirt, often with narrow winding alignments where very large trucks cannot operate. Only smaller, less cost-effective trucks can be used which have operating costs two to three times higher, per ton-km, than larger trucks. For example, a metric ton of coal carried the 160 kilometers from Alta Chicama to Salaverry in a 7-ton truck, which can operate in the highlands on poor roads, would cost about US $15 for running expenses (driver, fuel, tires, regular maintenance). With a 25-ton capacity truck on paved roads, the cost per ton would be about US $5 (data from CONREVIAL, 1981).

There would have to be substantial investments in road improvements in La Libertad and Ancash Departments and in storage and loading facilities at the ports of Salaverry and Chimbote. Highway reconstruction and improvement in the mountains can cost on the order of US $100,000 per kilometer for a well-engineered gravel highway. With heavy truck traffic, annual maintenance can (should) run US $8,000 per kilometer. However, by permitting a much larger volume of traffic, the improvements can be amortized over a larger revenue base and probably yield a total cost of transport with the large vehicles that is lower than the cost of the small vehicles on the unimproved road. Each case must be evaluated separately.

At the ports of Salaverry and Chimbote, storage and loading facilities would have to be improved to handle large volumes of coal. The consideration would be to try and optimize on the costs of high capacity loading systems versus savings in minimizing ship waiting time. Shoreside and dock-side improvements could cost several hundreds of thousands of dollars, but the savings in ship operating costs could make the entire shipping sequence economically feasible.

As an indication of the potential economies of loading facilities, in Salaverry the traditional manual system of loading ships with mineral concentrates would cost about US $11 per metric ton with a loading rate of 25 tons per hour. A portable conveyor belt system in conjunction with more efficient materials handling equipment would cost less than US $4 per ton, and have a loading rate of 300 MT/hour. The costs include capital recovery for a $500,000 investment in new equipment.

The second major problem area for Peruvian coal transport is the capacity of the Central Railroad to bring coal from the Huanuco, La Oroya and Huancayo regions to the coast. A major increase in freight tonnage would place considerable strains on track, rolling stock and personnel. In 1982 the Port of Callao exported nearly one million metric tons of mineral concentrates, most of which were transported to the port by rail from the central Andes. An additional million tons of coal would require major improvements in facilities and control systems. Assuming 50-ton capacity hopper cars and 50-car trains, movement of a million tons would require about eight trains per week, which would be a very large increase in operations for ENAFER, the state railroad enterprise.

There are no data available for estimating what the capital costs might be for such improvements. In terms of rolling stock, the coal traffic would require three or four train sets (locomotives and hopper cars). Track improvements would be necessary in order to preserve existing train frequencies and levels of service. International development financing would be necessary, with the debt servicing secured by earnings from increased exports of petroleum.

A coal slurry pipeline from the central Andes might be feasible, if the overall volume of coal to be shipped were sufficiently large. As was noted earlier, coal slurry pipelines require throughputs of several million tons per year over distances of at least several hundred miles to realize their economies of scale. In cases of lower volumes and distances, the pipeline mode will be feasible only if the existing alternatives—rail or highway routes--are grossly inadequate to accommodate the new traffic. Then the question must be asked whether the delivered cost of the coal energy with a slurry pipeline is less than the cost of other domestic or imported fuels.

A possible mitigation of the cost of a coal slurry pipeline system could result from use of a coarse coal technology, which would reduce the requirements for coal preparation. Also, some benefit could accrue from the transport water, which could be used for irrigation after being purified. Consideration would have to be given, of course, to the problem of obtaining an adequate water supply which did not impair the rights of existing users.

A possible lower cost, near term program for developing uses of coal would be "coal by wire," that is, development of small to medium sized (50 MW to 250 MW) mine-mouth power plants in one or more of the coal fields, and linking them to the national high voltage, long distance hydroelectric power transmission network. Much of the cost of energy transmission occurs in the preparation of rights-of-way and erection of towers. There may be unutilized transmission capability in existing high voltage circuits, or the transmission towers may have the capability to carry additional conductors from new coal-fired power stations. Thus, the incremental cost of transporting the coal energy to demand centers would be minimal.

All of these possibilities would entail large capital investments which would have to amortized over the next several decades. The benefits in the form of lower energy costs and increased foreign exchange earnings (from petroleum no longer needed for domestic energy) would appear to make these coal facilities, including the transportation improvements, attractive projects for international private and public lenders and investors.

IV. CONCLUSIONS

Chile and Peru appear to have the strongest prospects for significantly expanding use of domestic coal resources. They have relatively large reserves of high quality coal; they have a history of using coal in the metallurgical industries; and, in Chile, the government-owned copper enterprise, CODELCO, is developing coal-fired electric power generation to replace oil-based power for the Chuquicamata copper mining complex. Use of coal has been inhibited in Bolivia and Ecuador by the absence of good quality coal and the relative abundance of oil and gas. There has not, therefore, been much stimulus to improve the coal transportation capability of these countries' rail and highway systems.

The feasibility of Chile's development of coal-fired electric power generation for the Chuquicamata copper region, in the northern part of the country, rests in large part on the ability of the power stations in the port of Tocopilla, which provide the power for Chuquicamata, to be supplied by ship. The coal is transported from Punta Arenas, in the far south of the country, from which there is no overland route. Only low cost waterborne bulk carriers could feasibly transport the coal. Other coastal power stations, now fueled by oil, will become candidates for conversion to coal.

The geography of Peru's coal deposits, being located in the high Andes, has prevented the country from being able to develop waterborne transport of its coal. Primary reliance has been on rail and truck, for the relatively small amounts of coal that have been developed. The potential exists, nevertheless, for transport improvements to be made that will facilitate expansion of coal use. However, great care must be taken to avoid uncoordinated development of the coal transport capability. Otherwise there is a large risk of facilities being developed that will not be able to deliver the savings in costs upon which the feasibility of expanded coal use will rest.

The principal transport problem for Peruvian coal is the relatively low level of demand for coal. The volumes presently being moved will not justify major capital improvements in rail and highway facilities. Additional uses for coal must be identified, notably electric power generation and energy-intensive industries like cement and ceramics. If the consolidation of demand can be accomplished at industrial centers, such as Lima, Trujillo, Chimbote, San Nicolas, and Ilo, then the volumes of coal consumed may justify major transport improvements. The question then becomes, is it more economical to upgrade the Central Railroad and the major highways between the coal fields and the coast, or to develop slurry pipelines, or to develop mine-mouth power plants and pursue a policy of electrification for industrial users in the coastal regions?

An argument for upgrading the railroad and highway systems and bringing the coal to the coastal regions even if the costs for moving the energy content of the coal might be higher than would be the case with a slurry pipeline or mine-mouth power plant system, would be the induced economic and social development benefits stemming from better overland transportion. There have been instances of the choice being made to develop a rail system through undeveloped country for a power project, even though a water route or slurry pipeline system might be cheaper, because of the regional economic development benefits.

In summary, coal transportation improvements cannot be considered in a vacuum. The transport infrastructure has far-reaching impacts on the economic, social and political structure of a country, because it is expensive, long-lived, and tends to shape the direction of the development of population and economic resources. In particular, transportation of coal is of major significance because the commodity can account for a large share of the utilization of all transportation facilities. Therefore, choices must be carefully made to optimize the existing capabilities of the transport infrastructure, and to add increments of capability that will match increases in demand but which will avoid over-commitment of financial and physical resources in excess capacity.

REFERENCES

Agramonte, Ing. Jorge B. and Diaz, Econ. Alejandra V., "Inventario Preliminar del Carbon Mineral en el Peru," De Re Metallica, Lima, Enero-Febrero 1985, pp. 9-11.

Aude, T.C. and Thompson, T.L., "Coal Transportation Costs/Inflation," Proceedings of the Fourth International Conference on Slurry Transportation. Slurry Transport Association, Washington, D.C., 1979.

Aude, Thomas C. and Thompson, Terry L., "Coal Transportation - The Economic Alternative," Proceedings of the Seventh International Technical Conference on Slurry Transportation. Slurry Transport Association, Washington, D.C., 1982.

Bundesstelle fur Aussenhandelsinformation, Markt-Information: "Bolivien Energie-Wirtschaft 1981/82," Koln, 1984.

____________________, "Chile Energiewirtschaft 1982."

____________________, "Ecuador Energiewirtschaft 1982."

____________________, "Peru Energiewirtschaft 1982."

____________________, "Venezuela Energiewirtschaft 1982."

Dames & Moore, Coal and Fuel Evaluation Study for Florida Power and Light Company, 1976.

Dames & Moore, "Final Report: Mineral Transportation and Handling Feasibility Assessment," for Minero Peru Comercial (MINPECO) and the U.S. Trade and Development Program, San Francisco, July 1983.

Empresa Promotora del Carbon S.A., (PROCARBON), Carbon: Oportunidad del Peru, Lima (undated).

Goodman, Roger J., "Western Canadian Export Metallurgical Coal Industry's Trends and Prospects," Skillings' Mining Review, August 20, 1983, pp. 4-11.

Mining Annual Review, 1984, pp. 311-319 (Central and South America).

Peru, Ministerio de Transportes y Communicaciones, Direccion Sectorial de Estadistica, Compendio Estadistico, 1976-81, Lima, April 1982.

Plude, George H., "Bukit Assam: The Nascence of a Self-unloading System," Bulk Systems International, London, September 1984, pp. 51-53.

Reiber, Michael and Soo, S.L., Comparative Coal Transportation Costs: An Economic and Engineering Analysis of Truck, Belt, Rail, Barge and Coal Slurry and Pneumatic Pipelines, Center for Advanced Computation, University of Illinois at Urbana-Champaign, August 1977.

Roseman, Donald P., "Relative Costs of Alternative Modes of Ocean Transportation of Coal," Minerals Transportation 3 - Vol. 3: Proceedings of the Third International Symposium on Transport and Handling of Minerals. Vancouver, B.C., 1979.

Smith, John P., "Transportation: A Vital Element in Coal's Future," Mining Engineering, October 1982, pp. 1433-1437.

Thurlow, Ernest E., "Rail Transportation of Mineral Commodities," Mining Engineering, October 1982, pp. 1448-1456.

UTILIZACION DE CARBONES ANDINOS EN METALURGIA

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UTILIZACION DE CARBONES ANDINOS EN METALURGIA

INTRODUCCION.-

Con ciertas excepciones notables (Colombia, Venezuela), los países de la región andina carecen de reservas adecuadas de carbones coquizantes. Los carbones coquizantes se definen como aquellos carbones que sometidos a un proceso de destilación lenta y a alta temperatura dejan reciduos porosos con un alto contenido de carbono...el coque metalúrgico. En general, los carbones del centro de la región andina (correspondientes al Perú, Bolivia, y Ecuador) poseen buenas características térmicas pero bajo poder aglutinante.

Sin embargo, la mayoría de los países de la región e incluyendo al Perú, Bolivia, y Ecuador demuestran una necesidad creciente de sustituir importaciones y por lo tanto, una necesidad también creciente de maximizar la utilización de recursos naturales como el carbón. Hasta la fecha, poco se ha conseguido para aumentar en forma substancial la utilización industrial de carbones domésticos, en parte porque la demanda sectoral en aquellas aplicaciones que requieren carbón, cómo la generación de energía eléctrica o bien los usos metalúrgicos, no se han desarrollado en forma mas dinámica y en parte por falta de tecnología adecuada que permita la utilización de los carbones andinos. Este documento enfoca las posibilidades de aumentar la utilización de carbones andinos en metalurgia.

USOS METALURGICOS DEL CARBON.-

Fuera del uso térmico del carbón, el campo de aplicación mas importante es el campo metalúrgico, es decir, para la producción de metales.(Otras areas comprenden las aplicaciones químicas, físicas, o mecánicas*). Conviene distinguir, sin embargo, que en los procesos de producción metalúrgica existen dos grandes corrientes o alternativas: la producción primaria y la producción secundaria. Los procesos primarios normalmente envuelven la extracción minera, los procesos de concentración mecánica, y los procesos de fundición y refinación. Los procesos secundarios son aquellos basados en la recuperación de materias primas a partir de la chatarra.

* Por ejemplo, el uso del carbón activado en sistemas de adsorpción, o en electroquímica.

Como es natural, la chatarra no es un elemento abundante en los países de la región andina, ni tampoco en otros países en vías de desarrollo. Esta tiende a acumularse en relación al nivel industrial de una región y , por lo tanto, los mayores productores de chatarra son justamente aquelles regiones que, como los EE.UU. o bien los países europeos, tienen una larga historia de desarrollo industrial. Es por eso que en aquellos lugares de chatarra abundante los procesos de recuperación secundaria tengan bastante importancia y, en casos especiales como el plomo, hasta prevalezcan sobre el tonelage de producción primario.

También conviene recordar que el uso principal de los carbones en metalurgia es en los procesos de fundición. Dentro de esta categoría la siderurgia ocupa el papel mas importante debido a que en cuanto a tonelage los procesos de fundición de hierro sobrepasan en mucho a la fundición de otros metales. En el caso del hierro la fundición se efectúa tradicionalmente por medio del alto horno---un horno vertical de gran envergadura donde los minerales de hierro se calientan progresivamente ,se funden y reducen, y se refinan parcialmente en forma de hierro fundido (arrabio). Debido al tamaño del horno así como su alta temperatura y el nivel de turbulencia de los gases, el carbón debe primero transformarse en un material de alta resistencia mecánica, de alto contenido de carbono, y de alta actividad química: el coque. Estas propiedades físicas y químicas del coque son tan importantes que dan lugar a un rango de especificaciones, las que a su vez determinan la aceptación o el rechaso del material para un determinado uso industrial.

Aun cuando las especificaciones del coque pueden no reflejar la calidad intrínseca del coque, son sin embargo importantes porque representan criterios ya establecidos por los operadores de los altos hornos. Por lo tanto, no es de extrañar que las especificaciones del coque no sean constantes en el tiempo, pero que evolucionen en la misma medide que las prácticas industriales del alto horno mejoren. Desde un punto de vista práctico, hay que reconocer que ninguna especificación en este terreno puede ser demasiado rígida, ya que ellas afectan el suministro y los costos de operación. Naturalmente, las especificaciones de coque también varían geograficamente. La tabla 1 presenta el rango aproximado de las especificaciones químicas y físicas mas importantes.

Tabla 1
ALGUNAS ESPECIFICACIONES QUIMICAS Y FISICAS DEL COQUE METALURGICO

Especificaciones Quimicas	Rango Ideal	Rango Aceptable	Especificaciones Fisicas	Rango Ideal	Rango Aceptable
Ceniza, %	<8	<19	Tamaño,mm	25-60	20-100
Azufre, %	<0.6	<1.0	Estabilidad	55-60	50-55
Humedad,%	<8	<13	Dureza	70-75	60-65
Alkalinos, %	<0.2	<0.2	Indice M40	>80	>70
Volátiles, %	<1.0	<1.0	Indice M10	<7.0	<10.0

TECNOLOGIA DE COQUEFICACION CONVENCIONAL.-

En general, el proceso de coquefición consiste en calentar sin aire carbones de granulometría fina por periodos de 14 a 19 horas en hornos largos y angostos, que a su vez constituyen las baterías industriales de coque. Debido a que el proceso cubre un rango mas o menos amplio de temperaturas y envuelve reacciones físico-químicas bastante complejas, conviene considerar el comportamiento progresivo del carbón en función de los dos parámetros mas importantes en el proceso de coquefición: los componentes del carbón (es decir,su composición) y la temperatura.

Basicamente el carbón contiene componentes reactivos así como no-reactivos, y ambos tipos se comportan en forma muy diferente durante la coquefición. Por lo general, los componentes mas reactivos (por ejemplo: vitrinita, pseudo-vitrinita, exinita) exhiben un alto indice de reflectividad óptica y tienden a ablandarse rapidamente con la temperatura, llegando al estado liquido sobre temperaturas de 300 C., mientras que los componentes inertes (por ejemplo: fusinita, micronita, materia mineral) presentan menor reflectividad óptica y son generalmente infusibles. Como es natural, no existe una demarcación abrupta que defina en forma rigida y precisa las propiedades de cada componente del carbón (es decir, los macerales del carbón) ya que cada maceral refleja diferencias en compocición y origen.

En las primeras etapas de calentamiento, a temperaturas menores de 300 C, el proceso de coquefición no es en realidad nada mas que un proceso de destilación, donde los gases que se desprenden incluyen como componentes principales el vapor de agua y el dióxido de carbono. Esta primera etapa del proceso se puede visualizar como una continuación del proceso de carbonificación en la naturaleza--la eliminación progresiva del agua y CO2 de residuos vegetales antiguous.

A temperaturas mas altas, en el rango de 300 a 400 C, los componentes reactivos del carbó comienzan a ablandarse. Este ablandamiento es particularmente acentuado en la vitrinita que, por lo general comienza a emitir micro-burbujas de gas. Este gas así como gases similares que se desprenden de la superficie de otros macerales del carbón contienen hidrocarburos de bajo peso molecular y substancias de tipo aromático--el resultado de procesos de depolimerización. A medida que la temperatura aumenta, las micro-burbujas de gas crecen en tamaño y, a temperaturas de unos 450 C, han crecido lo suficiente para presionar los componentes inertes del carbón en contacto directo. Al mismo tiempo, los componentes reactivos del carbón han alcanzado bastante fluidez y logran encapsular a los inertes, formando dispersiones coloidales de partículas infusibles dentro de una masa fundida y porosa.

Tanto el punto de fusión incipiente así como el rango de temperaturas de fusión son extremadamente importantes, ya que esta segunda etapa de coquefícación controla no solamente la duración de los procesos de depolimerización y de condensacin posterior, sino también la naturaleza del vinculo entre las partículas de carbón inerte, es decir, la resistencia mecánica del coque. Una etapa de ablandamiento y fusión insuficiente suele impedir la condensación subsequente de gases de bajo peso molecular y, por lo tanto, dar lugar a un coque de poca resistencia mecánica, ya que estos procesos de condensación contribuyen a cementar los materiales mas inertes.

Mayores temperaturas, en el rango de 500 a 600 C, causan la solidificación de las películas fundidas que contienen los componentes inertes en una masa de semi-coque. Los anillos de carbono que anteriormente se mantenían separados por átomos de hydrógeno, ahora se funden y cristalizan. Durante esta etapa, los residuos de los macerales reactivos, particularmente la vitrinita, desarrollan anisotropía óptica--lo que comunmente se conoce como la estructura de mosaico--que es muy común en los coques de buena calidad y que, si se mantiene por tiempo suficiente a alta temperatura, da lugar a la grafitización progresiva del coque. En la medida que el semi-coque solidifica y se contrae a altas temperaturas, también desarrolla innumerables grietas y fisuras las que posteriormente determinarán su resistencia mecánica, su tamaño medio, y su hábito de fractura.

Debido a que el comportamiento de componentes inertes así como componentes reactivos juega un papel tan importante en el proceso de coquefícación, se desprende que estos componentes deben existir en proporciones bastante exactas para que el coque resultante tenga las propiedades físicas y químicas requeridas. Sin embargo, poquísimos carbones poseen estas proporciones ideales de macerales reactivos e inertes. Por lo tanto, es común mezclar carbones de diferentes composiciones para alcanzar la proporción adecuada entre distintos componentes. Otra ventaja de la mezcla de carbones es que rara vez componentes similares de diferentes carbones tienen un rango de ablandamiento y fusión similar; por lo tanto, la mezcla de carbones tiende a expandir la duración de la etapa de depolimerización, condensación, y coqueficación incipiente.

Se desprende de lo anterior que una de las propiedades que se persigue de la mezcla de diversos carbones es que tal mezcla se ablande y se funda dentro de un rango de temperatura mas o menos amplio, para así mejorar los procesos de cementación de materiales inertes. Debido a que el proceso de coqueficación es en realidad bastante complejo, no basta con tratar de manipulear el punto y rango de fusión; se trata de controlar las propiedades reológicas de cada componente maceral. Una buena mezcla de carbones no solo contiene la proporción adecuada de reactivos e inertes, sino además las propiedades físico-químicas de estos materiales son tales que facilitan el desarrollo de una película plástica de duración y grosor suficiente para incorporar y cementar bien todos los materiales inertes.

Otra propiedad que se desprende de la etapa plástica del proceso (la etapa de depolimerización, condensación, y cristalización incipiente) es la presión que el carbón ejerce sobre las paredes del horno durante la coqueficación. Este aspecto es importante porque tales presiones pueden sobrepasar la resistencia mecánica de las paredes del horno, y causar daño irreparable a la planta. La presión deriva de la etapa plástica y de debe a que etapas posteriores de contracción no logran neutralizar la expansión de elementos volátiles. En general, los carbones de alto contenido volatil tienden a ejercer presiones menores que los de menor contenido volatil--un fenómeno contrario a la intuición que de debe al alto contenido promedio de macerales reactivos en carbones de tipo volatil, lo cual hace que dichos carbones tengan mas fluidez y distribuyan mejor las presiones mecánicas.

<u>Parámetros Tecno-Económicos</u>.-

Se desprende de lo anterior que hay varias condiciones que facilitan las varias etapas del proceso; estas se pueden visualizar como los parámetros críticos de la coqueficación: la temperatura del proceso, la densidad de la carga de carbón, el punto así como el rango de fusión de la carga (que a su vez depende de la mezcla de carbones), y el nivel de humedad de la carga. Naturalmente, todos estos factores están intimamente ligados de manera que no se puede variar uno sin afectar a otro. La discusión siguente sin embargo trata de separar el efecto de cada uno de estos factores como si estos fueran independientes los unos de los otros.

Temperatura de Coquefícación. Hasta cierto punto, la historia de la fabricación de coque es la historia del aumento progresivo de la productividad del proceso a causa de mayores temperaturas de coquefícación. La productividad del proceso, es decir las toneladas diarias por día, tiene relación directa con la velocidad de avance del frente de ablandamiento dentro del horno, es decir con la cinética de la segunda etapa de coquefícación--fusión incipiente, depolimerización, y formación parcial de semi-coque. Esta velocidad de avance del frente de fusión se expresa normalmente en mm por hora. En la práctica es normal encontrar ritmos de avance del orden de los 25 a 30 mm por hora.

El efecto mas immediato de la temperatura de coquefícación es económico:a mayor temperatura mayor productividad. Sin embargo, una mayor temperatura también acarrea beneficios de tipo técnico. Por ejemplo, a mayor temperatura el grosor de la banda de fusión aumenta y la fluidez de los carbones también aumenta. Además una alta temperatura facilita la grafitización del coque y, por lo tanto, su resistencia a la abrasión. Todos estos factores facilitan el empleo de mezclas de carbón conteniendo mayores proporciones de carbones de baja calidad.

Dosificación de la Mezcla. Como se mencionó anteriormente, la practica de mezclar carbones de diferentes caracteristicas físicas y químicas es bastante normal. El efecto mas immediato de esta práctica es económico, pero al igual que en el caso del factor anterior (temperatura) esto también acarrea beneficios de tipo técnico. En general el uso de carbones diferentes en una mezcla extiende el rango de temperatura de fusión, y por lo tanto permite el uso de carbones de menor calidad sin comprometer la calidad del coque.

Los factores mas importantes en la dosificación de carbones incluyen: el número de carbones en la mezcla, el contenido de volátiles en la mezcla, la distribución de tamaños de la mezcla (es decir, la granulometría), la humedad de la mezcla, y el uso de materiales inertes (como el cisco de coque) en la mezcla.

Densidad de Carga. La densidad de la carga de carbón influencia tanto la productividad como la calidad del coque. A mayor densidad de carga, mayor productividad, pero también mejor resistencia mecánica del coque ya que la mayor cercanía de las partículas de carbón durante la fusión promueven una mejor cementación de los granos inertes. Sin embargo, una densidad de carga mayor acarrea presiones sobre las paredes del horno que pueden ser excesivas, y esto naturalmente limita el aumento indiscriminado de la densidad de carga.

Uno de los factores que disminuye la densidad de carga sin agregar nada positivo al proceso es la humedad del carbón. Es por eso que el secado parcial del carbón, o el agregar pequeñas cantidades de petroleo generalmente resulta beneficioso.

También se desprende de lo anterior que las plantas industriales de coquefícación deben optimizar los parámetros de coquefícación mas importantes o, dicho en otra forma, facilitar las varias etapas del fenómeno de coquefícación. Esto se puede constatar al examinar los procesos convencionales y las variaciones que permiten expandir el rango de carbones para producir coque.

El Horno de Coque Convencional.-

El proceso convencional de coquefícación se practica en hornos rectangulares y elongados, totalmente recubiertos de refractarios de silica. Las dimensiones de estos hornos naturalmente varian de acuerdo al fabricante y al período en que tal horno entró en producción. Por lo general, estos hornos tienen dimensiones que varian entre los 8 y los 16 metros de largo, entre los 4 y los 8 metros de altura, y entre los 35 a 50 cm de ancho.

Por lo general, el proceso comienza con la preparación y molienda del carbón. Se trata de conseguir un carbón de no mas de 3 mm de tamaño máximo, cuyas propiedades físicas y quimicas se ajusten los mas posible a lo discutido anteriormente. Este carbón se introduce en los hornos generalmente desde arriba, por medio de un carro cargador que se desliza sobre rieles y que consiste realmente en una tolva de carga móvil. Dependiendo de las dimensiones particulares del horno, este acepta entre unas 15 a 40 toneladas de carbón. Una vez terminada esta operación, se cierra el orificio de carga, se abren las válvulas que permiten la colección de gases, y comienza el ciclo de calentamiento.

El proceso de coquefícación termina de completarse unas 14 a 18 horas mas tarde, una vez que el total de la carga original ha pasado por las varias etapas de coquefícación, incluyendo de 1 a 4 horas a alta temperatura antes de la descarga final. Esta descarga se efectúa por medio de un aparato que empuja el total de la carga en forma lateral hasta que esta cae dentro de un carro móvil. Immediatamente después el coque que está en un estado incandescente se somete a un enfriamiento rápido por agua, y posteriormente se vuelca sobre una superficie inclinada que permite continuar su etapa de enfriamiento en forma mas lenta.

Lo anterior representa una reseña breve del proceso convencional de coquefícación. Ciertas modificaciones permiten extender el rango normal de este proceso a carbones de menor poder coquefícante. Tales modificaciones se basan en uno de los parámetros mas importantes de la coquefícación--la densidad de carga--y dan lugar a los procesos de "pre-calentamiento" y a los procesos de apisonamiento (stamping en inglés).

Los Procesos de Pre-Calentamiento.-

A diferencia de los métodos normales de coquefícación, en donde el carbón se introduce en frío dentro de los hornos, los métodos de precalentamiento envuelven la introducción dentro de los hornos a temperaturas que varían entre los 150 a 250 C. Como es de esperar, tales temperaturas tienden a eliminar la humedad del carbón, lo cual implica un menor volúmen de volátiles durante la etapa de destilación, así como una mayor densidad de carga y un ciclo de coquefícación mas rápido--ambos factores de importancia en la productividad de una batería de coque.

La mayor productividad asociada con los métodos de pre-calentamiento de debe principalmente a la eliminación parcial de la etapa de secado del carbón-- etapa que en general puede requerir del orden de las 10 horas después de la carga inicial de un horno, y que se necesitan para eliminar humedades del orden del 7 a 10%. El aumento de productividad no solo proviene de la abilidad de cortar el tiempo de secado a mas o menos la mitad, sinó también debido a que los requerimientos térmicos del secado (que oscilan alrededor de un 25% del calor de coquefícación en una batería convencional) son mucho menores.

El otro aspecto de la productividad es el asociado con la densidad de carga: se consiguen mas toneladas de coque por unidad de volúmen de horno y por unidad de tiempo con el pre-calentamiento. Además del efecto de la densidad de carga en la productividad, existe otro factor favorable de una alta densidad de carga--la proximidad de las partículas constituyentes del carbón, la cual promueve una cementación superior de los elementos inertes del coque. Esta mayor densidad de carga se consigue porque al eliminar la humedad superficial también se elimina el factor aglutinante del agua sobre las partículas de carbón, especialmente durante la carga del horno.

Fuera de las ventajas ya mencionadas arriba, otras características favorables de los métodos de pre-calentamiento incluyen las siguentes:

o Reducción de las pérdidas por calor. Naturalmente, cualquier reduccin en el tiempo de coquefiсación acarrea menores pérdidas de calor.

o Aumento de la velocidad de avance del frente plástico durante las faces iniciales del proceso. El no tener que eliminar gran parte de la humedad del carbón significa que la masa plástica de carbón y semi-coque necesita transmitir mucho menos calor para subir la temperatura del centro del horno.Esto permite un frente plástico mas amplio, y consecuentemente lleva a la formación de coque mas homogeneo y fuerte.

o Reducción del fisuramiento durante el enfriamiento final del coque. Este es otro aspecto de una homogeneidad superior y mejor conductividad térmica.

Conviene notar que ninguna de las caracteristicas que se han enumerado mas arriba dependen de uno u otro proceso especifico. Ellas pueden demostrarse en mayor o menor grado dependiendo del proceso que se halla elegido, pero existirán en todos los métodos de pre-calentamiento. Pero, así como existen ciertas ventajas generales asociadas con el pre-calentasmiento del carbón, también existen ciertas desventajas como por ejemplo: (1) dificultades en introducir la masa de carbón caliente dentro de un horno, (2) problemas de acarreo de polvo de carbón dentro del sistema de recolección de gases, y (3)problemas de control, especialmente en la composición de la mezcla y su temperatura.

<u>Métodos de Apisonamiento</u>.-

La metodología del apisonamiento (Stamping) se desarrolló principalmente el los paises europeos que, como Francia o Checoslovakia, cuentan con carbones poco coquizantes, y hoy en día casi no se conoce fuera de aquellas plantas antiguas de europa. El método consiste en cargar en carbón fuera del horno, en cámaras de dimensiones ligeramente inferiores a las del horno mismo, de manera que la introducción del carbón dentro del horno se pueda efectuar por medio de un fondo móvil, una vez que el total de la carga se haya apisonado externamente. El mecanismo de densificación de la carga consiste, tal como lo indica el nombre , en una serie de martinetes que apisonan el carbón a medida que este cae dentro de la cámara externa, proceso que requiere entre 15 a 30 minutos.

TECNOLOGIAS NO CONVENCIONALES DE COQUEFICACION.-

Esta categoria comprende modificaciones substanciales al proceso convencional, ya sea por medio de la aglomeración parcial o total de la carga, o bién por medio del uso de aditivos especiales que confieran poder coqueficante a mezclas de carbón no-coqueficable. Como es de esperar, cada una de estas opciones confiere ciertas ventajas y desventajas, las que se discuten brevemente a continuación en términos de los procesos mas conocidos.

Al igual que en la siderurgia, existen dos clases de procesos de tipo no convencional que extienden el uso de carbones no coqueficables; ambos se basan en la aglomeración del carbón. Sin embargo, una clase de procesos sencillamente utiliza carbón aglomerado en briquetas como parte de la carga total del horno, supliendo el resto de la carga con mezclas de carbón de tipo normal. Estos procesos se pueden clasificar como de "aglomeración de carbón" (en inglés:"formed coal processes"). El otro tipo de proceso mantiene el caracter aglomerado del carbón en el producto final y se conoce con el nombre de procesos de aglomeración de coque (en inglés:"formed coke processes")

Procesos de aglomeración de carbón.-

Estos procesos, que igualmente podrían llamarse de briquetado de carbón ya que la formación de briquetas es el método preferido de aglomeración, generalmente envuelven mezclas de carbones poco o no coquizantes y aglomerantes como la brea o el alquitrán de carbón, las cuales se introducen en hornos de coqueficación junto con mezclas de carbón molido de tipo convencional. Generalmente la proporción de briquetas no sobrepasa el 40% de la carga, aunque en algunos ensayos se ha llegado al 80%. Y por lo general, el carbón destinado al briquetado se somete al pre-secado para bajar su humedad a menos de un 3%, y al pre-calentamiento para aprovechar la plasticidad del carbón y así producir briquetas de alta densidad.

Uno de los efectos favorables de una carga mixta es que las briquetas de carbón tienden a hicharse bastante mas que la matriz de carbón durante las primeras etapas de calentamiento, y por lo tanto aumentan la compresión de la carga durante el período ideal--la etapa plástica que comienza a temperaturas sobre los 300 C. El otro efecto favorable es que este tipo de proceso requiere pocas modificaciones al equipo de coqueficación, es decir que la batería de coque necesitaría pocas modificaciones fuera de las requeridas por el proceso de briquetización mismo.

Procesos de Aglomeración de Coque.-

A diferencia de los procesos anteriores, en que la configuración del equipo y planta de coque no difiere apreciablemente de lo convencional, los procesos de aglomeración de coque, conocidos también bajo el nombre de coque formado, se caracterizan por configuraciones radicalmente distintas de las de un horno convencional. Estos procesos comparten varias caracteristicas similares:

o Todos producen un producto aglomerado de tamaño y forma constante, que por lo general es una briqueta.

o Todos utilizan carbones de poco poder coqueficante o car bones no metalúrgicos.

o Todos someten al producto a una etapa de endurecimiento que por lo general se basa en el tratamiento térmico.

Aditivos coqueficantes.-

Durante la última década se han investigado toda una familia de sustancias quimicas--aquellas que imparten un carácter coqueficante a carbones de mala calidad. Estas sustancias en general se asemejan quimica y fisicamente a los carbones de alto poder coqueficante, e imparten ciertas caracteristicas aglutinantes a mezclas de carbón no coqueficantes. Dentro de los primeros tipos de substancias coqueficantes se pueden mencionar los alquitranes naturales y las breas de alquitrán que provienen de los sub-productos del coque. Sin embargo, este tipo de aditivo ha demostrado una efectividad mas bien variable, y que depende de las condiciones de coqueficación así como de la mezcla de carbón. Por esta razón, se han desarrollado otros tipos de aditivos--substancias que en general no dependen de los sub-productos de una batería de coque, como los siguentes:

- ACTIV, una substancia que deriva de la hidrogenación catalitica del asfalto al vacío, y cuyo principal adherente es la Nippon Mining del Japón. El producto se asemeja a los componentes mas reactivos del carbón, conteniendo desde un 15% a un 40% de volátiles, una reflectividad media similar a la vitrinita, e indices de fluidez sumamente altos (del orden de las 50.000 DDPM).

-KRP, otro producto de la hidrogenación catalitica, pero esta vez aplicada a los residuos del petroleo. Los principales proponentes del proceso incluyen Kureha Chemical Industry, Sumikin Coke, y Chiyoda Chemical, todas compañías japonesas. El producto también se asemeja bastante a la vitrinita en cuanto al indice de fluidez, de reflectividad, y al contenido de materias volátiles.

-Productos de la refinación del carbón, en particular aquellas sustancias que resultan de los procesos químicos de liquefacción del carbón, como por ejemplo: el proceso SRC-NKK (desarrollado por la Nippon Kokan del Japón), el proceso SRC-Gulf (desarrollado en los EE.UU. por la Gulf Oil), y otros procesos similares.

Perspectivas de las Tecnologías No-Convencionales.-

Debido a que los procesos anteriores difieren substancialmente del proceso convencional (proceso cuyo diseño original no comprendía ni el control ni la automatización de plantas) se piensa que los nuevos métodos ofrecen potencial para mejorar tanto la calidad como la economía de la producción de coque. Por ejemplo, la mayoría de los procesos que se discuten en la literatura actual se prestan bien a la automatización y al control ambiental, ambos factores que son favorables para reducir los costos de capital asi como los costos operacionales de una planta. Sin embargo, si tal potencial existe cabe preguntarse porqué ninguno de estos procesos de coque formado ha alcanzado aún la etapa comercial.

Una razón poderosa tiene que ver con la recesin económica reciente, y especialmente con el impacto de la recesión en la industria siderúrgica. Tal como ha ocurrido en otros sectores metalúrgicos, existe una sobreproducción actual de carbones coquizables, lo cual significa que la necesidad de substituir estos carbones por otros de menor calidad ha disminuido mucho. Otra razón es de carácter económico y financiero. Ocurre que una demostración comercial de estas tecnologias nuevas requiería una cantidad de material que seria sumamente costosa de producir debido al monto de inversión en planta piloto. Una tercera razón tiene que ver con las tendencias de producción de acero en horno eléctrico en regiones industrializadas, y con las dificultades de los paises en vias de desarrollo de arriesgar inversiones substanciales en tecnologias que no se han demostrado aún en forma comercial.

Una última razón se refiere a las innovaciones en técnicas siderurgicas, que no solo ofrecen mejorar la calidad de los aceros industriales, pero también extender las alternativas de producción en base a rangos mas amplios de materias primas. Las implicaciones de tales avances tecnológicos en la región andina se exploran a continuación.

INNOVACIONES METALURGICAS.-

Se ha mencionado anteriormente que el uso mas importante de los carbones coqueficantes es en campo metalûrgico, tanto en siderurgia cómo en la fundición de no-ferrosos. Es por esto que las tendencias tecnológicas en estos dos grandes campos adquieren mucha importancia. El cuadro nûmero 2 cuantifica algunas proyecciones recientes sobre la producción siderurgica mundial. Aun mas importantes que las proyecciones globales del cuadro 2 son las tendencias tecnológicas de producción que se indican en el cuadro No3. Lamentablemente, los datos excluyen al sector no-ferroso; sin embargo se podría extrapolar que las tendencias del campo siderûrgico se extienden también al âmbito de otros metales bâsicos : un vuelco creciente hacia procesos pirometalûrgicos de alta temperatura--los llamados procesos de arco o de plasma, y naturalmente el horno eléctrico en siderurgia.

Cuadro No 2
PRODUCCION SIDERURGICA MUNDIAL
(Millones de Toneladas Métricas)

Región	1990	1995	2000
Europa Occidental	154.3	157.7	162.4
Europa Oriental	215.5	222.7	229.8
Norte América	115.6	117.3	120.1
América Latina	39.1	46.4	53.6
Africa/Medio Oriente	17.9	21.6	26.0
Asia y Oceania	219.6	244.6	262.4
TOTAL	762.0	810.3	854.3

Cuadro No 3
TENDENCIAS TECNOLOGICAS EN SIDERURGIA
(Porcentage de producción por tipo de Proceso)

Región	1990		2000	
	HE(1)	LD(2)	HE	LD
Europa Occidental	28.3%	71.1%	30.8%	69.2%
EE.UU.	31.3	64.3	37.4	62.6
Japón	24.6	75.4	25.6	74.4

Los porcentages individuales pueden no sumar 100% debido a la existencia de procesos residuales (Siemens-Martin).
(1) Horno eléctrico
(2) Horno LD

En términos de crecimiento, los datos del cuadro No 3 indican que en las tres areas mas importantes de producción siderúrgica, el horno eléctrico será el proceso dominante (aun cuando en términos de volúmen el horno LD siga contribuyendo mayor tonelage). Este fenómeno es especialmente evidente en los EE.UU. donde el crecimiento del sector siderúrgico integrado (es decir, alto horno + LD) es casi nulo, menor del 0.25%, mientras que la producción de horno eléctrico crecerá cerca de seis veces mas rápido.

Las proyecciones anteriores asumen que no se producirán cambios importantes tecnológicos que modifiquen los costos operacionales de diferentes regiones. Dentro de tales circumstancias, la mayoria de los paises industrializados agregarán poco a su capacidad de producción, y lo que agreguen serán principalmente en el sector de hornos eléctricos. Esta visión es consistente con la abundancia relativa de chatarra en los paises industrializados y con la baja rentabilidad de empresas siderúrgicas integradas durante los últimos años. Sin embargo, cabe preguntarse si cambios importantes en los insumos del sector siderúrgico convencional no podrian influenciar seriamente las proyecciones anteriores. En este sentido, las areas mas criticas son la capacidad efectiva de coqueficeión y el suministro potencial de chatarra, ya que ambas podrian ejercer tal influencia que modifiquen el ritmo de innovación tecnológica y su aceptación industrial. Estos factores se discuten brevemente a continuación.

Capacidad de Coquefición.-

Debido a la importancia critica que reviste el coque en operaciones siderúrgicas convencionales, no es de extrañar que la mayoría de las plantas integradas se han preocupado de contar con capacidad adecuada de coqueficación. Sin embargo, los últimos años han danãado la capacidad financiera de muchas grandes empresas siderúrgicas, con el resultado de que algunas se han visto obligadas a posponer las operaciones necesarias de mantención o de reemplazo de baterias de coque. Cabe destacar también que la vida útil normal de una batería de coque rara vez excede los 25 a 30 años, y que la mayoría de las plantas ubicadas en América del Norte asi como muchas en Europa ya han sobrepasado este limite de tiempo. De hecho, casi diez años atrás la capacidad de coque de los EE.UU. estaba estimadas en unos 67 millones de tonelada métricas, de las cuales más de un 55% provenía de baterias de coque de mas de 21 años. Naturalmente que desde esa fecha y a causa de la poca rentabilidad de esta industria el deterioro de la capacidad instalada ha sido creciente, aunque dificil de estimar en forma exacta.

Disponibilidad de Chatarra.-

El otro aspecto importante de la producción siderúrgica futura concierne la disponibilidad de chatarra o, mejor dicho, la posible falta de disponibilidad, lo que podría obligar a muchos productores no integrados (es decir, aquellos dependientes del horno eléctrico) a buscar substitutos.

Desgraciadamente son pocos los estudios recientes que intentan examinar esta materia. Lo que es peor, todavía existe una confusión aparente entre la disponibilidad actual de chatarra y su disponibilidad potencial. Por ejemplo, el Institute of Scrap Iron and Steel de los EE.UU. estimó el inventario de chatarra en los EE.UU. en 620 millones de toneladas a comienzo de 1982, sin considerar que el inventario potencial es muy dinámico y que puede fluctuar en forma considerable con cambios de precio. Además existe el problema del potencial de recuperación de chatarra--el concepto de que existe un periodo de tiempo bastante estrecho dentro del cual la chatarra potencial puede ser recuperada en forma económica, y que posteriormente la misma chatarra deja de ser disponible ya sea por que ha sido diluída, o bien por cambios de ubicación que impiden su recuperación económica.

Innovaciones tecnológicas.-

Se desprende de lo anterior que una posible falta de capacidad de coquefícación junto con una deficiencia de chatarra podrían acarrear consequencia serias para toda la industria. Sin embargo, una de estas consecuencias sería la de impulsar ciertos procesos metalúrgicos que, cómo la fundició en base a plasma (en inglés, plasma smelting), ofrecen alternativas para substituir la chatarra.

La tecnología de fundición en base a plasma incluye varios procesos, en su mayoría de origen escandinavo, aunque ninguno de estos pueda considerarse como probado a escala comercial. Hemos selecionado uno de estos, el proceso INRED de la compañía Boliden, para ilustrar el costo relativo de esta alternativa para la producción de productos no planos en varios países. Los resultados aparecen en el cuadro No 4 que refleja una planta hipotética de 400 mil toneladas de producción de barras de alambrón. Se presume que la planta incluye colada continua, refinación en cucharas, y en general los últimos avances tecnológicos.

Cuadro No 4
PRODUCCION DE ALAMBRON EN UNA MINI PLANTA
BASADA EN EL PROCESO INRED
(Dólares de 1983 por tonelada métrica)

Ubicación de la planta	1983 Costo Directo	1983 Costo Indirecto	1983 Costo Total	1993 Costo Directo	1993 Costo Indirecto	1993 Costo Total
EE.UU.	253	81	334	281	81	362
Japón	242	66	308	280	66	346
Francia	201	71	272	226	71	297
Alemania	204	71	275	234	71	305
Inglaterra	188	71	259	211	71	282

Se desprende del análisis anterior que las alternativas tecnológicas prentan posibilidades interesantes para los paises de la región andina. Efectivamente, si los nuevos procesos metalúrgicos (cómo los de arco de plasma) parecen ser atractivos en los paises industrializados, podrian ser aun mas atractivos en la región andina, especialmente si evitan inversiones substanciales en plantas de coquefícación, en altos hornos, y en otros equipos convencionales de gran envergadura. Además este tipo de proceso se adapta bien a la metalurgia no-ferrosa y, lo que es mas importante, presenta la gran ventaja de utilizar carbones no coqueficantes y de baja calidad.

CONCLUSIONES.-

Se han considerado tanto los procesos convencionales así c'mo procesos no convencionales para la producción de coque en los paises andinos. En general no parecen haber dificultades insuperables que eviten la producción de coque doméstica en la región. Se trata mas bien de comparar entre las varias alternativas para elegir aquellas(s) que proporcione(n) la mejor solución desde un punto de vista tecno-económico.

Las principales ventajas de los métodos convencionales de coquefícación son que tales métodos envuelven un riesgo de inversión bastante pequeño desde un punto de vista técnico; es decir, tanto los procesos de pre-calentamiento así cómo los de apisonamiento se han probado en escala comercial. Sin embargo, también se sabe que tales procesos tienen un tamaño de planta mínimo que puede o no corresponder a las necesidades internas de los paises de la región. Otra posible desventaja es que todos los procesos convencionales requieren proporciones mínimas de buenos carbones en la mezcla. Es decir que este tipo de método obliga a importar ciertas cantidades mínimas de carbones de buena clase.

Virtualmente todos los métodos no-convencionales para la producción de coque disminuyen la dependencia de carbones de buena calidad en la mezcla, aunque algunos métodos lo consiguen en mayor grado que otros. Todos los métodos--los que incluyen aditivos asi cómo aquellos que emplean la aglomeración de carbón o coque--presentan ciertas ventajas potenciales en cuanto al tamaño mínimo de una planta y en cuanto a los procesos de control. Desgraciadamente, ninguno de los métodos no-convencionales a los que se ha aludido anteriormente ha sido demostrado en escala comercial y, dada la situación económica de la siderurgia mundial, seràdificil que se demuestre une factibilidad económica en un futuro cercano.

Finalmente se han considerado ciertas alternativas fuera del campo de la coquefìcación: el efecto de avances tecnológicos que obviarían la necesidad de contar con coque metalúrgico, pero que utilizarían los recursos domésticos de carbón de la región.

ANTHRACITE BRIQUETTING: A STRATEGY FOR THE DEVELOPMENT OF THE COAL MINING INDUSTRY IN PERU

C. G. Soldi
Empresa Promotora del Carbon
Peru

ANTHRACITE BRIQUETTING: A STRATEGY FOR THE DEVELOPMENT OF THE COAL MINING INDUSTRY IN PERU

C. G. SOLDI
EMPRESA PROMOTORA DEL CARBÓN
PERÚ

1. INTRODUCTION

PERUVIAN COAL DEPOSITS HAVE BEEN KNOWN AND STUDIED FOR MORE THAN A CENTURY, BUT NO SERIOUS EFFORT HAS BEEN MADE YET TO PUT THEM INTO OPERATION AT A REASONABLE SCALE.

PERU HAS TRADITIONALLY BEEN A MINERAL EXPORTING COUNTRY AND BECAUSE OF ITS GEOGRAPHY, MOST OF THE ENERGY REQUIRED BY ITS RELATIVELY MODEST INDUSTRY HAS BEEN SATISFIED THROUGH HYDRO-POWER GENERATION.

DURING THE LAST CENTURY, A SLOW PROCESS OF INDUSTRIALIZATION TOOK PLACE BUT BECAUSE OF THE RELATIVELY LOW PRICE OF OIL, MOST OF THE COUNTRY'S INDUSTRIAL INFRASTRUCTURE WAS DESIGNED TO USE OIL AS FUEL AND LITTLE ATTENTION WAS PAID TO COAL AS AN ALTERNATIVE SOURCE OF ENERGY.

SINCE 1970, THE COUNTRY HAS MADE GREAT EFFORTS TO INCREASE ITS OIL PRODUCTION, CONSIDERING THAT OIL SOLD IN THE INTERNATIONAL MARKET PROVIDES THE FOREIGN CURRENCY REQUIRED TO SUPPORT THE INDUSTRIALIZATION PROCESS OF THE COUNTRY.

UNFORTUNATELY, THIS EFFORT HAS NOT BEEN AS SUCCESSFUL AS EXPECTED AND WHILST OIL PRODUCTION HAS REMAINED AT AROUND 200,000 BBL/D OVER THE LAST TEN YEARS, THE INTERNAL DEMAND HAS INCREASED STEADILY AT 3.5% PER YEAR AND THE COUNTRY IS NOW FACING THE POSSIBILITY OF BECOMING AN OIL IMPORTER IN THE SHORT TERM IF NO URGENT ACTION IS TAKEN.

NO PRECISE FIGURES ARE AVAILABLE FOR PERUVIAN COAL RESERVES, BUT THESE ARE CERTAINLY WELL OVER 500 MT, ANTHRACITE BEING THE MOST ABUNDANT TYPE OF COAL KNOWN TO EXIST IN THE COUNTRY. SEMI-ANTHRACITE AND LOW-VOLATILE BITUMINOUS COAL DEPOSITS HAVE ALSO BEEN STUDIED AND WORKED ON A SMALL SCALE BASIS, BUT THEIR EXTENT AND IMPORTANCE SEEM TO BE MODEST COMPARED TO THOSE OF ANTHRACITE COAL DEPOSITS.

WHAT IS CERTAIN IS THAT PERUVIAN COAL HAS BEEN STUDIED ONLY SUPERFICIALLY AND NO FINAL WORD CAN BE SAID ABOUT ITS QUALITY UNTIL IT IS MINED AND BURNT ON A LARGER INDUSTRIAL SCALE.

EMPRESA PROMOTORA DEL CARBÓN (PROCARBON) IS A STATE-OWNED COMPANY ESTABLISHED BY THE PERUVIAN GOVERNMENT IN 1982 TO DEFINE A STRATEGY TO DEVELOP THE COAL MINING INDUSTRY IN PERU AND THIS PAPER REFERS TO THE ACTIONS TAKEN DURING THE LAST THREE YEARS TO ACHIEVE THIS GOAL.

2. THE COAL INDUSTRY IN PERU

DESPITE ITS LONG MINING TRADITION, PERU HAS NEVER LOOKED AT COAL WITH THE SAME INTEREST IT HAS DEVOTED TO GOLD, SILVER, COPPER, ZINC, LEAD AND MANY OTHER METALS PRODUCED SINCE THE 16TH. CENTURY.

ONLY WHEN ORES OR CONCENTRATES HAD TO BE TREATED BY PYRO-METALLURGICAL PROCESSES, SOME MINING COMPANIES MINED COAL, BUT SINCE THEIR MAIN INTEREST WAS THE MANUFACTURE OF COKE, THEY RESTRICTED THEIR OPERATIONS TO TWO OR THREE SMALL BITUMINOUS COAL DEPOSITS WITH THE PURPOSE OF SATISFYING THEIR OWN NEEDS. THE TECHNOLOGY BROUGHT TO THE COUNTRY FOR THE MANUFACTURE OF METALLURGICAL COKE WAS DESIGNED FOR OTHER TYPES OF COAL AND THIS CAUSED SERIOUS PRODUCTION PROBLEMS, SO SOME OF THESE COMPANIES DECIDED TO IMPORT COAL TO BLEND IT WITH THE LOCALLY PRODUCED BITUMINOUS COALS.

BETWEEN 1945 AND 1955, SOME PERUVIAN ANTHRACITE MINES WERE PUT INTO OPERATION TO SATISFY THE POST-WAR DEMAND FOR THIS TYPE OF COAL IN THE INTERNATIONAL MARKET, BUT AS SOON AS THAT TEMPORARY ABNORMAL SITUATION ENDED, THESE MINES WERE CLOSED DOWN.

THE FIRST CONCLUSION THAT CAN BE DRAWN FROM THIS BRIEF OVERVIEW IS THAT COAL MINING IN PERU HAS BEEN RESTRICTED TO A LIMITED NUMBER OF USERS FORCED TO MINE COAL TO SATISFY THEIR USUALLY VERY MODEST OWN NEEDS OR TO SOME TRADITIONAL EXPORT-ORIENTED METAL MINERS WHO TRIED TO TAKE ADVANTAGE OF A TEMPORARY SHORTAGE OF ANTHRACITE IN THE INTERNATIONAL MARKET.

TAKING INTO CONSIDERATION THESE TWO HISTORICAL FACTS, PROCARBON CONCLUDED THAT NO SOUND AND SOLID COAL MINING INDUSTRY COULD FLOURISH IN PERU IF THERE WAS NOT A STABLE MARKET FOR COAL IN THE COUNTRY.

IN ORDER TO STUDY THE DOMESTIC MARKET FOR COAL, POTENTIAL INDUSTRIAL USERS WERE IDENTIFIED AMONGST THOSE OIL CONSUMERS WHICH COULD EVENTUALLY UNDERGO A CONVERSION PROCESS TO ADAPT THEIR INSTALLATIONS TO BURN COAL, BUT THE LACK OF COAL-BURNING EXPERIENCE IN THE COUNTRY, THE FACT THAT ANTHRACITE WAS THE MOST ACCESSIBLE TYPE OF COAL AND THE DISTANCE FROM THE COALFIELDS TO THE INDUSTRIAL CENTERS WERE THREE SERIOUS DRAWBACKS TO THIS ALTERNATIVE WHICH SEEMED TO BE THE MOST LOGICAL BUT HAD TO BE LEFT ASIDE BECAUSE OF THE ABOVE MENTIONED DIFFICULTIES.

3. THE NEED FOR A SHORT-TERM STRATEGY

DURING THE PROCESS OF GATHERING TECHNICAL INFORMATION ON INDUSTRIAL EQUIPMENT DESIGNED SPECIFICALLY TO BURN ANTHRACITE AS FUEL, WE WERE INFORMED THAT THE REPUBLIC OF KOREA WAS IMPORTING AROUND 2 MT OF ANTHRACITE PER YEAR, SO WE THOUGHT THEY COULD HELP US IN SOLVING OUR PROBLEM.

WHEN WE FOUND OUT HOW THEY USED THE ANTHRACITE, WE STARTED LOOKING AT THE POSSIBILITY OF ADAPTING THE SYSTEM TO OUR COUNTRY AND FINALLY DECIDED TO GO AHEAD WITH A PILOT PROJECT DESIGNED TO PROVE THE VIABILITY OF THAT ALTERNATIVE.

SEVERAL FACTORS FAVOURED THE PROJECT,THE MOST IMPORTANT OF WHICH WAS THAT THE QUALITY OF THE ANTHRACITE WAS NOT A PROBLEM SINCE ASH CONTENT COULD BE AS HIGH AS 35%, THUS ELIMINATING THE NEED FOR WASHING THE COAL AND MAXIMUM SIZE REQUIRED WAS 8 MM, THAT IS TO SAY, THE FINE FRACTION OF THE MINING OPERATION COULD BE USED DIRECTLY, ALMOST WITH NO TREATMENT. THESE TWO CHARACTERISTICS ALLOWED THE DEVELOPMENT OF A RELATIVELY EASY MARKET IN A VERY SHORT PERIOD OF TIME FOR LOCAL COAL MINERS SUFFERING FROM RESTRICTIONS IMPOSED BY THE EXISTENT SMALL NUMBER OF USERS (MAINLY BRICK-MANUFACTURING PLANTS AND SMALL FOUNDRIES), FOR WHOM THE SIZE OR THE ASH CONTENT OF THE COAL COULD BE A PROBLEM.

THE POSSIBILITIES OF OPENING UP A DOMESTIC MARKET FOR ANTHRACITE REQUIRING ALMOST NO TREATMENT WAS SEEN AS AN INTERESTING OPTION,NOT AS A FINAL GOAL, BUT AS A LOW-COST, SHORT-TERM STRATEGY DESIGNED TO PUT INTO OPERATION A NUMBER OF SMALL OR MEDIUM SIZE COAL MINES AND TEST THE PRODUCT ON A LARGER SCALE THAT THAT ALLOWED BY THE CURRENT MARKET CONDITIONS.

THE ONLY FACTOR PLAYING AGAINST THE PLANNED STRATEGY WAS THE COUNTRY'S CLIMATE WHICH IS MILD IN MOST REGIONS AND SINCE THE PROJECT CONSISTED OF BRIQUETTING THE ANTHRACITE TO PRODUCE A DOMESTIC FUEL FOR COOKING AND HEATING, THE SECOND PURPOSE HAD TO BE RESTRICTED TO RELATIVELY FEW COLD AREAS HIGH IN THE ANDES OR TO MINING CAMPS, MOST OF WHICH ARE LOCATED OVER 4000 M ABOVE SEA LEVEL AND OPERATE CENTRAL HEATING INSTALLATIONS.

THE FACT THAT THE CONSUMER WOULD BE EVENLY DISTRIBUTED THROUGHOUT THE COUNTRY WAS A GREAT ADVANTAGE, SINCE THE TRANSPORT COSTS COULD BE KEPT TO A MINIMUM, THUS ELIMINATING A SERIOUS PROBLEM IN A COUNTRY LIKE PERU WHICH HAS A VERY DIFFICULT GEOGRAPHY AND A POOR TRANSPORT INFRASTRUCTURE.

4. THE ANTHRACITE BRIQUETTING PROJECT

HAVING IDENTIFIED ONE POSSIBLE WAY IN WHICH LOW-QUALITY ANTHRACITE COULD BE USED, PROCARBON REQUESTED IN 1983 THE TECHNICAL ASSISTANCE OF THE KOREA INSTITUTE OF ENERGY AND RESOURCES (KIER) TO CARRY OUT A JOINT SURVEY OF THE PERUVIAN ANTHRACITE FIELDS AND EXPLORE THE POSSIBILITY OF PRODUCING A BRIQUETTE FOR THE PERUVIAN LOCAL MARKET. A TWO-MONTH FIELD AND LABORATORY WORK WAS CARRIED OUT, CONSISTING OF SAMPLE COLLECTION OF SIX MINES, BRIQUETTING OF THE ANTHRACITE AND COMBUSTION TESTING OF THE BRIQUETTES UNDER SEVERAL CONDITIONS.

THE CONCLUSION OF THIS PRELIMINARY WORK SHOWED THAT EXCEPT FOR THE LOW CLAY CONTENT OF THE ANTHRACITE ASH, THE COAL QUALITY WAS VERY SIMILAR TO THE ONE USED IN KOREA TO PRODUCE THE POPULAR "YONTAN", OF WHICH THE KOREAN POPULATION CONSUME 22 MT PER YEAR.

IN ORDER TO PRODUCE COMPARABLE RESULTS, THE TESTING WAS CARRIED OUT ON STANDARD KOREAN BRIQUETTES MADE WITH PERUVIAN ANTHRACITE. THESE CONSISTED OF CYLINDRICAL HONEYCOMB-TYPE BRIQUETTES, 150 MM IN DIAMETER, 146 MM IN HEIGHT, WITH 22 HOLES PARALLEL TO THE CYLINDER AXIS AND WEIGHING 3.6 KG, VERY SIMILAR TO THOSE PRODUCED IN KOREA, CHINA AND OTHER COUNTRIES OF ASIA.

ONCE THE TECHNICAL PROBLEM WAS SOLVED, THE LOCAL MARKET HAD TO BE INVESTIGATED AND THE SIMILARITIES FOUND BETWEEN THE PERUVIAN AND THE KOREAN COOKING HABITS, ESPECIALLY AMONG THE RURAL POPULATION, WERE SURPRISING ENOUGH AS TO ENSURE THE SUCCESS OF THE PROJECT. IT WAS DETERMINED THAT OVER 80% OF THE COUNTRY'S POPULATION USED SOME TYPE OF FUEL OTHER THAN ELECTRICITY OR GAS TO COOK.

AMONG THESE 16 MILLION POTENTIAL USERS OF COAL, A LARGE PROPORTION USED KEROSENE, A POPULAR DOMESTIC FUEL HEAVILY SUBSIDIZED THE GOVERNMENT TO ENSURE THAT IT REACHED THE LOW-INCOME HOUSEHOLDS AT A REASONABLE PRICE.

IT WAS FOUND THAT 8% OF THE COUNTRY'S OIL PRODUCTION WAS CONVERTED INTO DOMESTIC KEROSENE AND THAT THE SUBSIDY TO ITS PRICE AMOUNTED TO US$ 450,000 PER DAY, REPRESENTING A SUBSIDY OF US$ 164 MILLION/YEAR. IF THE 6 MILLION BARRELS OF OIL CURRENTLY BEING CONVERTED INTO KEROSENE WERE SOLD IN THE INTERNATIONAL MARKET, AN ANNUAL INCOME OF AROUND US$ 150 MILLION WOULD RESULT, BESIDES THE SAVING OF US$ 164 MILLION NOW BEING SPENT IN THE FORM OF SUBSIDY.

BUT THIS COULD ONLY BE POSSIBLE IF THE COUNTRY'S LOW-INCOME POPULATION HAD ACCESS TO AN ALTERNATIVE FUEL OFFERING THE SAME ADVANTAGES OF KEROSENE.

A STUDY CARRIED OUR BY PROCARBON IN 1984 SHOWED THAT IF ONLY 10% OF THE CURRENT KEROSENE CONSUMPTION WAS REPLACED BY ANTHRACITE BRIQUETTES, A DEMAND FOR 400 T/DAY OF COAL COULD BE ESTABLISHED AND IF THIS PRODUCTION

CAME FOR SMALL MINES, THE INVESTMENT REQUIRED TO PUT THEM INTO OPERATION WOULD BE RELATIVELY LOW.

THE SAVINGS IN KEROSENE SUBSIDY WOULD AMOUNT TO US$ 16 MILLION/YEAR, ALLOWING THE EXPORT OF 600,000 BARRELS OF OIL VALUED AT US$ 15 MILLION, THUS REPRESENTING A NET BENEFIT TO THE COUNTRY OF AROUND US$ 31 MILLION IN ONE YEAR.

HAVING PROVED THAT THE PROJECT WAS TECHNICALLY AND ECONOMICALLY VIABLE, PROCARBON IS NOW WORKING ON THE MOST DIFFICULT ASPECT OF IT: THE INTRODUCTION OF A NEW PRODUCT TO A MARKET NOT USED TO COAL AND HEAVILY PREJUDICED BY THE IDEA THAT COAL IS A FUEL THAT BELONGS TO THE PAST. THE WORK IS NOW CENTERED ON THE MANUFACTURE OF STOVES, BOILERS, ROOM HEATERS, ETC. DESIGNED TO USE COAL BRIQUETTES AS FUEL, BUT BECAUSE THESE HOME APPLIANCES SHOULD FIT WITHIN THE CULTURAL BACKGROUND OF THE USERS, SPECIAL DESIGNS ARE BEING DEVELOPED TO MAKE THEM LOOK AS "MODERN" AS ELECTRIC, GAS OF KEROSENE STOVES OR HEATERS.

THE SIZE OF THE BRIQUETTE ITSELF IS ALSO BEING STUDIED TO GUARANTEE ITS ACCEPTABILITY, SINCE THE FACT THAT ONCE LIT CANNOT BE EXTINGUISHED, COULD GENERATE SOME DISCOMFORT BY THE FACT THAT ENERGY FOR WHICH ONE HAS PAID IS NOT BEING USED, EVEN IF THE OVERALL COST IS LOW WHEN COMPARED TO ANY OTHER FUEL AVAILABLE IN THE MARKET.

THE FOLLOWING FACTS CAN BE MENTIONED AS SOME OF THE ACHIEVEMENTS OF THE PROJECT:

A) PERUVIAN ANTHRACITE IS NOW BEING CONSIDERED AS AN ALTERNATIVE FUEL FOR THE COUNTRY IN THE NEAR FUTURE AND THE DOMESTIC USE SEEMS TO BE THE EASIEST AND MOST INMEDIATE LOCAL MARKET FOR IT.

B) A LOW-COST ANTHRACITE BRIQUETTE IS BEING PRODUCED ON A PILOT SCALE WITH PERUVIAN ANTHRACITE. THE PILOT PLANT, INSTALLED AT THE CATHOLIC UNIVERSITY OF PERU IS MANUFACTURING A BRIQUETTE DESIGNED TO BURN CONTINUOUSLY FOR 12 HOURS, ITS SELLING PRICE TO THE USER BEING ESTIMATED AT US¢ 15 EACH. CONSIDERING THAT A LOW-INCOME FAMILY IN PERU USES AROUND TWO LITRES OF KEROSENE PER DAY FOR COOKING AND THAT THIS REPRESENTS A DAILY EXPENDITURE OF US¢ 17, THE COAL BRIQUETTE IS A VIABLE ALTERNATIVE FROM THE ECONOMIC POINT OF VIEW OF THE USER.

C) THE POSSIBILITY OF SELLING LOW-QUALITY ANTHRACITE IN THE DOMESTIC MARKET HAS BROUGHT A RENEWED INTEREST IN ABANDONED ANTHRACITE MINES NOW BEING EXPLORED AND RE-OPENED.

5. FUTURE ACTIONS

PROCARBON IS NOW CONSIDERING THE POSSIBILITY OF INSTALLING A SMALL INDUSTRIAL BRIQUETTING PILOT PLANT TO MARKET-TEST THE PRODUCT AND PROMOTE THE OPENING-UP OF SEVERAL ANTHRACITE MINES IN ONE OF THE BETTER-KNOWN COAL DISTRICTS OF THE COUNTRY.

FOR THIS PURPOSE, THE UNITED NATIONS DEVELOPMENT PROGRAM (UNDP) HAS OFFERED PROCARBON TECHNICAL ASSISTANCE AND A PRELIMINARY SIX-MONTH STUDY IS TO BE CARRIED OUT STARTING IN EARLY 1986.

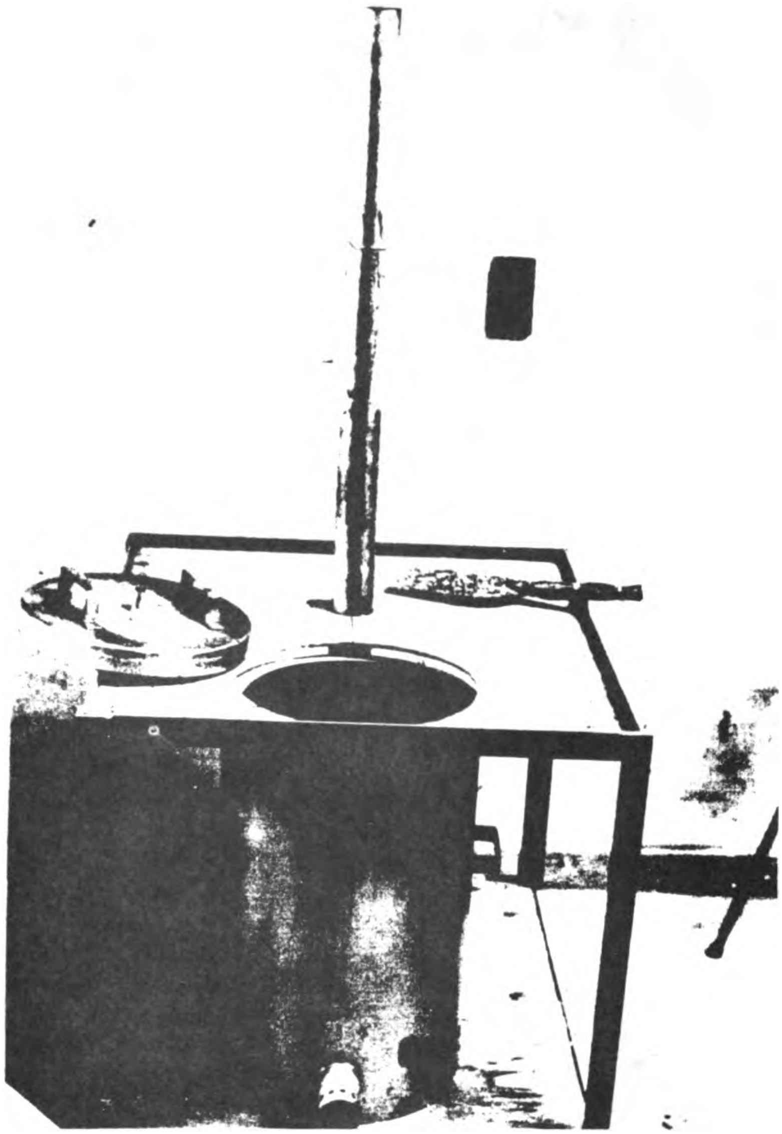
COAL MINERS ARE NOW LIMITED TO SELL ONLY 60% OF THEIR PRODUCTION, BECAUSE OF THE FINE SIZE AND HIGH ASH CONTENT OF THE REMAINING 40% OF ANTHRACITE BEING PRODUCED. POTENTIAL USERS OF COAL ARE NOT PREPARED TO CHANGE THEIR INDUSTRIAL INSTALLATIONS UNTIL A CONSTANT SUPPLY OF COAL AT A REASONABLE PRICE IS ENSURED, WHILST COAL MINERS ARGUE THAT PRODUCTION IS LIMITED BECAUSE THERE IS NO DEMAND FOR COAL AND PRICES ARE HICH BECAUSE THEY HAVE TO CHARGE 100% OF THEIR COSTS TO 60% OF THEIR PRODUCTION.

UNDER THESE CIRCUMSTANCES, THE COAL BRIQUETTING PROJECT COULD HELP TO BREAK THIS VICIOUS CIRCLE AND IF SUCCESSFUL IN THE LONG TERM, GENERATE A NUMBER OF ANCILLIARY LABOUR-INTENSIVE INDUSTRIAL ACTIVITIES OF WHICH COAL-MINING ITSELF COULD BE THE LEAST IMPORTANT FROM THE EMPLOYMENT GENERATION POINT OF VIEW.

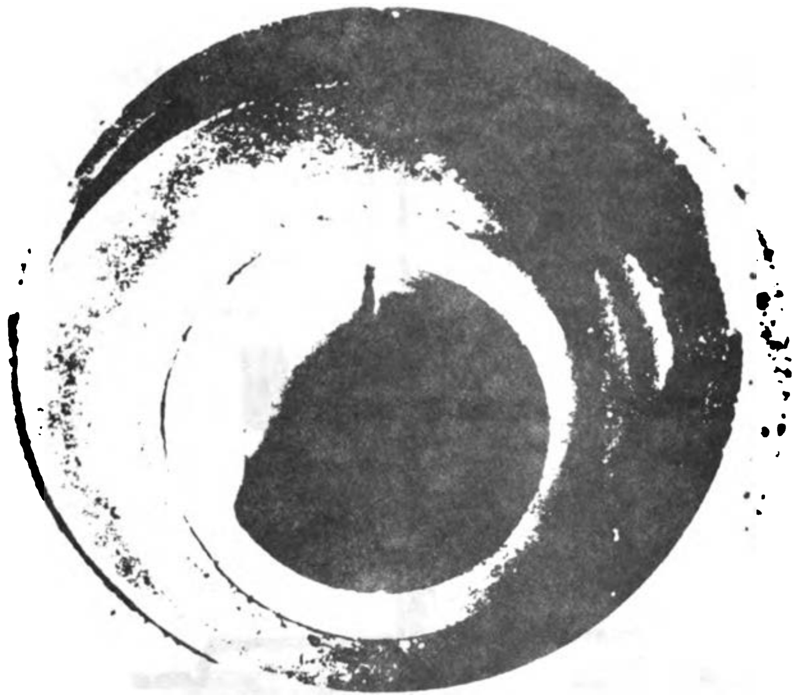
ANY INCREASE IN THE PRODUCTION OF LOW-QUALITY ANTHRACITE WILL BRING AN INCREASE OF HIGH-QUALITY ANTHRACITE AND THIS IS EXPECTED TO GENERATE THE CONFIDENCE IN SUPPLY REQUESTED BY THE INDUSTRIAL USER TO REPLACE ITS OIL-BURNING INSTALLATIONS. AS INDUSTRIAL CONSUMERS IMPOSE MORE STRINGENT CONDITIONS ON THE ANTHRACITE THEY BUY, THE NEED FOR COAL-WASHING PLANTS WILL BECOME APPARENT AND THIS WOULD RESULT IN HIGHER QUALITY ANTHRACITE BEING AVAILABLE IN THE MARKET FOR SPECIAL APPLICATIONS.

IT IS HOPED THAT THE FIRST STEPS ALREADY TAKEN WILL RESULT IN THE PROMOTION OF THE COAL MINING INDUSTRY IN PERU, WHICH IS THE FINAL OBJECTIVE OF THIS APPARENTLY MODEST COAL BRIQUETTING PROJECT CURRENTLY BEING CARRIED OUT BY EMPRESA PROMOTORA DEL CARBÓN AND SUPPORTED BY THE PERUVIAN GOVERNMENT.

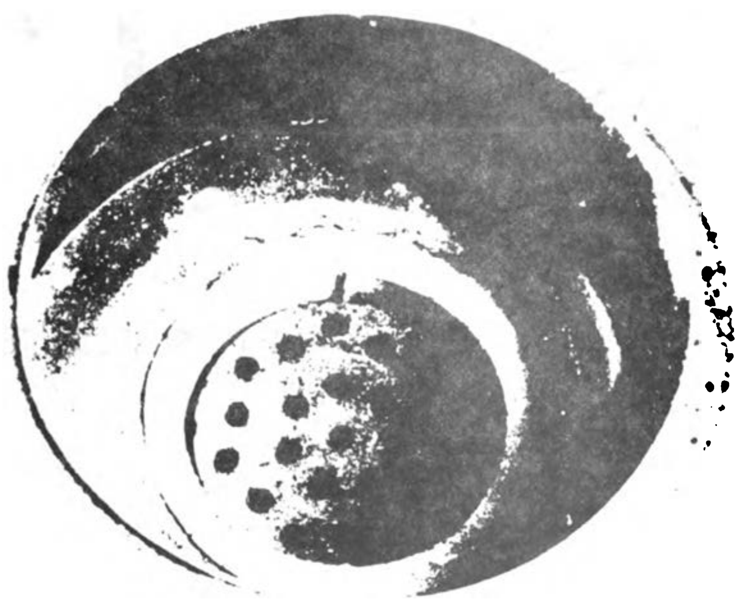
* * *



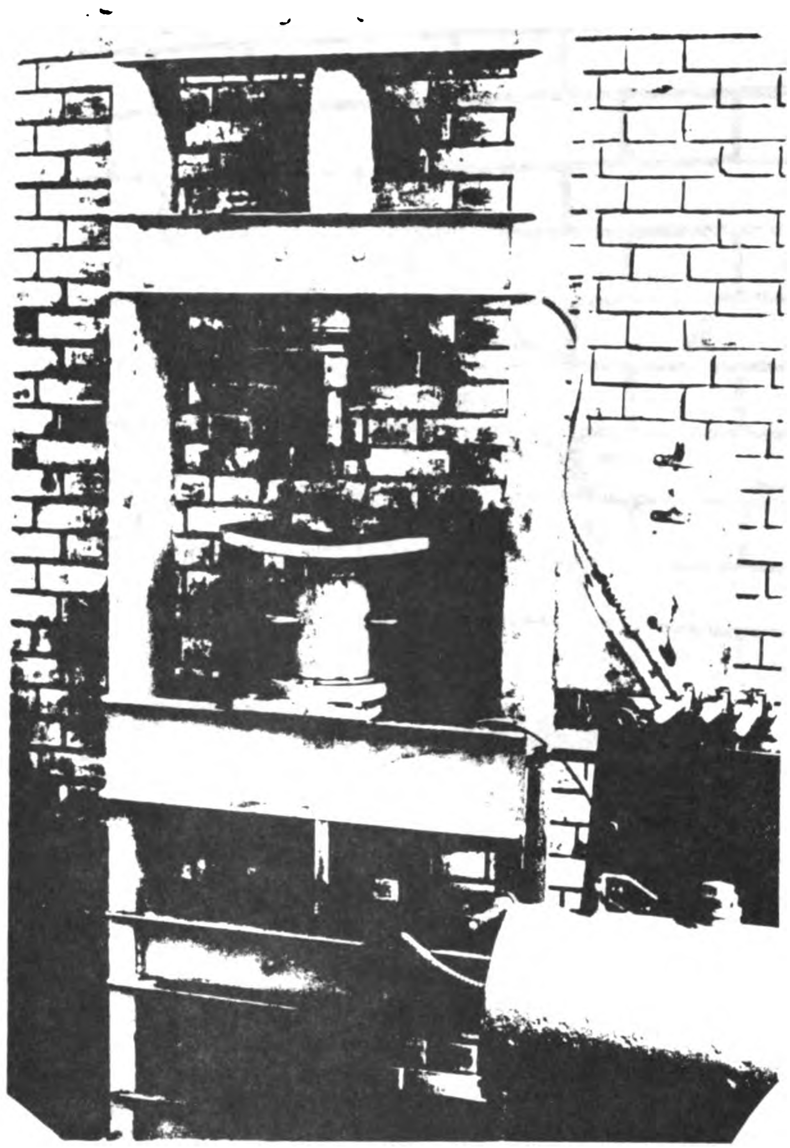
MOVABLE LABORATORY STOVE FOR COMBUSTION TESTING



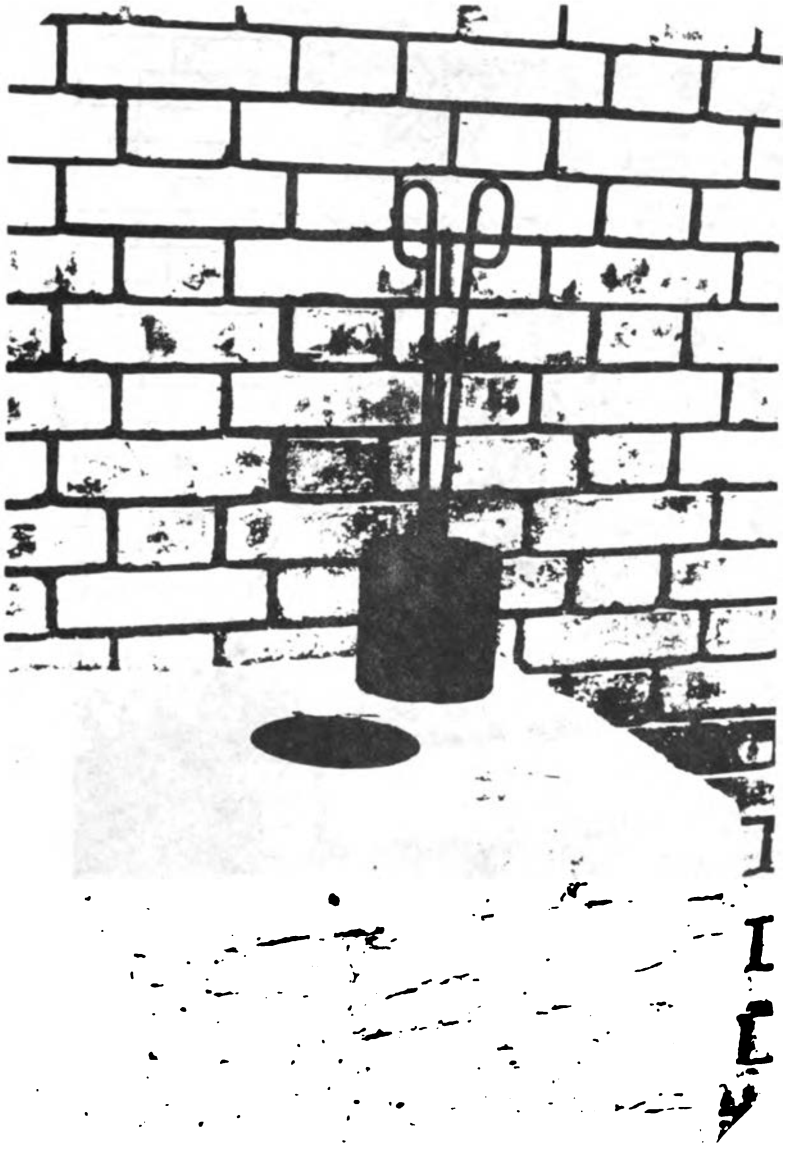
TOP VIEW OF STOVE SHOWING REFRACTORY CYLINDER



TOP VIEW OF STOVE WITH COAL BRIQUETTE IN BURNING POSITION



LABORATORY BRIQUETTING MACHINE



LOW-COST ADOBE STOVE WITH COAL BRIQUETTE
AND METAL TONGUES USED FOR HANDLING IT

COAL UTILIZATION: THERMAL ELECTRIC STATIONS

B.F. Gilbert and R.A. Hevia
Fuel Supply Service, Inc.
Miami, Florida

June 14, 1985

COOPERATIVE WORKSHOP ON THE UTILIZATION OF COAL AS AN ALTERNATE TO PETROLEUM FUELS IN THE ANDEAN REGION

COAL UTILIZATION: THERMAL ELECTRIC STATIONS

BY: B.F.GILBERT AND R.A.HEVIA

FUEL SUPPLY SERVICE, INC.

JUNE 14, 1985

The objective of this presentation is to give a brief description of what is considered current practice in the area of coal utilization as a fuel for steam electric generating stations and also for industrial steam generating installations.

The subjects I will briefly cover today are:

1-COMBUSTION AND STEAM PROCESS PRINCIPLES
2-TYPICAL EQUIPMENT AND APPLICATIONS
3-COAL SPECIFICATIONS
4-ENVIRONMENTAL CONSIDERATIONS
5-COAL CONVERSION ALTERNATIVES
6-CONVERSION PROJECT FEASIBILITY STUDIES

Since this objective is quite broad in scope and any of these subjects could constitute the subject for a presentation by itself, I will limit myself to an overviev of the most important topics of each subject, which should be examined when considering new coal fired installations or the conversion of existing installations.

1-COMBUSTION AND STEAM PROCESS PRINCIPLES

The principle involved in the development of heat by combustion, as generally accepted and applied to combustion in a furnace, can be stated as follows. In a boiler furnace the heat energy evolved from the union of combustible elements with oxygen depends upon the ultimate products of combustion and not upon any intermediate combinations that may occur in reaching the final result.

Most fuels used in industrial or electric steam generating stations, coal, oil, gas, wood and their various derivatives have only three elemental constituents, carbon, hydrogen and sulfur. In most cases the percent of sulfur is so low that it can be neglected in heat production calculations, even though it must be taken into consideration for other reasons, mainly physical and economic, such as corrosion effects, adverse environmental impact and the cost of the fuel.

To achieve complete combustion of the combustible elements and compounds in the fuel with all the oxygen required, sufficient space, time, mixing or turbulence and a temperature high enough to ignite the fuel constituents must be provided.

A furnace for firing a fossil fuel is a device for generating controlled heat for the purpose of doing useful work. In the case of industrial or steam electric generating station boilers the heat generated is used to produce steam to do the required work. The objective of the boiler designer is to arrange the heat transfer surfaces and fuel burning equipment to optimize thermal efficiency and economic investment.

Heat generated in the combustion process appears as furnace radiation and sensible heat in the products of combustion. Water circulating through the tubes that form the furnace walls absorbs as much as 50% of this heat, which in turn generates steam by the evaporation of part of the water. In addition to the fuel type and its combustion process, furnace design must consider the thermodynamic principles applicable to water heating and steam generation.

Furthermore, the design of a boiler is governed to a great extent by the design of the furnace and also the other heating surfaces required. The selection of the type of unit for a given service depends upon many factors, such as:

- Main steam flow, pressure and temperature requirements.
- Reheat steam flow, pressure and temperature requirements.
- Feedwater temperature and conditions.
- Load characteristics
- Type of fuel and fuel burning equipment required
- Efficiency and economics.

2-TYPICAL EQUIPMENT AND APPLICATIONS

In general, steam generators have traditionally been classified into three types, according to their water and steam path configuration. These types are:

- Shell type boilers: Simply a closed vessel containing water.
- Fire tube boilers: Hot combustion gasses pass through tubes located in the vessel to increase heat transfer area.
- Water tube boilers: Water is circulated through tubes which are exposed to the hot combustion gasses. Basically the reverse of the fire tube boiler.

As requirements for steam capacity and pressure increased, it became apparent that the water tube boiler had the advantage over the other types due mainly to the lower stresses from pressure and temperature due to the smaller sizes of its pressure parts. Also, it was more flexible in design and easier to adapt to a variety of services and fuel types. Thus, since World War Two, most industrial and steam electric station boilers, except those of very small size (less than 25,000 lb./hr. steam flow) have been of the water tube type.

Depending on the size, the steam flow, pressure and temperature requirements, most boiler manufacturers have developed various standardized models of their water tube boilers to suit specific needs. Depending on the manufacturer, these standard models are available in sizes up to approximately 350,000 lb./hr. steam flow. Due to the variety of different models available, I will not attempt to describe or name them here. This information is readily available form any boiler manufacturer's literature. See Fig. 1 for some typical models of these boilers.

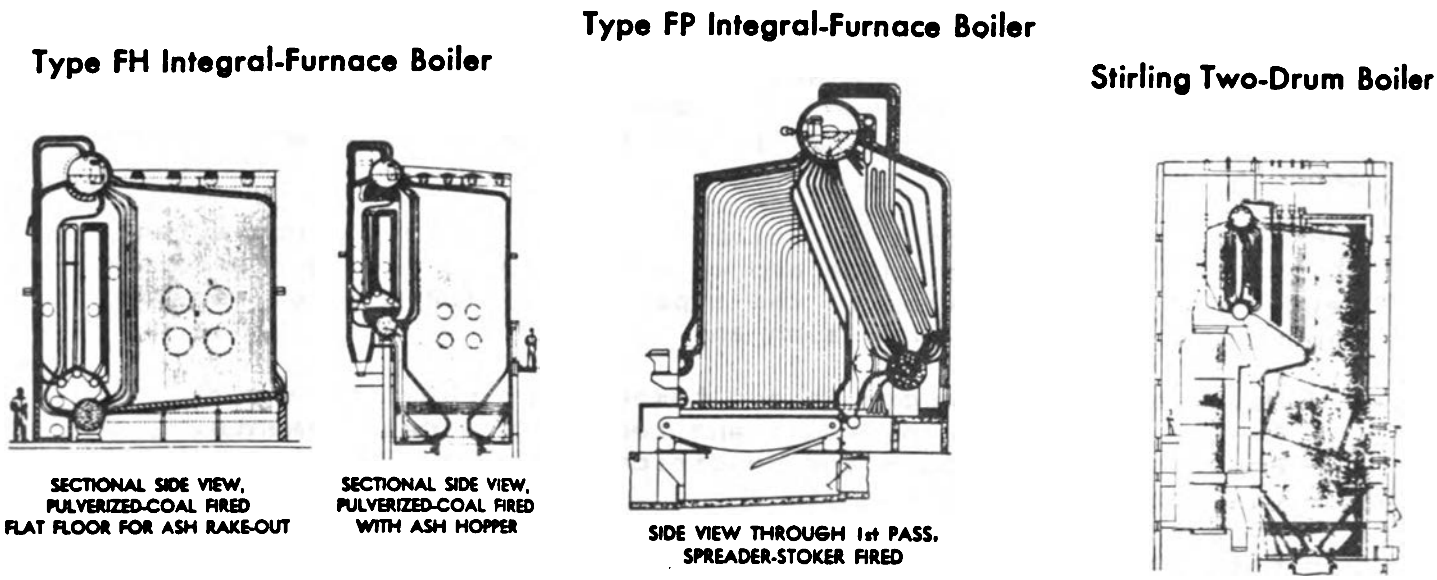


FIG. 1 TYPICAL STANDARD STEAM GENERATORS

As we have discussed before, the most common fuels for these boilers are: coal, oil or gas. Naturally, different types of fuel firing equipment is needed for each of these fuels. Selection of oil or gas burners is relatively straightforward and simple once the type of oil or gas is known. Selection of coal burning equipment is more complicated and involves other design factors in addition to the coal type and specification.

The three main types of coal burning equipment are:

- Coal spreader stoker
- Cyclone type burner/furnace

- Pulverized coal

The following brief summary of the particular features and details of each of the above mentioned types of coal burning equipment will give some idea of the principal points affecting the choice of method and equipment for burning coal.

- **Stoker:** The spreader stoker is a versatile means for burning a relatively wide range of bituminous coal types and can also successfully burn lignites. Ash removal may be accomplished by either a dumping grate or a moving grate. With this stoker there is a tendency for carry-over of fly ash and carbon particles, thus it is necessary in most cases to install a fly ash collection and reinjection system to reduce thermal loss from unburned carbon in the ash. In selecting a boiler for spreader stoker firing, care must be taken in the arrangement of the internal parts to avoid erosion. Boilers best suited to this coal firing method are straight through, gas flow types.

- **Cyclone furnaces:** Cyclone furnace coal firing has shown to be a method of firing coal parallel to pulverized coal. However the range of coals suitable for this firing method is somewhat more restricted and thus the method cannot be economically applied to as small a boiler as pulverized coal. However, burning crushed coal eliminates the high initial capital and operating cost of pulverizing equipment. Since a significant portion of the ash is eliminated as slag right in the burner area, the furnace and stack gasses are substantially clean, thus, the additional costs for erosion control and fly ash collection systems are reduced. One particular disadvantage of the cyclone furnace is that it tends to generate high levels of NO_x due to the high temperatures at which combustion of the fuel takes place. Thus it has not been used in new installations in recent years due to environmental concerns.

- **Pulverized coal:** Pulverized coal can be adapted to almost any size boiler, but its disproportionally high incremental equipment price, for pulverizers and auxiliary equipment, tends to establish a practical lower limit of boiler size of approximately 50,000 to 100,000 lb/hr. steam flow. The equipment can be designed to burn practically any type of bituminous coal or lignite. With modification, proper selection of the equipment and fuel preparation, even anthracitic coals can be burned. Some typical features of pulverized coal firing systems are:

- Almost any coal available is suitable for use.
- Economically suitable for a very wide range of boiler sizes.
- Wide flexibility in operation and high thermal efficiency.
- Proper coal preparation and handling of the pulverized coal are required for safety.
- Dust collectors are required in most installations.

These three different coal firing methods require different coal characteristics and preparation methods. The following table outlines the more important coal characteristics:

TABLE 1
COAL CHARACTERISTICS RELATED TO METHOD OF FIRING

Characteristic:	Method of firing: Stoker	Pulverized	Cyclone
Total Moisture, Max. %	15-20	15	20
Vol. Matter, Min. %	15	15	15
Total Ash, Max. %	20	20	25
Sulfur, Max. %	5	-	-
Ash Soft. Temp. Max. F.	-	-	2400
Coal Size:	3/4 in. top 50% through 1/4 in.mesh	80% through 200 mesh	80% through 8 mesh

Traditionally, a spreader type stoker was normally used for boilers of up to 250,000 to 350,000 lb./hr. steam flow because in this size range, the benefits of using pulverized coal did not warrant the increased cost. Today, the advantages of each system must be evaluated thoroughly during the design stage before selecting a particular fuel burning system.

In addition to the type of coal, selection of the most suitable coal burning equipment must consider the following parameters:

- **Investment:** Stokers are cheaper than cyclone furnaces or pulverized coal, but their use is limited by boiler size. Pulverized coal is more expensive equipment wise, but gives more flexibility of operation and coal sources.
- **Operating Characteristics:** For a small plant with inexperienced labor, a stoker is better suited. For a large plant, with experienced labor, pulverized coal is preferable.
- **Efficiency:** A well designed spreader stoker will typically have an unburned carbon loss of approximately 4 to 8%, whereas a properly designed pulverized coal boiler will have a typical unburned carbon efficiency loss of less than 0.4%. Although small plants can many times tolerate this lower efficiency, in the larger plants the fuel cost is so significant that efficiency may be the controlling factor dictating the use of pulverized coal.

Important characteristics of an efficient pulverized coal burner are:

- No excess oxygen or unburned combustibles in the flue gas.
- A wide and stable firing load range.
- Fast response to changes in firing rate.
- High equipment availability with low maintenance.
- Good atomization and mixing of the fuel with the combustion air.

See Fig. 2 for illustrations of typical coal burning equipment. The most frequently used coal burner is the Circular Type Burner. This burner has several desirable characteristics. Some of these are: It does not require much attention to obtain a reliable and efficient performance. It can be equipped to burn either oil or gas as alternate fuels. Individual burners of this type are available in various sizes up to a maximum of approximately 200 million Btu/hr. In this type of burner, tangential vanes built into the air register creates the necessary turbulence to adequately mix the fuel particles with the combustion air.

Other types of burners commonly used are the: Multiple-Intertube, Multiple Tip Burner and the Cross tube Burner. Although these are different in physical arrangement, their purpose is the same, to ensure the proper mixture of fuel and air for the optimum heat release to occur.

The different boiler manufacturers all have their preferred burner designs and arrangements. Typically burners are arranged in one of three manners:

- Horizontally Fired Systems: Where the axis of the burner is horizontal. With this system burners are usually located in the bottom third of the furnace front and/or rear walls.
- Tangentially Fired Systems: Burners are located at the apex of the corners of the furnace, with their axis horizontally oriented.
- Vertically Fired Systems: The burner axis is vertically arranged in the boiler. They are more complex to operate and maintain and are usually only used to fire low volatile solid fuels.

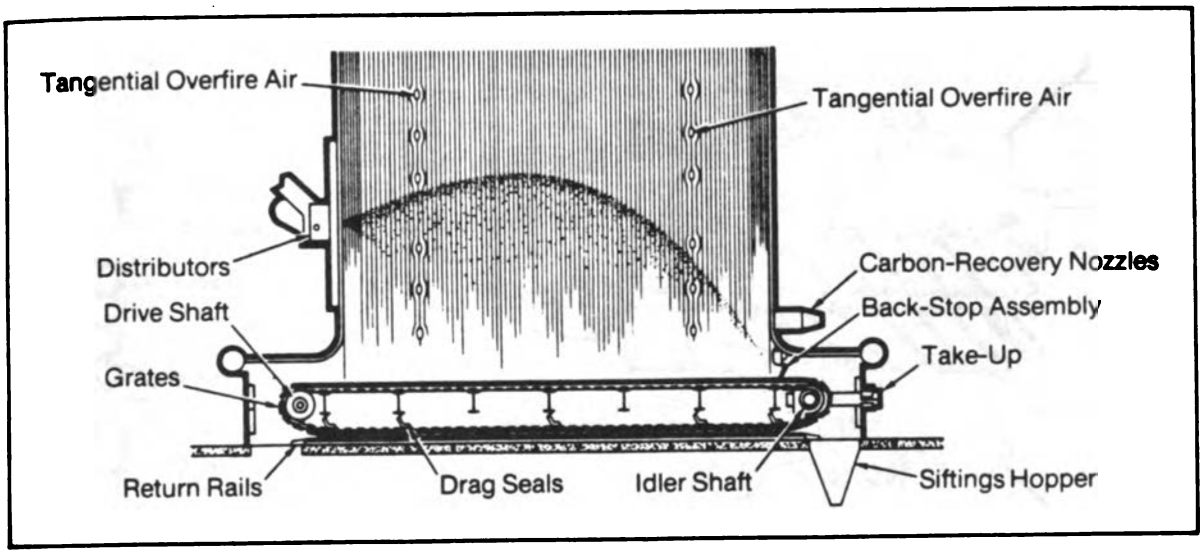
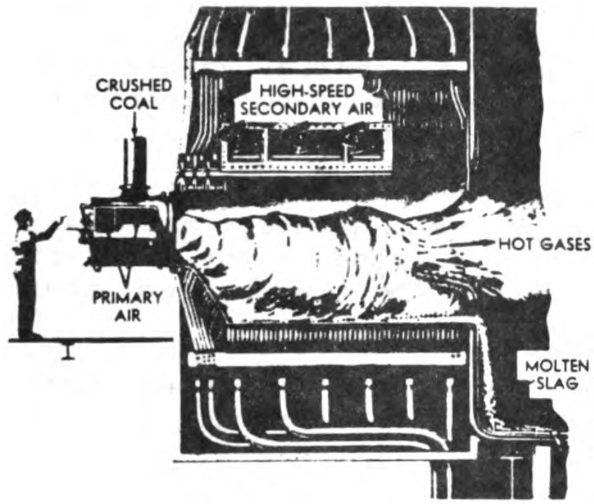
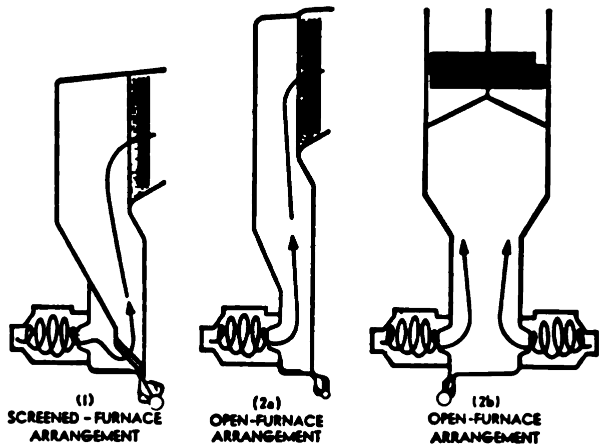


FIG. 2A TYPICAL SPREADER STOKER EQUIPMENT

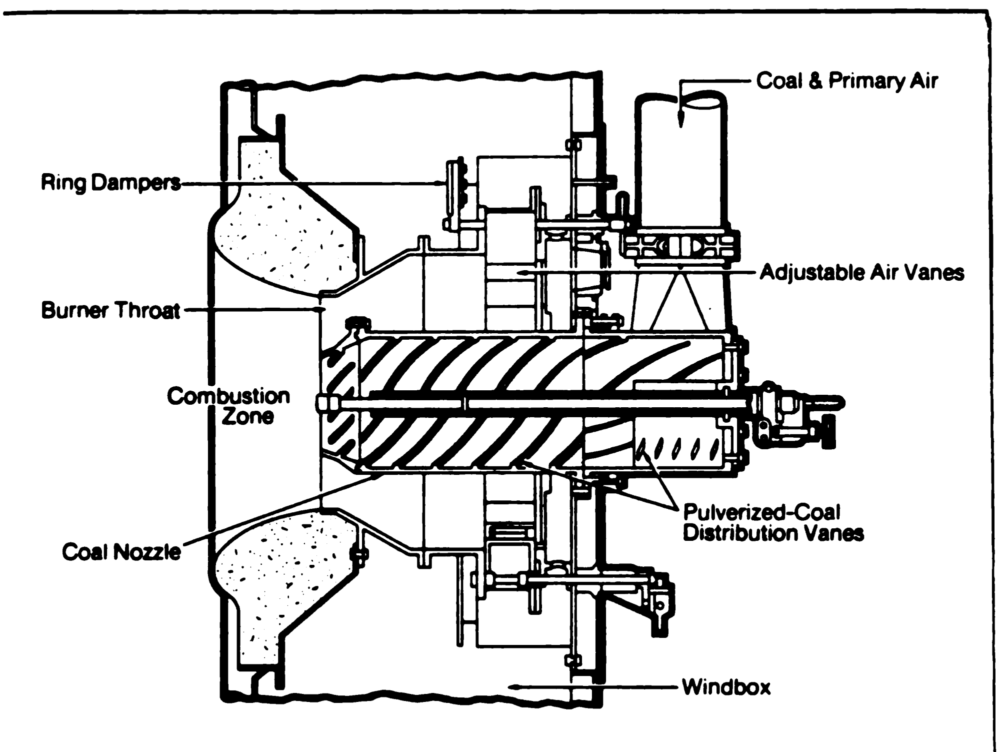


The Cyclone Furnace, in the form of a horizontal cylinder, is completely water cooled by connection to the main boiler circulation. All combustion gases leave through the re-entrant throat at the rear. Molten slag drains from the bottom at the rear through a small opening into the adjacent boiler furnace

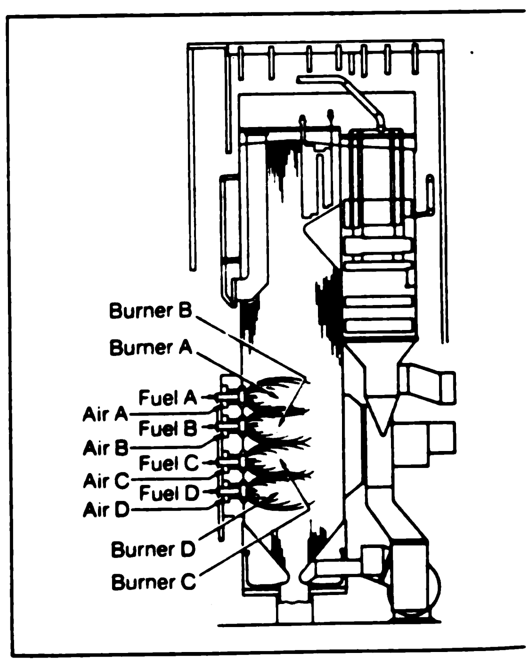


Types of boiler furnaces used with Cyclone Furnaces

FIG. 2B TYPICAL CYCLONE BURNER AND FURNACE



Burner for horizontal firing of coal



Flow pattern of horizontal (wall) firing

FIG. 2C TYPICAL PULVERIZED COAL BURNER AND FURNACE

3-COAL SPECIFICATIONS

In addition to the basic design factors such as unit size, type of service, (industrial or electric generating station), location, etc., the designer must consider other factors which influence the overall design of the steam generator. Of these other factors the most important one is the type of fuel and its combustion characteristics. As an example, coal, although the most common fuel in many parts of the world, is the most difficult to burn, is lower in heat content per unit of weight than liquid fuels and has a much higher ash content. Typically, coal ash consists of a number of objectionable chemical elements and compounds which may adversely affect the operation of the boiler. Knowledge of these elements and compounds prior to design of the boiler is essential if the designer is to consider them in his design and make provisions for their handling in such a manner as to avoid performance and operating problems. Problems that can occur due to ash characteristics are slagging, fouling, corrosion and plugging of boiler, superheater and air heater surfaces.

Therefore, prior to designing a steam generator, or selecting a a vendor's standard design steam generator, it is necessary to have decided on the fuel type, or types, that will be used and the specifications for such fuels and their components. These specifications will have a direct effect on the design parameters which are necessary to provide the required conditions for the proper burning of the fuel and the liberation of heat under the most efficient conditions, while minimizing fuel related operational problems.

Two major specification parameters are the heat content of the fuel per unit weight and the ash content. These parameters will have a direct effect on the quantity of fuel required and, depending on the fuel itself and its ash content, will have a direct effect on the size of the steam generator furnace and on the design of the required auxiliary equipment. Typical heat and ash content for coal, oil and gas fuels are as follows:

TABLE 2
TYPICAL HEAT AND ASH CONTENT OF VARIOUS FUELS
(Moist and mineral matter free basis)

COAL	Bituminous: 10,500 to 14,000 Btu/lb.	Ash: 4 to 12%
	Sub-bituminous: 8,300 to 10,500 Btu/lb.	Ash: 6 to 18%
	Lignitic: up to 8,300 Btu/lb.	Ash: 6 to 12%
OIL	No. 6 Residual: 18,250 Btu/lb.	Ash: 0.1% max.
	No. 4 Residual: 18,900 Btu/lb.	Ash: 0.05% max.
	No. 2 Distillate: 19,500 Btu/lb.	Ash: Trace
GAS	Natural: 22,000 Btu/lb. (~ 1,000 Btu/cu-ft.),	Ash: None

steam generators, see Fig.3 which graphically shows the effect of the type of coal on furnace sizes required for the same heat output

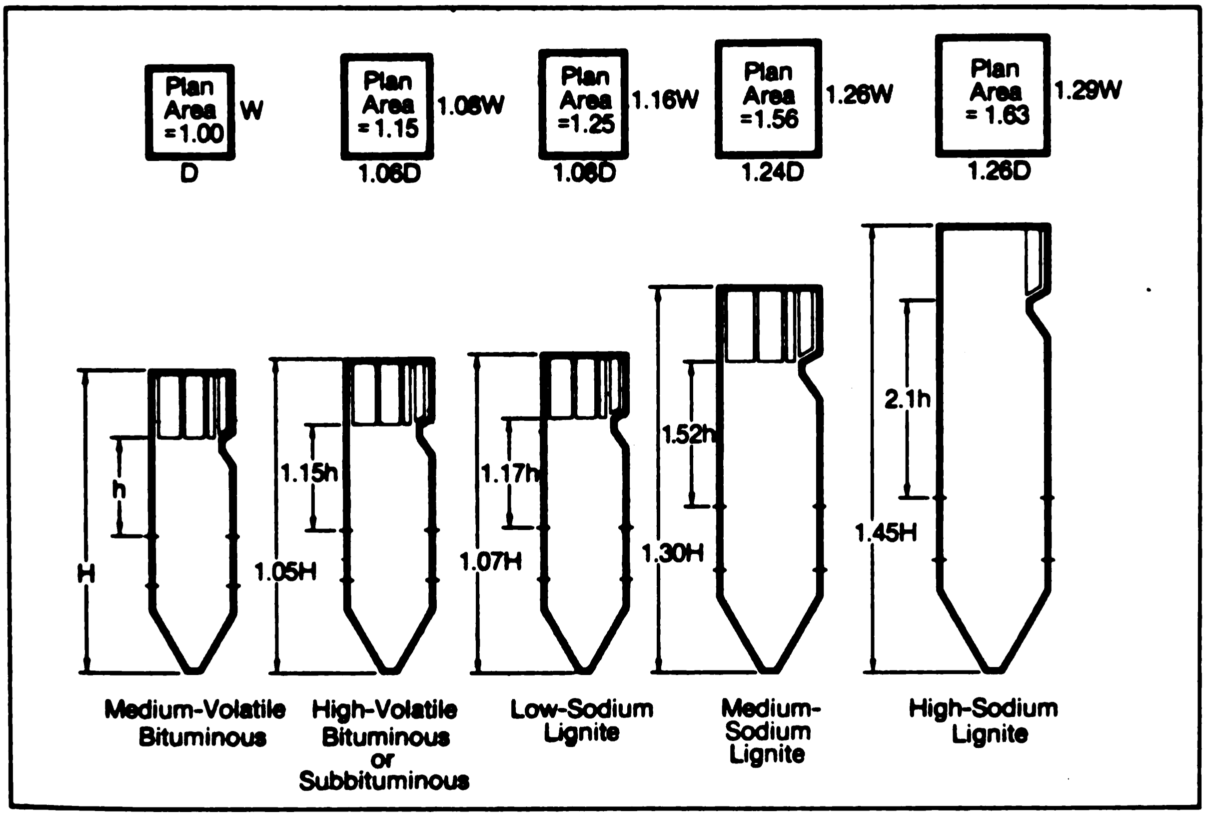


Fig. 3 EFFECT OF COAL RANK ON FURNACE SIZE(Const. heat Output)

Since coal performance, particularly its methods and principles of burning are closely associated with the different types of equipment and their design requirements, coals have been classified to provide the necessary data to predict their probable performance under various operating conditions. In this area of the world the most used classification system is the Classification of Coals by Rank based on the ASTM D-388 Method. See Table 3. There also are other systems of coal classification, such as the International Classification into Hard Coals by Type and Brown Coals by Type. For purposes of simplicity this paper will use only the Classification by Rank in its references to types of coal.

In addition to the type of coal, its particular properties also play a most important role in the design and selection of the equipment. Table 4 gives a summary of the most common properties of various rank coals.

TABLE 3
CLASSIFICATION OF COALS BY RANK, ASTM D-388

FC = Fixed Carbon; VM = Volatile Matter; Btu = British Thermal Units

Class	Group	Limits of Fixed Carbon or Btu Mineral-Matter-Free Basis	Requisite Physical Properties
I Anthracitic	1. Meta-anthracite	Dry FC, 98% or more. (Dry VM 2% or less)	
	2. Anthracite	Dry FC, 92% or more and less than 98%. (Dry VM, 8% or less and more than 2%)	
	3. Semianthracite	Dry FC, 86% or more and less than 92%. (Dry VM, 14% or less and more than 8%)	Nonagglomerating[b]
II Bituminous[c]	1. Low-volatile bituminous	Dry FC, 78% or more and less than 86%. (Dry VM, 22% or less and more than 14%)	
	2. Medium-volatile bituminous	Dry FC, 69% or more and less than 78%. (Dry VM, 31% or less and more than 22%)	
	3. High-volatile A bituminous	Dry FC, less than 69%. (Dry VM, more than 31%); and moist[d] Btu, 14,000 or more	
	4. High-volatile B bituminous	Moist[d] Btu, 13,000 or more and less than 14,000[e]	
	5. High-volatile C bituminous	Moist Btu, 11,000 or more and less than 13,000[e]	Either agglomerating or nonweathering[f]
III Subbituminous	1. Subbituminous A	Moist Btu, 11,000 or more and less than 13,000[e]	Both weathering and nonagglomerating
	2. Subbituminous B	Moist Btu, 9,500 or more and less than 11,000[e]	
	3. Subbituminous C	Moist Btu, 8,300 or more and less than 9,500[e]	
IV Lignitic	1. Lignite	Moist Btu, less than 8,300	Consolidated
	2. Brown coal	Moist Btu, less than 8,300	Unconsolidated

[a]Does not include a few coals of unusual physical and chemical properties which come within the limits of fixed carbon or Btu of the high-volatile bituminous and subbituminous ranks. [b]If agglomerating, classify in low-volatile group of the bituminous class. [c]There may be noncaking varieties in each group of the bituminous class. [d]Moist Btu refers to coal containing only its natural bed moisture. [e]Coals having 69 per cent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon regardless of Btu. [f]There are three varieties in the high-volatile C bituminous coal group, 1) agglomerating and nonweathering, 2) agglomerating and weathering, and 3) nonagglomerating and nonweathering.

TABLE 4
TYPICAL COAL PROPERTIES

	Bituminous					Subbituminous			Lignite
			High Volatile						
	Low Volatile	Medium Volatile	A	B	C	A	B	C	A
Agglomerating character	Agg.	Agg.	Agg.	Agg.	*	Non Agg.	Non Agg.	Non Agg.	Non Agg.
Proximate, %									
Moisture (seam)	2.0	2.0	4.0	7.0	10.0	14.0	19.0	25.0	40.0
Volatile matter, VM	21.1	32.3	38.4	33.8	35.9	35.3	34.5	25.8	25.9
Fixed carbon, FC	68.6	55.8	51.5	47.3	43.3	41.2	37.5	40.9	27.4
Ash	8.3	9.9	6.1	11.9	10.8	9.5	9.0	8.3	6.7
HHV, Btu/lb, As-fired	13,150	13,210	13,410	11,610	10,590	9,840	8,560	7,500	5,940
Flammability index, F	1,010	1,030	950	1,030	990	970	970	990	890
Ultimate (MAF), %									
Hydrogen	5.0	5.5	5.6	4.6	5.5	5.4	5.1	5.6	4.3
Carbon	88.5	84.1	82.5	81.0	74.3	74.2	69.8	66.4	67.0
Sulfur	0.4	1.1	2.5	0.9	4.0	0.5	0.8	0.6	0.9
Nitrogen	1.3	1.7	1.5	1.3	1.4	1.2	1.1	1.3	1.2
Oxygen	4.8	7.6	7.9	12.2	14.8	18.7	23.2	26.1	26.6

* Agglomerating but noncaking

As we have discussed, the single most important parameter in steam generator design is the fuel type. In the design of a coal fired steam generator, the heat content and the ash are the two most important parameters to consider. As we have previously seen the heat content is important from the amount of fuel required for the generation of the required heat. However, equally as important, and many times more critical to the proper operation, the properties of the coal must also be known and taken into consideration.

For this purpose, the steam generator designer uses the Proximate and Ultimate analysis of the coal. Some key parameters of these Analysis are:

- Moisture
- Volatile Matter
- Fixed Carbon
- Ash
- Sulfur
- Heating Value
- Ash Fusion Temperature
- Reactivity
- Free Swelling Index
- Grindability

It would be impossible in the time and space available to discuss the relative importance of each of the items in the Proximate and Ultimate Analysis lists. Many of these are well known by all familiar with coal and its use, and certainly are well known by the boiler manufacturers. Therefore I will make only brief mention of some of the more critical parameters and their effect on the selection and design of the boiler and its equipment.

- **Volatile Matter:** This item refers to the amount of volatile components in the coal and is of importance due to its effect on the initial combustibility of the fuel. Coals with low volatile matter are more difficult to ignite. Typical range of this parameter for steaming coals is from 15 to 35%. 15% is considered the minimum value for coals normally used as fuels for boilers.
- **Sulfur:** Important from the environmental point of view and from its potential corrosive effect on the boiler components and other equipment. If strict controls on the emission of SO2 from the unit are required, this parameter becomes a critical one, requiring the use of very expensive and complicated equipment for gas cleaning, or the use of coals with very low sulfur content. usual range of this parameter is from < 1% up to ~6%.
- **Grindability:** Indicates the relative ease with which the coal can be ground or pulverized to the required size for the proper operation of the handling and burning equipment. It is a primary consideration in the design of the grinding equipment and the pulverizer system. Preferred range for this parameter is from 60 to 100. Coals with grindabilities below 50 are considered difficult to pulverize.
- **Heating Value:** As already discussed, important from the point of view of quantity of coal required to supply the necessary heat. It also influences the size of the required furnace. Usual range for this parameter is from 6,300 Btu/lb. for the low rank lignites, to 14,000 plus Btu/lb. for the higher rank bituminous coals.
- **Ash:** An extremely important parameter in the design of a boiler and a coal burning plant. The management of the coal ash is one of the major design considerations for a coal fired steam generator. The quantity of the ash and the behaviour of the mineral matter in the coal, as it influences slagging reactions during combustion is a significant factor in furnace sizing in terms of volume, plan area, and fuel burning zone. The percentage of ash in coal is significant because of the amount of slagging and fouling that it can cause, the burden that it places on ash handling equipment and disposal facilities, the frequency of sootblowing and the rate of wear on the grinding and pulverizing equipment. Typical ash content range is from 5% to 15% for most coals used for steaming purposes.
- **Ash Fusion Temperature:** This parameter indicates the temperature at which the mineral matter in the ash begins to become fluid.

The test for ash fusion temperature is usually run according to ASTM-D-1857 Standards, and is based on using a pyramid shaped ash sample 3/4 in. high with a 1/4 in. equilateral triangle base width. This test can be run in either a reducing or an oxidizing atmosphere. The Ash fusion Temperature most commonly reported is the Softening (H = W) Temperature, obtained in a reducing atmosphere. Typical range of this parameter is from ~1800 to 2800 F. for eastern US coals.

Four stages of ash fusion temperature are usually reported in American practice:

- **Initial deformation:** The initial rounding of the cone
- **Softening:** When the cone height has reduced to the same size as the base.
- **Hemispherical:** When the height of the lump equals one half the width of the base.
- **Fluid:** When the mass is no higher than 1/16 inch.

There are various other methods for determining Ash Fusion Temperature. Some of these are: The British Standard Method, The German Standard Method and the International Standard Method, ISO-540. For simplicity, I will only refer to the ASTM Standard.

The Ash fusion Temperature is greatly influenced by the chemical composition of the mineral matter in the ash. This is commonly expressed under the heading of Chemical Analysis, or Mineralogical Composition of the ash. The Base to Acid ratio is derived from this analysis and becomes a key factor in predicting the behaviour of the ash in the boiler.

In addition to the Ash Fusion Temperature and the Base to Acid Ratio, there are other parameters also used for evaluating the ash behaviour in the furnace. These are: The Iron to Calcium ratio, the Silica to Alumina ratio, the Iron to Dolomite ratio, the Dolomitic percentage and the Ferric percentage.

4-ENVIRONMENTAL CONSIDERATIONS

In a coal fired powerplant, there are two main areas of environmental concern. The first relates to the emission of pollutants resulting from the combustion process to the environment. The second area of concern relates to the safe disposal of the liquid and solid wastes produced from the coal handling area and the ash and ash components.

I will address the area of emissions first. There are three classes of emissions which are considered significant in a coal fired powerplant. These are: Particulate Emissions, Sulfur-Oxide Emissions and Nitrogen-Oxide Emissions.

- **Particulate Emissions:** A pulverized coal plant can be expected to have approximately 60 to 80% of the coal ash normally leaving the furnace with the flue gas as Flyash. The previously discussed variations in coal characteristics have a significant effect on the control and removal of Flyash particles from the flue gas. Fig. 3 shows the classification of particulate emissions by size and the applicable methods of control.

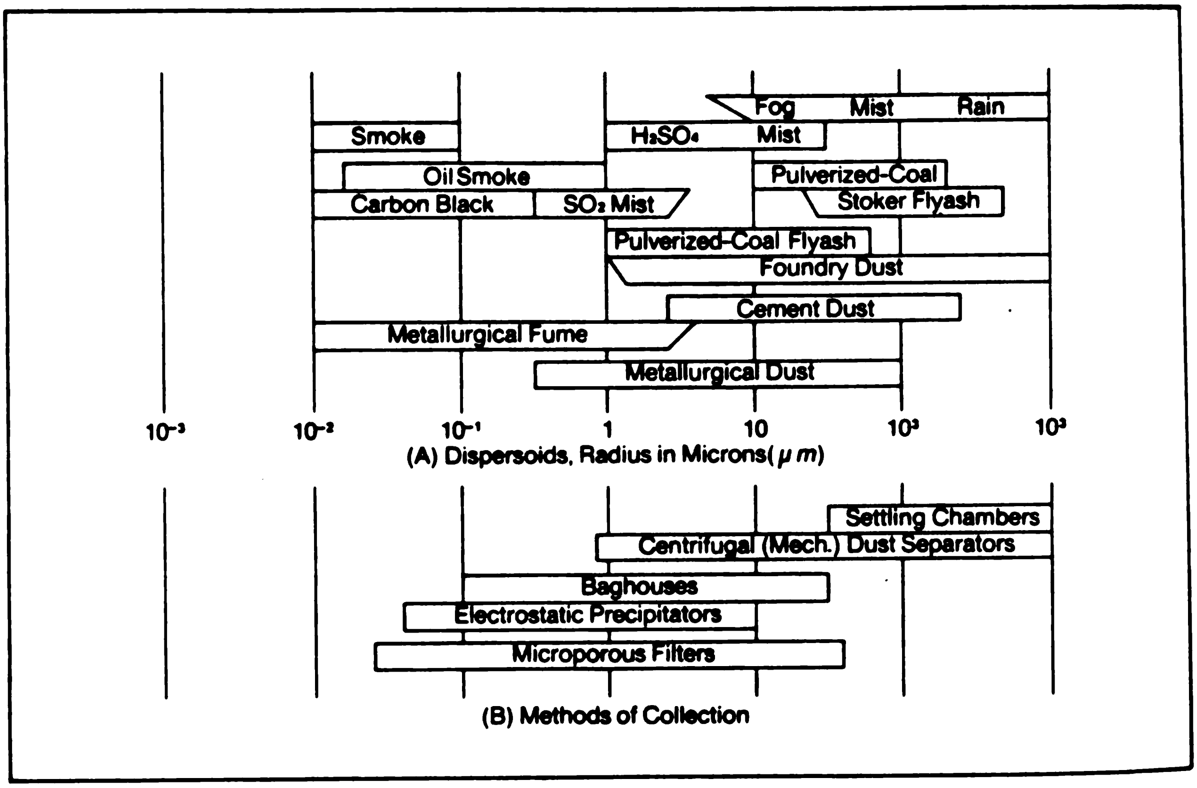


Fig. 3 TYPICAL PARTICULATE SIZES AND METHODS OF CONTROL

Methods of particulate emission control are mostly mechanical, with the most common being:

- **Mechanical Cyclone Collectors:** These devices achieve particulate removal by centrifugal, inertial and gravitational forces. Efficiency of collection is very high for particle sizes greater than 20 microns, but efficiency drops off rapidly for particle sizes in the range of minus 10 microns. In current coal fired plant design, Cyclone Collectors are seldom used as they are not able to meet the required collection efficiency to meet applicable environmental regulations in the US.
- **Electrostatic Precipitators:** In these devices, suspended particles are electrically charged, then driven to collecting electrodes by an electrical field. The collecting electrodes are periodically rapped to cause the collected particles to drop into collecting hoppers. There are two main designs of Electrostatic Precipitators in current use, the Weighted Wire and the Rigid Frame type. Precipitator design is a complex science, which must consider many parameters such as coal and coal ash properties, ash resistivity and size being key parameters, operational

requirements, collection efficiency requirements, etc. Due to environmental requirements in the US, all new coal fired plants must have Electrostatic Precipitators, or an equally effective device for removal of particulate emissions.

- **Fabric Filtration:** Fabric Filters or Baghouses have a long history of applications in processes to control stack emissions. However, until reciently, available materials limited their service to installations where the flue gas temperature was below 250 F. Since the 1970's, as new materials were developed, their use in coal fired power plants began to increase. They have demonstrated good operating characteristics and high particulate removal efficiency. Thus, their use is increasing, specially in retrofit applications where the high cost and large space requirements of an Electrostatic Precipitator presents problems. Typically Baghouses have a constant collection efficiency, but varying pressure drop, whereas Precipitators have a relatively constant pressure drop, but varying efficiency.

- **Sulfur-Oxides Emissions:** Traditionally, sulfur-oxide emission control has been achieved through one, or a combination of, the following methods: use of low sulfur coal; use of fuel desulfurizing method; or, use of flue gas desulfurizing methods. If changing to a low sulfur coal is not possible, then one of the other methods must be used. To date, the primary method used in the US is that of Flue Gas Desulfurization. Various types, all involving complex reactions and expensive and complicated to operate equipment are available. Two basically different designs are available: The throwaway and the regenerative types. Most types currently in use in the US are of the throwaway type, but in many other parts of the world the regenerative type is being successfully used.

The basic process used in the throwaway type is to spray the flue gas with lime-limestone slurry, a double alkali, or dilute sulfuric acid to effect a reaction with the sulfur in the flue gas and have it precipitate into collection hoppers. The sludge is then collected and disposed of in a safe land fill, hence the name throwaway.

The regenerative processes are more complicated and involve the recovery of the chemicals used for recycling and/or the recovery of elemental sulfur or sulfuric acid, thereby reducing the amount of waste produced and the waste disposal problem and in some cases, producing a potentially valuable end product.

Until recently, desulfurization of the fuel prior to combustion has not been a widely used method of emission control for steaming coals, beyond that sulfur removal which took place during the coal washing process, (removal of some of the pyritic sulfur as part of the mineral matter removed in the washing process.) However, in the last few years, various "coal beneficiation" processes have been developed, some as part of the work done in coal water mixtures (CWM) fuels which allow for the removal of a significant part of the pyritic sulfur. Claims are made by some processes developers to the effect that the total sulfur content of a coal can be reduced by up to 50%. I will discuss this in more detail in the section on CWM fuels.

- **Nitrogen-Oxides Emissions:** To date the control of NOx emissions from power plants have been mainly through better control and reduction of excess combustion air, use of off-stoichiometric firing and use of over-fire air to reduce flame temperature and flue gas recirculation . However because of more stringent controls on NOx emissions in other parts of the world, new control systems have been developed. These are really flue gas treatment systems and basically fall into one of the following four categories: Catalytic Decomposition, Selective Catalytic Reduction, Selective Non-Catalytic Reduction and Absorption.

As previously mentioned the other area of environmental concern, in coal fired power plant is that associated with the safe disposal of liquid and solid wastes from the coal storage and handling areas and the ash and ash components.

- **Coal Handling and Storage Area:** As can be expected, the handling of coal can result in environmental problems associated with fugitive dust and rain water run off from the storage and handling areas. Control of these two items is important if contamination of the surrounding area and surface and ground waters is to be prevented. Control of dusting is usually accomplished by design features built into the unloading system, such as covered rotary car dumpers, water sprays into the bottom car dumping pits, spraying of the coal itself, both on the rail car and/or in the coal storage pile itself and in extreme situations, by the use of covered coal storage areas. Control of rain water run off from the storage and handling area is usually accomplished through the installation of an impervious liner on the ground where the coal is to be stored and the provision of a system of drains to collect the run off. The collected run off water is then taken to an impoundment area, where it can remain without contaminating the surrounding ground and/or surface waters until it evaporates, or is treated to remove undesirable contaminants prior to releasing it to the environment. Naturally, if other considerations dictate the use of an enclosed coal storage area, the problem with run off collection and treatment is significantly reduced.

- **Collection and Handling of Ash:** Bottom ash from the furnace is usually collected and conveyed away from the boiler using a wet method. The ash is then sluiced to an ash pond where it is impounded, again, to prevent contamination of the environment. The Flyash collected from the electrostatic precipitator or other particulate control system can be handled in either a wet or a dry manner. If the Flyash is going to be disposed of in the same ash disposal area as the bottom ash, then a wet system is the most logical choice. However if there is a potential for sale of the Flyash as an aggregate to concrete or some such other use, then a dry handling system, based on use of storage silos is preferred. Where a throwaway lime/limestone system is used for removal of sulfur from the flue gas, the resulting waste must be collected and impounded to prevent contamination of the environment. This a very significant design problem and cost in a coal fired powerplant. Its magnitude is such that it has prompted the development of the renewable types of sulfur removal equipment, which although much more complex and capital intensive, do reduce the magnitude of the waste handling and storage problems. If the power plant is located in an area where available land is restricted or the area has a sensitive environment, then the renewable type systems for removal of sulfur from flue gas should be considered.

5-COAL CONVERSION ALTERNATIVES

There are two fundamentally different approaches to converting existing steam generating capacity from oil or gas fuels to coal or coal derived fuels. This conversion can be accomplished by the conversion of the boiler to either the indirect, or the direct firing of the coal fuel.

- Indirect Firing This nomenclature applies to those conversion alternatives that involve the conversion of the coal in a separate process plant to a liquid or gas fuel that can then be fired in the original boiler with essentially minimum modifications to the boiler. The most commonly known methods are referred to as Coal Liquefaction and Coal Gasification.

- Coal Liquefaction There are various systems for liquefying coal now in their commercialization stage. All the systems have as a primary objective the removal of the coal ash and the increase of the hydrogen to carbon ratio of the coal. Although this can be successfully accomplished, the production plant required is quite complex and requires a significant investment which cannot be presently justified unless there are some very special conditions present which make this the only feasible manner of accomplishing the conversion. Table 5 shows the typical fuel specification derived from some of the best known coal liquefaction processes.

TABLE 5
SPECIFICATIONS OF TYPICAL BOILER FUELS FROM LIQUEFACTION PROCESSES

Process:	SRC-I	SRC-II	H-Coal	CFFC
Type of Fuel:	Solid	Distillate	Distillate	Heavy Oil
Type of Process:	Noncatalytic	Noncatalytic	Catalytic	Catalytic
Pour Point, °F:	50 (Melting Point)	25	20	65
HHV Btu/lb:	15,700–16,000	17,300	17,500	16,800
Approximate Boiling Range, °F	850+	400–800	400–975	400+
Weight %				
Hydrogen	5.9	7.8	9.0	6.8
Sulfur	0.8	0.3	0.03	0.3
Nitrogen	2.0	0.9	0.4	1.2
Ash	0.15	Nil	Nil	0.05

- **Coal Gasification** The development of the coal gasification processes is now in its third generation. These processes are expected to be able to supply significant quantities of substitute natural gas in the next 10 to 20 years. Basically, all these processes involve the controlled burning of coal in an atmosphere deficient in oxygen. Typically these gasification processes produce low or medium Btu content gas. Gas produced from the low Btu processes typically contains 100 to 125 Btu/Scf, while the medium Btu process gas typically contains on the order of 275 to 300 Btu/Scf. On the other hand, natural gas, due to its high methane content has a heating value of 1000 Btu/Scf. In general, again, this process requires the building of large complex gasification facilities and the commitment of large amounts of capital. Therefore, unless there are some particular circumstances that override these factors, gasification has not proven to be a financially viable means of converting existing steam generating capacity to coal fuels. See Fig. 4 for a general diagram of the gasification process.

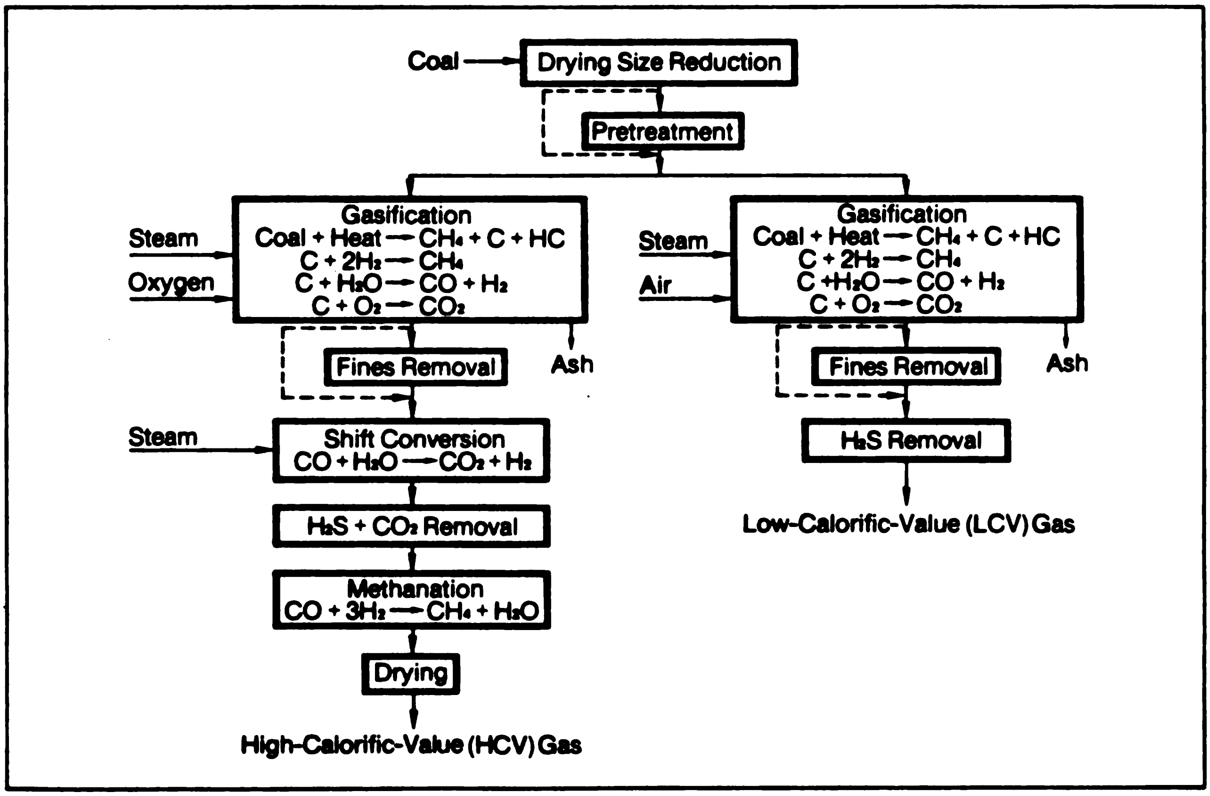


Fig. 5
GENERAL PROCESS DIAGRAM FOR COAL GASIFICATION

- Direct Firing This method involves the conversion of the boiler itself to accept coal, and to successfully burn coal in the boiler. Naturally, there are many things that can be done both to the boiler and to the coal to make it easier to fire, reduce the cost of the conversion, approximate the firing of fuel oil and enhance the reliability of the converted unit. It would be impossible to address each of these issues in detail, therefore I will describe the two basic approaches to the conversion of boilers to coal fuels and in a later section of this report address the study process required to determine the technical feasibilty and financial viability of the conversion.

Conversion of a boiler to coal fuel can be achieved by either a conversion to the firing of the solid coal in a stoker, cyclone furnace or as pulverized coal. For simplicity I will refer to such a conversion as a conversion to solid coal firing. The other approach available is that of conversion of the boiler to the firing of coal in a slurry form. Coal-Oil, Coal-Water and Coal-Methanol-Water Mixtures are the most common examples of Coal Slurry Fuels.

- Solid Coal Firing As previously mentioned this involves the modification of the plant site to be able to receive bulk coal from the mine, store it, handle and prepare the coal for firing, all on the plant site, and modification of the boiler with the addition of the required coal burning and ash handling equipment. Although the coal may be washed at the mine to remove some of the ash and mineral matter, provision must be made in the design of the conversion for firing the as received coal and handling and disposing of the resulting ash and ash byproducts, as well as the wastes from the coal storage and handling areas. The addition of all this new equipment to the plant results in a significant capital expenditure which must be recovered during the life of the project from saving in fuel cost, if the project is to be financially feasible. Conversion of oil and/or gas units to coal is routinely done, and the technical aspects of such a conversion can be easily determined through studies by experienced Architect/Engineering firms. Reliability of converted units is usually good and operation of such units does not present major problems if the coal supplied meets the design specifications. The major disadvantage of this type of conversion is the major disadvantage of this type of conversion is the large amount of additional land area required and the required capital investment.

- Coal Slurry Fuels Basically, preparation of Coal Slurry Fuels involves the grinding of the coal to a fine consistency, addition of a small amount of additives and mixing it with a fluid. In some cases, such as Coal-Oil and Coal-Methanol Slurries, this fluid is also a fuel. In the case of Coal-Water, it is not. The main purpose of mixing the coal with a fluid is to make it handle and burn as a liquid fuel without going to the complexity and expense of a coal liquefaction process.

During the past few years various proprietary processes have been developed for the production of the coal slurry fuels. Each manufacturer, or producer naturally promotes his process as the best. A detailed comparison of the processes would be inapropriate here, as that could well be the subject of a discussion an presentation itself.

Advantages of the use of Slurry fuels over Solid Coal are:
- Little, if any, additional land is required for coal handling and storage.
- Can be handled and stored in existing fuel oil facilities after minor modifications of such facilities.
- Many slurry preparation processes allow the deep cleaning of the coal, with a reduction of ash of up to 50% of the normal as received amount in the coal.
- Possible reduction in the ash content of the coal reduces in many cases, the required boiler modifications, and the problems associated with handling and disposal of the ash.
- It is a more environmentally acceptable fuel than solid coal.
- The fuel can be produced in a centrally located plant which can make use of economies of scale to reduce production costs and distribute fuel to a number of converted plants using suitably modified petroleum transportation equipment.

TABLE 5
TYPICAL COAL SLURRY FUELS

	Component, % by wt.		
COAL OIL MIXTURE:	Oil, 49 max.,	Coal, 49 max.,	Add.<2
COAL METH. WATER MIXTURE:	Coal,65 max.,	Meth. 20 max.,	Water 14 Add.<1
COAL WATER MIXTURE:			
Moder. Load, No Add.	Coal, 55 max.,	Water, 44 max.,	Add.~1
Highly loaded	Coal, 70 max.,	Water, 27 max.,	Add.<3

- **Fluidized Bed Boilers** For many years fluidized bed reactors have been used in non-combustion reactions in which the intimate contact of the reactants in a fluidized bed will result in high product yield with improved economy of time and energy. A fluidized bed is a layer of solid particles kept in turbulent motion by bubbles created by air,or other gasses, being forced into the bed from below. See Fig. 6 for a schematic of a fluidized bed combustion boiler. In a fluidized bed boiler, a fuel is introduced into this bed and burned. All the solid particles in the bed are quickly heated by the churning action of the bed and if the heat absorbing surface is submerged in the bed, the temperature of the solid bed particles can be controlled at a pre-determined level. The intimate contact of the hot solids and combustion gases with the heat absorption surfaces results in a high heat transfer coefficient. This is the fundamental design principle of a fluidized bed boiler.

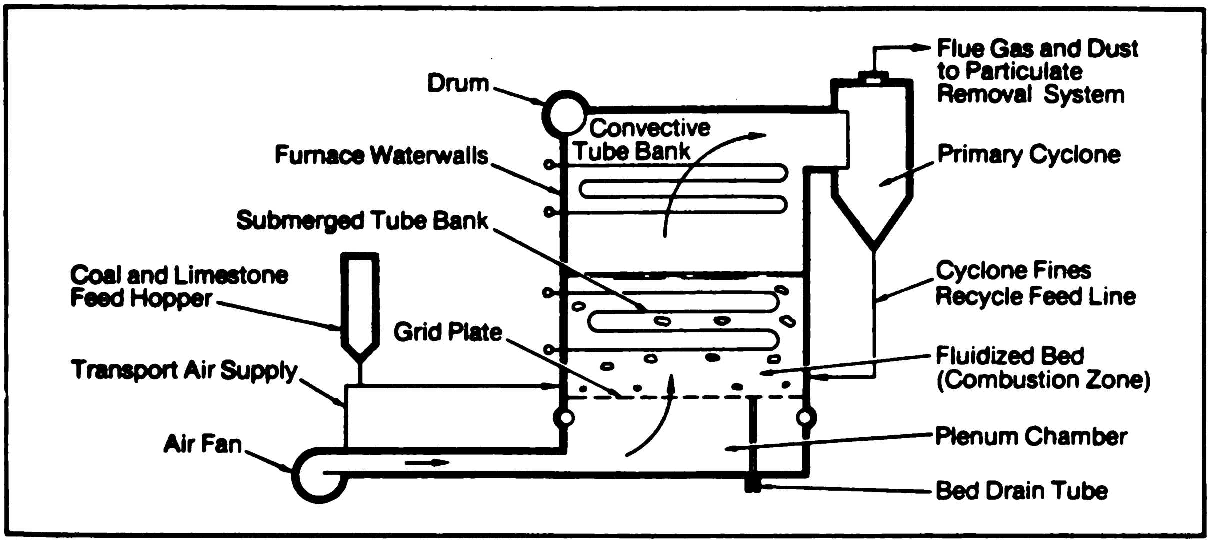


FIG. 6
DIAGRAM OF A FLUIDIZED BED BOILER

The outstanding advantage of a fluidized bed boiler is its ability to burn many types of fuel, which otherwise would be difficult to burn. From the standpoint of coal fuels, the advantage of a fluidized bed boiler is its ability to burn many grades of coal, including high sulfur coals in a bed of heated limestone. This results in an environmental advantage over many of the other types of coal burning boilers in that the removal of the sulfur in the coal occurs in the bed and eliminates the need for the complex and expensive sulfur removal equipment necessary with other types of boilers when using high sulfur coals. Additionally, since the combustion of the fuel takes place at relatively low temperatures formation and emission of NOx is significantly reduced. The two most common types of fluidized bed boilers now in use are the Atmospheric Fluidized Bed Boiler (AFB) and the Pressurized Fluidized Bed Boiler (PFB).

In the atmospheric fluidized bed boiler, as its name implies, the combustion occurs at atmospheric pressure. Although larger and less efficient, these AFB's are simpler to design and operate. In the pressurized fluidized bed boiler, the combustion reaction occurs at a pressure of approximately 10 atmospheres (150 psi). Thus, they tend to be more efficient and smaller in size for the same capacity, but more complex to design, build and operate. To date most fluidized bed boilers in the US are of the atmospheric type, with the first generation of the pressurized type now being considered ready for utility demonstrations See Fig. 7 for a schematic of a proposed pressurized fluidized bed boiler.

Fluidized bed boilers are now being considered for the conversion of existing plants to coal. In this case they seem especially well suited for repowering older, smaller boilers which may be at the practical end of their useful or economic life.

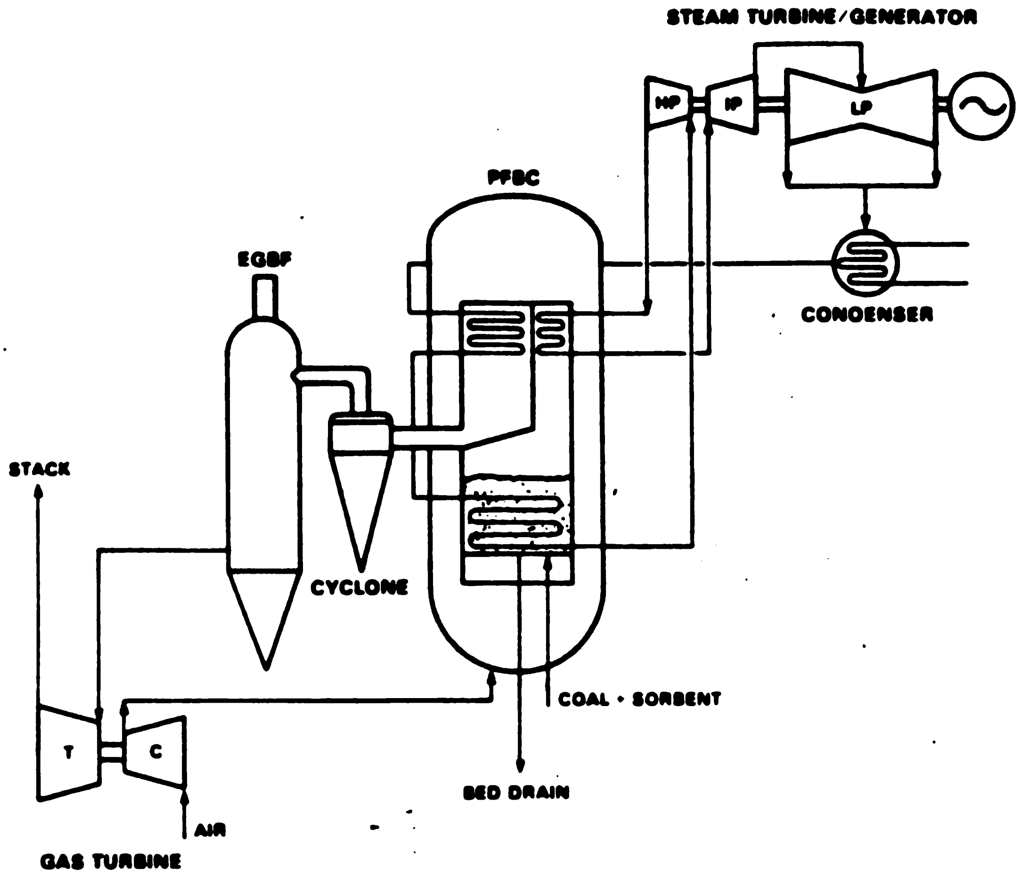


FIG. 7
SCHEMATIC OF A PROPOSED PRESSURIZED FLUIDIZED BED BOILER PLANT

6-CONVERSION PROJECT FEASIBILITY STUDIES

As has been discussed here, there are many factors including principles of combustion, fuel type and specification, environmental concerns, plant and boiler modifications, reliabilty of operation, capacity of the converted plant and last but not least, financial considerations, that must be addressed prior to making a decision whether to convert a plant to a different fuel, and to what fuel, or in this case to what coal based fuel.

To address all these factors and to make sure that all key concerns are properly addressed prior to making a decision, it is essential that technical and economic feasibility studies be conducted under the direction of knowledgeable, experienced personnel familiar with coal conversion work. Prior experience with such study programs has shown that there are certain key components that must be included in the evaluation. These are:

- A detailed study of the coal sources available for fuel use must be completed to determine available reserves, mining and production costs, specifications of the coal and expected quality over the life of the project.
- An in depth engineering study of the plant or boiler to be converted must be made to determine the most feasible type of coal conversion for that plant. Consideration must be given to engineering, operational, environmental and financial factors and a matrix developed to select the best combination of fuel type, modifications and costs, versus operating capacity and reliability.
- The available coal source/supply must be evaluated against the plant conversion study results to determine that the available coal can be processed into the desired fuel; what is the best and most economical fuel that can be made from the available coal and determine if it meets the fuel requirements assumed in the plant conversion study.
- Once the data from the above studies is available, a fuel transportation study must be made to determine the best means for delivery of the coal to the plant or the coal to the process plant and the fuel to the steam plant. Once the route and means have been determined, a cost can be calculated.
- When accurate cost estimates are available for the coal supply, plant conversion, transportation of the coal and/or fuel and the processed fuel itself (if applicable), an overall financial feasibility study can be made for the project, taking into consideration the converted plant's new capacity (if derated), operating capacity factor, heat rate and incremental maintenance and operating costs. This study will show the financial feasibility of the project, payback period and total cumulative savings over the life of the project.
- In many cases, the overall financial feasibility study for the project may not show the complete economic feasibility or benefits of a conversion project. In this case an overall economic feasibility study must be undertaken to evaluate critical factors which although outside of the conversion project itself, must be considered due to their potential benefit. Particularly important are questions regarding increased use of a natural resource versus an imported fuel, foreign exchange consideration, development of a new local industry, creation of new jobs, etc. Only after consideration of these factors, will the true overall economic feasibility of the project be determined.

REFERENCES

COMBUSTION, FOSSIL POWER SYSTEMS, Combustion Engineering, Inc. Windsor, CT. Third Edition, 1981.

STEAM, ITS GENERATION AND USE, The Babcock and Wilcox Co., New York, NY. Thirty-Seventh Edition, 1963.

REPOWERING A LARGE OIL-FIRED POWER PLANT USING A TURBOCHARGED, PRESSURIZED FLUIDIZED BED COMBUSTOR, Florida Power and Light Co. Miami, FL. 1985.

COAL WATER MIXTURES AS A UTILITY BOILER FUEL, Florida Power and Light Co. Miami, FL. 1984.

SANFORD UNIT 4 COAL OIL MIXTURE TEST REPORT, Florida Power and Light Co. Miami, FL. 1980.

SEMINARIO COOPERATIVO SOBRE LA UTILIZACION DEL CARBON COMO UNA ALTERNATIVA A LOS HIDROCARBUROS EN LA REGION ANDINA

PRODUCCION Y MERCADEO DEL CARBON COLOMBIANO

Por: Dr. Jairo Londoño Arango.

Lima, Perú Junio de 1.985

CONTENIDO

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LISTA DE CUADROS

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RESUMEN

El objeto del presente documento es el de presentar un diagnóstico sobre la producción y el mercadeo del carbón colombiano con el fin de mostrar a los asistentes al "Seminario Cooperativo sobre utilización del carbón como una alternativa a los hidrocarburos en la región andina" lo que se ha logrado en Colombia, principalmente, a través del sistema cooperativo en la explotación subterránea de carbón y su posterior comercialización por parte de estos productores.

Se presenta, en primer lugar, un análisis detallado de la producción de carbón utilizando para ello los datos del último censo minero realizado en 1983 para, posteriormente, pasar a describir brevemente los sistemas de explotación, el nivel de tecnificación y los rendimientos alcanzados concluyendo con una presentación de la estructura del sistema cooperativo y el de comercialización del carbón colombiano junto con una presentación esquemática de las opciones que tiene Colombia en el campo de la sustitución de combustibles.

I - LA MINERIA DEL CARBON

El carbón continúa siendo un recurso natural inexplotado en Colombia. El valor estimado de la producción de carbón en 1983 fue de US$ 100 millones.

La minería del carbón se inició hace unos 100 años utilizando métodos bastante primitivos hasta hace poco tiempo.

El primer impulso hacia una minería semi-industrial tuvo lugar en el quinquenio 1945-1950 cuando Acerías Paz del Río y otras industrias ingresaron al mercado, lo que trajo como consecuencia una duplicación casi inmediata de la demanda.

La juventud de esta industria, junto con una demanda interna casi estática, ha mantenido nuestra minería en los niveles de la pequeña y mediana empresa.

A partir de 1973 apareció un nuevo ciclo para la industria carbonífera cuando surgieron nuevos consumidores en el país (pequeñas siderúrgicas, ingenios azucareros, plantas termoeléctricas a base de carbón y el mercado de exportación), logrando, en solo 5 años, un incremento de los precios internos en el mismo porcentaje obtenido en casi 4 quinquenios de exceso de demanda en casi todos los mercados locales de este recurso.

1.1. Contribución a la economía nacional

La contribución del carbón a la economía nacional es hoy casi marginal. La contribución del carbón al Producto Interno Bruto ha sido de un escaso 0,10% en los últimos años.

Sin embargo, los planes de expansión interna de la industria, junto con los programas de exportación a corto y mediano plazo, nos permiten pensar que para 1985 esta participación se incrementará a niveles cercanos al 3% partiendo de la base de que para esa fecha el país estará consumiendo no menos de 5,5 millones de toneladas anuales de carbón y exportando 3 millones de toneladas por año.

El consumo de energía en Colombia en los últimos años muestra una evolucion que puede traducirse en cifras, hasta donde ellas son conocidas, así:

Fuente	1970	1974	1979	1983
Petróleo	71.9%	70.6%	56.2%	57.0%
Gas	19.2%	18.1%	29.3%	28.2%
Electricidad	6.8%	9.4%	12.8%	12.9%
Carbón	1.7%	1.5%	1.3%	1.4%
Resto	0.4%	0.4%	0.4%	0.5%

Las cifras anteriores nos indican cómo la demanda de hidrocarburos aumentó en forma constante durante el período 1965-1974 para luego disminuir la participación porcentual del petróleo por el paso del país de exportador a importador de combustibles. Mientras esto ocurría, la participación del carbón decrece en forma constante hasta 1974 para luego permanecer más o menos estable hasta la fecha. La hidroelectricidad en cambio, muestra su tendencia propia de su crecimiento del orden del 8% al 10% anual durante todos estos períodos.

Conviene también anotar aquí que el número de personas empleadas por la industria minera del carbón es de unos 16.000 mineros que trabajan con una baja eficiencia, aunque en algunas minas mecanizadas los promedios sobrepasan las 2,5 toneladas por hombre-turno. Lo anterior representa que apenas un 0,002% de la población económicamente activa se dedica a esta actividad, siendo por tanto éste uno de los frentes más promisorios para incentivar en nuestro actual sistema económico, buscando con ello una política de generación masiva de empleo, en zonas marginadas.

El esquema anterior de participación del carbón en la economía nacional y la situación mostrada contrastan cuando se los compara con los otros rubros proyectados para el sector energía, el cual demandará, para mantener nuestro desarrollo, de una gran proporción de los guarismos del mañana colombiano.

En efecto, si se mantienen las tasas esperadas de crecimiento económico (3% como promedio anual) hasta 1990, la demanda de energía pasará de 300 MBPE/D en 1978 a 620 MBPE/D en 1990 que deberá ser fundamentalmente servida por hidroelectricidad, carbón, gas y petróleo.

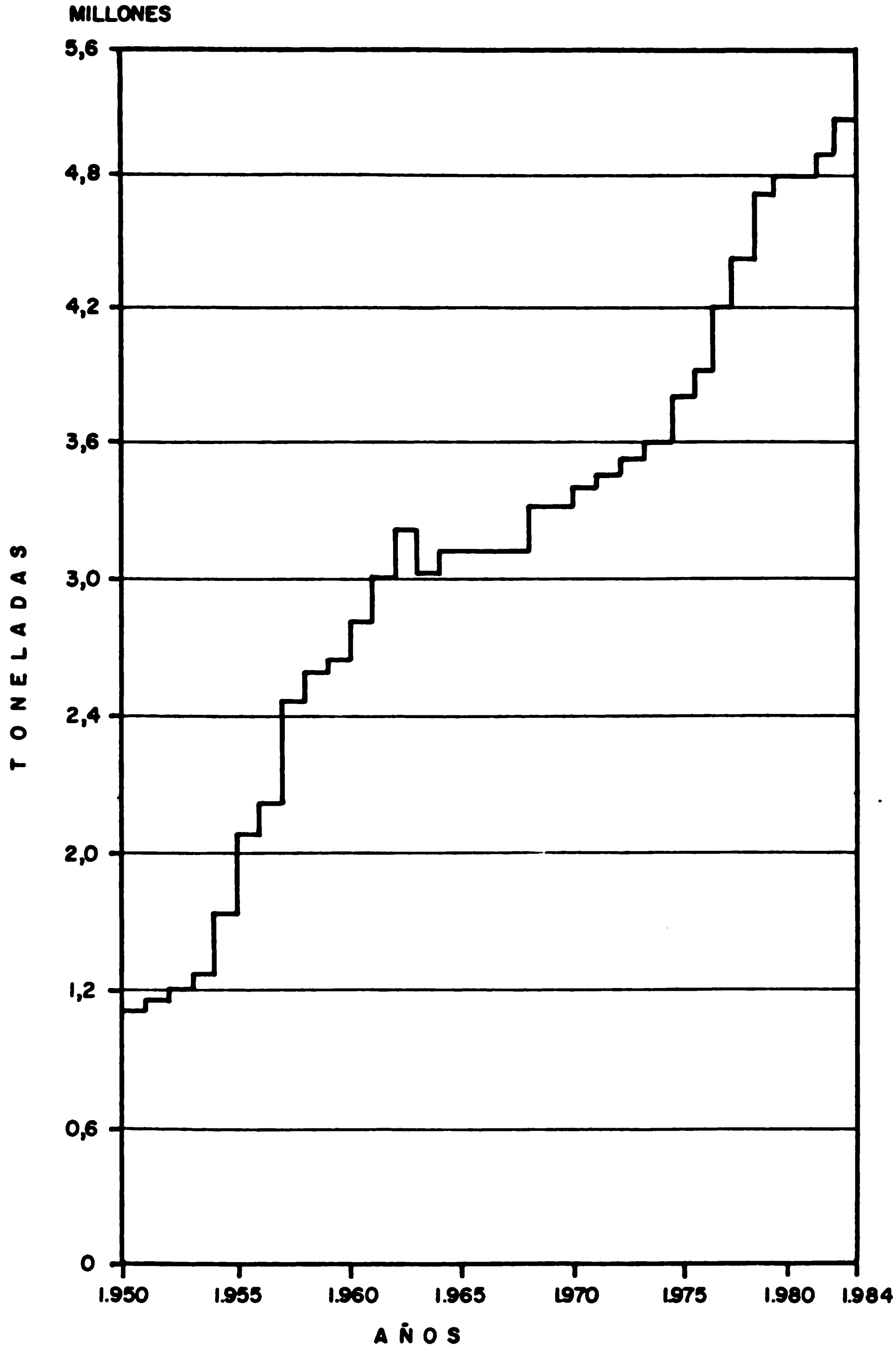
Se espera que el país sustituirá las actuales importaciones de petróleo y gasolina a partir de 1987 en el equivalente a US$ 500 anuales y, de paso, generará divisas por las exportaciones de crudo cuyo valor se estima en unos US$ 1200 por año.

Adicionalmente, el aporte neto del carbón térmico a la balanza del sector para el período contemplado será de casi US$ 6.000 millones mientras que el de carbón coquizable se espera que sea de US$ 500 millones que con los otros rubros de exportación alcanzarían a generar un superávit a partir de 1986.

En resumen, el desarrollo económico y social del país se encuentra bastante ligado y dependiente de los desarrollos futuros del sector energético, siendo el carbón y el petróleo los productos que individualmente aportarán mayor número de divisas para equilibrar la balanza y sostener el ritmo actual de crecimiento de la economía colombiana.

1.2. La producción de carbón

FIGURA Nº 1



PRODUCCION DE CARBON
1.950 - 1.984

La producción actual de carbón en Colombia se estima en cerca de 5,3 millones de toneladas por año para 1983 y en 5,8 millones para el presente año.

Entre 1955 y 1962, la tasa de crecimiento de la producción fue bastante elevada (véase figura No. 1) por el incremento de la demanda causado por el ingreso al mercado de algunas plantas térmicas y la ampliación de algunas industrias consumidoras de este recurso energético (plantas de cemento, papel, etc).

Durante el período 1962 a 1968 la demanda permaneció casi estática causando una disminución en la tasa de incremento de la producción y trayendo como consecuencia un notable deterioro en los precios internos, los cuales disminuyeron, durante este período, en pesos constantes.

A partir de 1972 a 1973 se inicia un nuevo auge de la industria que no se traduce en un desmesurado incremento de la producción lo que obliga a los consumidores a tener que entrar a un mercado competido, incrementándose notablemente los precios y fijándose, por primera vez, normas claras bajo las cuales se negociará el producto en el futuro. Se establecieron así premios, castigos por la calidad del carbón, incentivos por mayor tonelaje entregado, fórmulas de reajustes periódicos de precios, descuentos por contenido de humedad, etc.

Por último, a partir de 1982 se produce un nuevo estancamiento del sector que ha colocado en serios aprietos a los productores llevando inclusive al cierre de varias minas.

La producción de carbón en Colombia no ha alcanzado aún niveles importantes a escala mundial porque su mercado siempre ha estado ligado a consumos de tipo local y regional establecidos en Bogotá, Medellín, Cali y Boyacá. Cada uno de estos mercados crea así, un área de influencia que provee las necesidades de las industrias allí establecidas. El siguiente cuadro nos muestra la distribución de la producción actual por departamentos:

Departamento	Producción	%
Boyacá	1'500.000	28,5
Cundinamarca	1'555.000	29,5
Antioquia	680.000	12,9
Valle y Cauca	695.000	13,2
Norte de Santander	255.000	4,8
Otros	580.000	11,1
Total	5'265.000	100.0

La evolución histórica de la producción durante los últimos 35 años puede ser apreciada en la Figura No.1.

Antes de 5 años, el país tendrá que cuadruplicar la actual producción para poder atender a sus necesidades internas y a la creciente demanda internacional que está buscando la manera de recibir nuestro carbón a corto plazo.

En el Censo Nacional del Carbón 1983 fueron registradas 1579 minas de las cuales 130 (el 8%) se encuentran inactivas (Véase cuadro No. 1) entendiéndose por mina inactiva aquella en la cual durante el año anterior al Censo no se había adelantado ninguna labor minera. La mayoría de las minas de carbón del país se encuentran concentradas en los departamentos de Boyacá (el 47%) y de Cundinamarca (el 33%) en ambos casos dispersas en gran parte de su territorio; el departamento de Antioquia concentra sus minas hacia el suroeste; los departamentos del Valle y del Cauca tienen su centro de gravedad carbonífero en una franja que se extiende desde Yumbo por el norte hasta el Tambo por el sur; la región conformada por Norte de Santander centraliza gran parte de sus minas en el extremo oriental del departamento, particularmente en el municipio de Cúcuta.

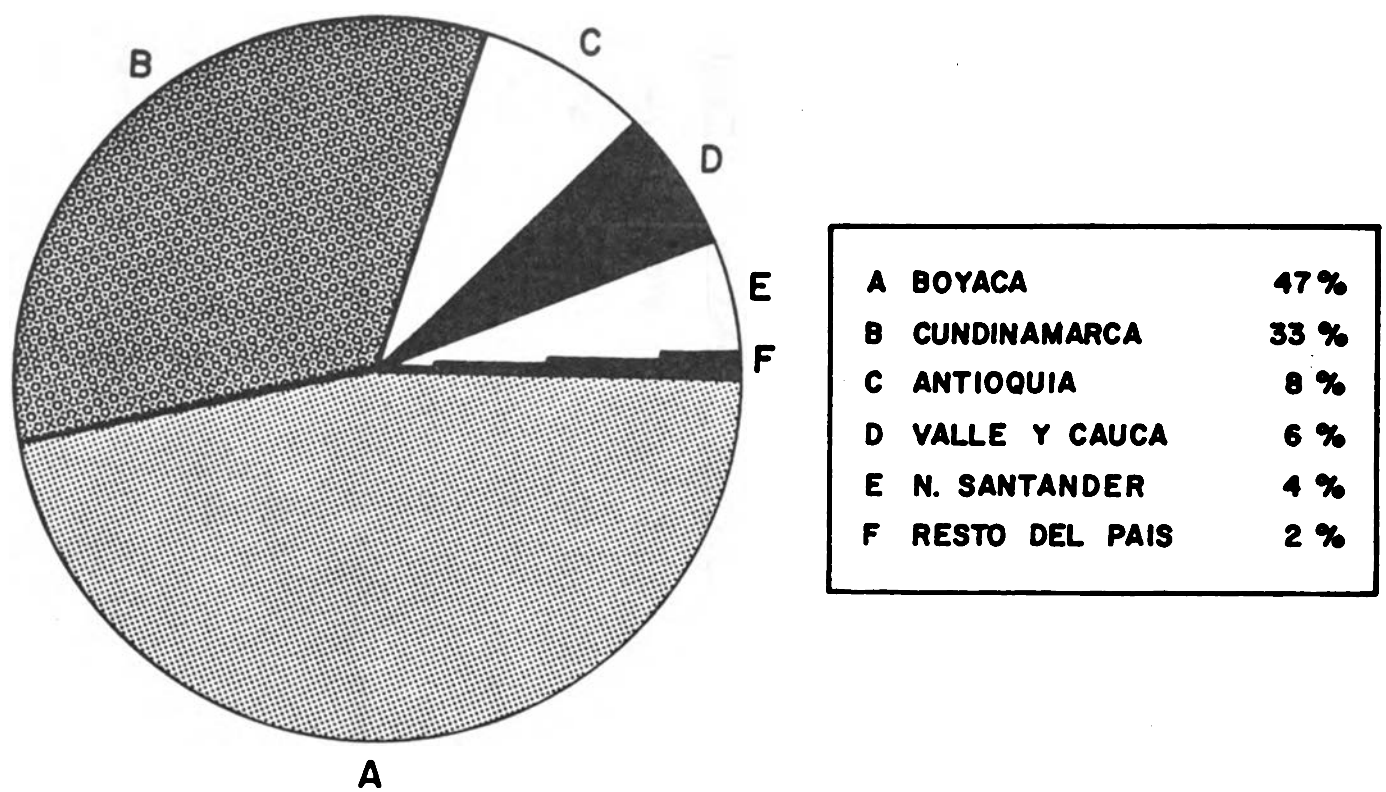
La producción de carbón de tipo térmico constituye el eje de la minería en el país, puesto que el 84% de las minas activas poseen yacimientos de carbones reconocidos como de uso térmico (Véase cuadro No.2); un 11% de las minas corresponde a explotaciones de carbón de tipo coquizable. También se advierte la presencia de un 5% de minas principalmente en Cundinamarca, que cuentan tanto con mantos de carbón tér-

CUADRO No. 1

COLOMBIA
NUMERO DE MINAS SEGUN EL ESTADO DE LA EXPLOTACION
1983

Regiones	Inactivas	Activas	Total	Importancia Relativa (%)
Boyacá	68	676	744	47.1
Cundinamarca	46	478	524	33.2
Antioquia	7	120	127	8.0
Valle y Cauca	2	92	94	6.0
Norte de Santander	1	67	68	4.3
Resto del país	6	16	22	1.4
Total	130	1449	1579	100.0

GRAFICA Nº I



COLOMBIA - DISTRIBUCION DE LAS MINAS ACTIVAS EN LAS REGIONES 1.983

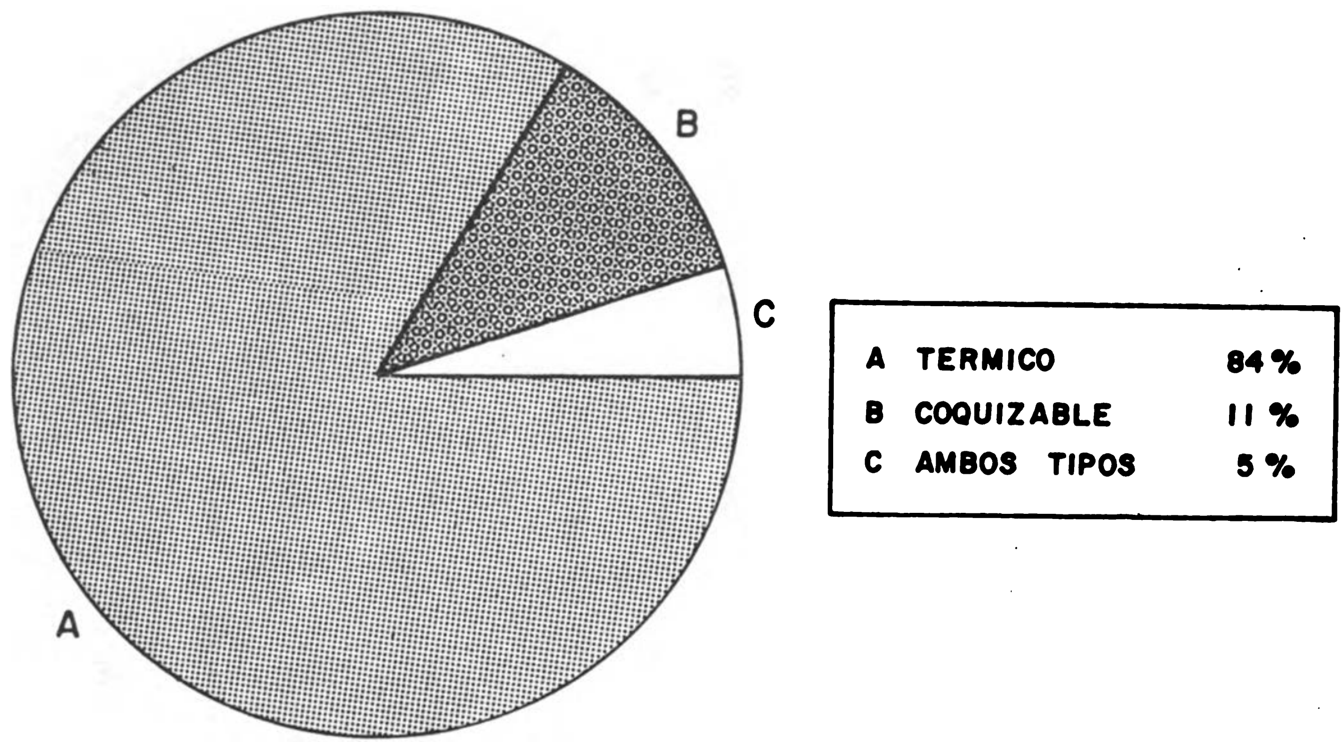
CUADRO No. 2

COLOMBIA
MINAS ACTIVAS POR REGION SEGUN TIPO DE CARBON
1983

Regiones	Térmico	Coquizable	Ambos Tipos	Total
Boyacá	600	52	20	672
Cundinamarca	343	79	52	474
Antioquia	114	0	0	114
Valle y Cauca	92	0	0	92
Norte de Santander	41	20	5	66
Resto del país	15	0	0	15
Total	1205	151	77	1433
Importancia relativa (%)	84.1	10.5	5.4	100.0

Minas sin información: 16

GRAFICA Nº 2



COLOMBIA - DISTRIBUCION DE LAS MINAS SEGUN SU TIPO DE CARBON 1.983

mico como con mantos de carbón coquizable.

La producción estimada de carbón para 1983 asciende a 4.9 millones de toneladas (Véase cuadros Nos. 3 y 3A) de las cuales 300.000 se destinaron a la exportación. No obstante, la valoración de la producción por parte de los mineros solo alcanzó 3.9 millones de toneladas. Este subregistro, aún cuando puede explicarse por más de un factor, se debe en parte a la no información sobre este tema en 118 minas.

Sobresalen por su producción de carbón térmico los municipios de: Socha, Topagá y Sogamoso en Boyacá; Cucunubá, Guachetá, Lenguazaque y Sutatausa en Cundinamarca; Amagá y Fredonia en Antiquia; Cali, Jamundí y Yumbo en el Valle. En la producción de carbón coquizable se distinguen los municipios de Socha y Samacá en Boyacá, así como el de Guachetá en Cundinamarca.

Por niveles de producción es notoria la concentración de minas con volúmenes de extracción inferiores a 2.000 toneladas-año (Véase cuadro No.4); 1097 explotaciones, o sea un 82% pertenecen a esta categoría aportando, sinembargo, solo el 18% de la producción nacional. El resto de las explotaciones están dispersas en categorías que van de 2.000 toneladas anuales en adelante. Resalta el hecho de que en los niveles comprendidos entre las 10.000 y las 60.000 toneladas-año tan solo se localizan 32 minas, o sea el 2% las cuales aportan el 22% de la producción total; esta apreciación destaca la baja participación de la "mediana mi-

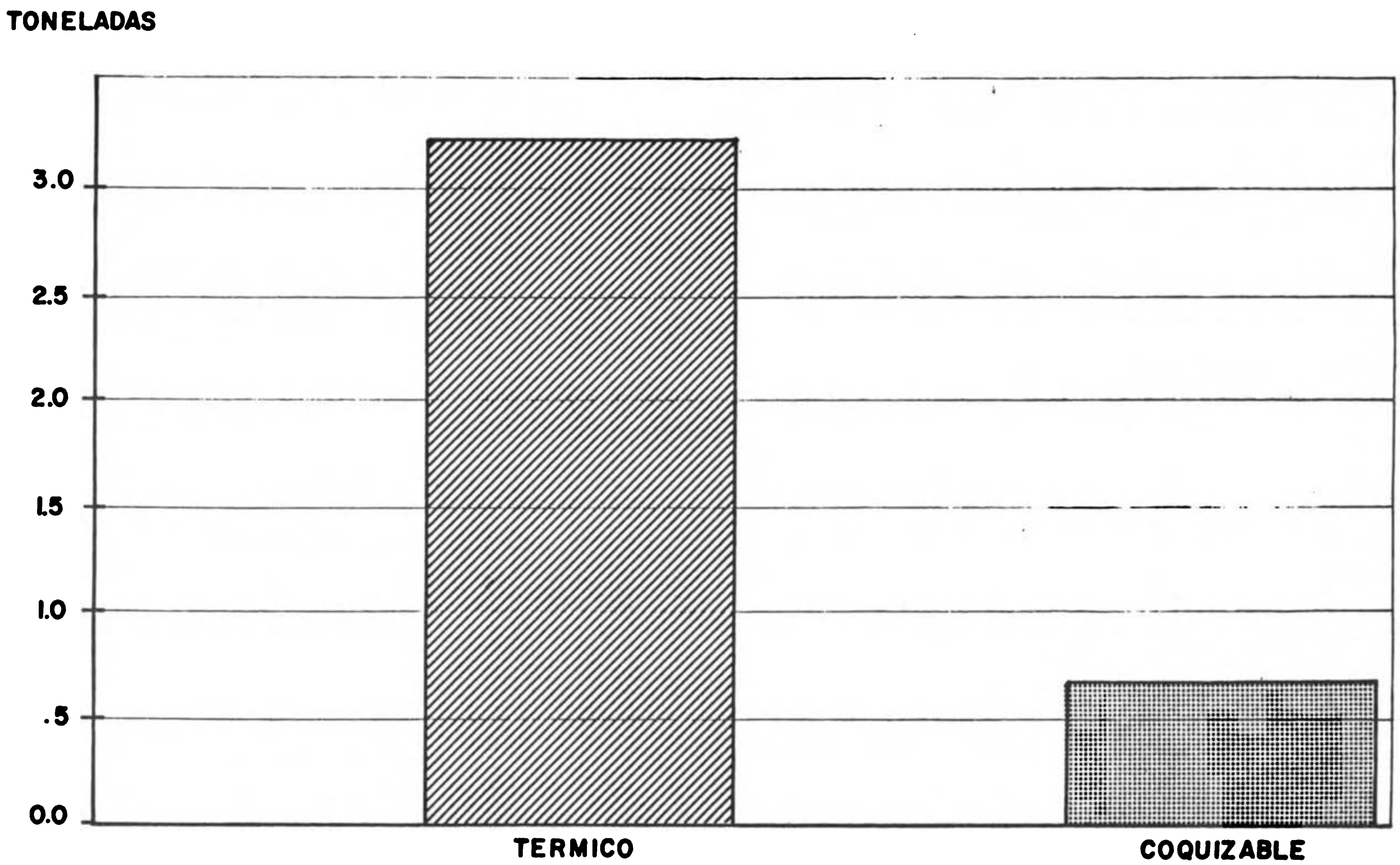
CUADRO No. 3

COLOMBIA
PRODUCCION SEGUN TIPO DE CARBON EN LAS MINAS ACTIVAS
1983
TONELADAS

Regiones	Térmico	Coquizable	Total
Boyacá	608.784	382.219	991.003
Cundinamarca	713.246	250.503	963.749
Antioquia	548.184	0.000	548.184
Valle y Cauca	575.446	0.000	575.446
Norte de Santander	185.956	25.457	211.413
Resto del país	579.120	0.000	579.120
Total	3210.736	658.179	3668.915
Importancia relativa (%)	83.0	17.0	100.0

Minas sin información: 118

GRAFICA Nº 3



COLOMBIA - PRODUCCION SEGUN TIPO DE CARBON 1.983

CUADRO No. 3 A

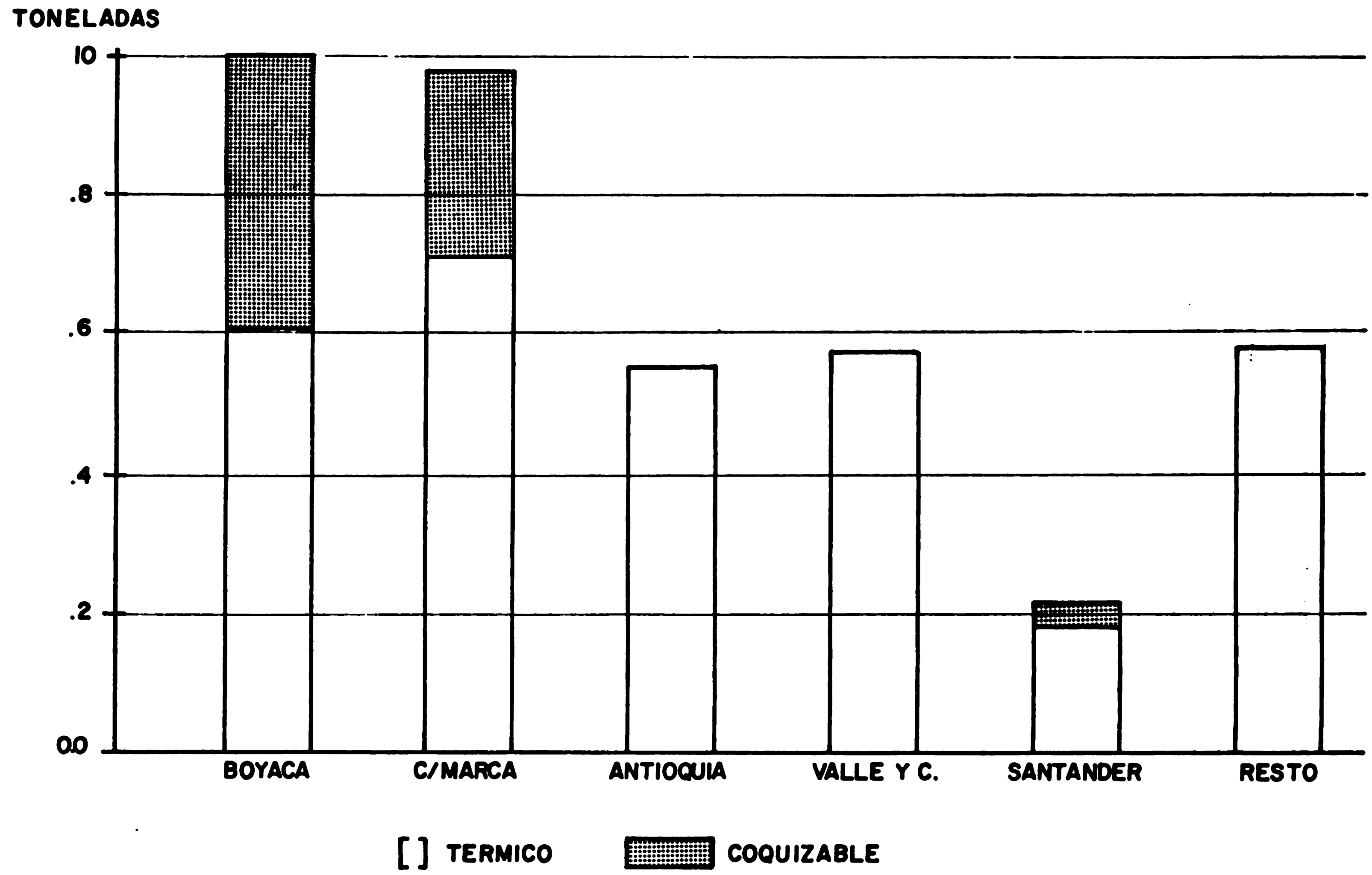
COLOMBIA
PRODUCCION TOTAL DE CARBON
1983
MILES DE TONELADAS

VALORES AJUSTADOS (1)

Regiones	Térmico	Coquizable	Total
Boyacá	920	480	1400
Cundinamarca	1200	255	1455
Antioquia	620	0	620
Valle y Cauca	645	0	645
Norte de Santander	185	30	215
Otras regiones	580	0	580
Total	4150	765	4915

(1) Con base en el Censo Nacional y la información de demanda disponible en CARBOCOL.

GRAFICA Nº 4



COLOMBIA - 1.983 - DISTRIBUCION DE LA PRODUCCION EN LAS REGIONES SEGUN EL TIPO DE CARBON

CUADRO No. 4

COLOMBIA
PRODUCCION Y NUMERO DE MINAS SEGUN NIVELES DE EXTRACCION ANUAL
1983

TONELADAS

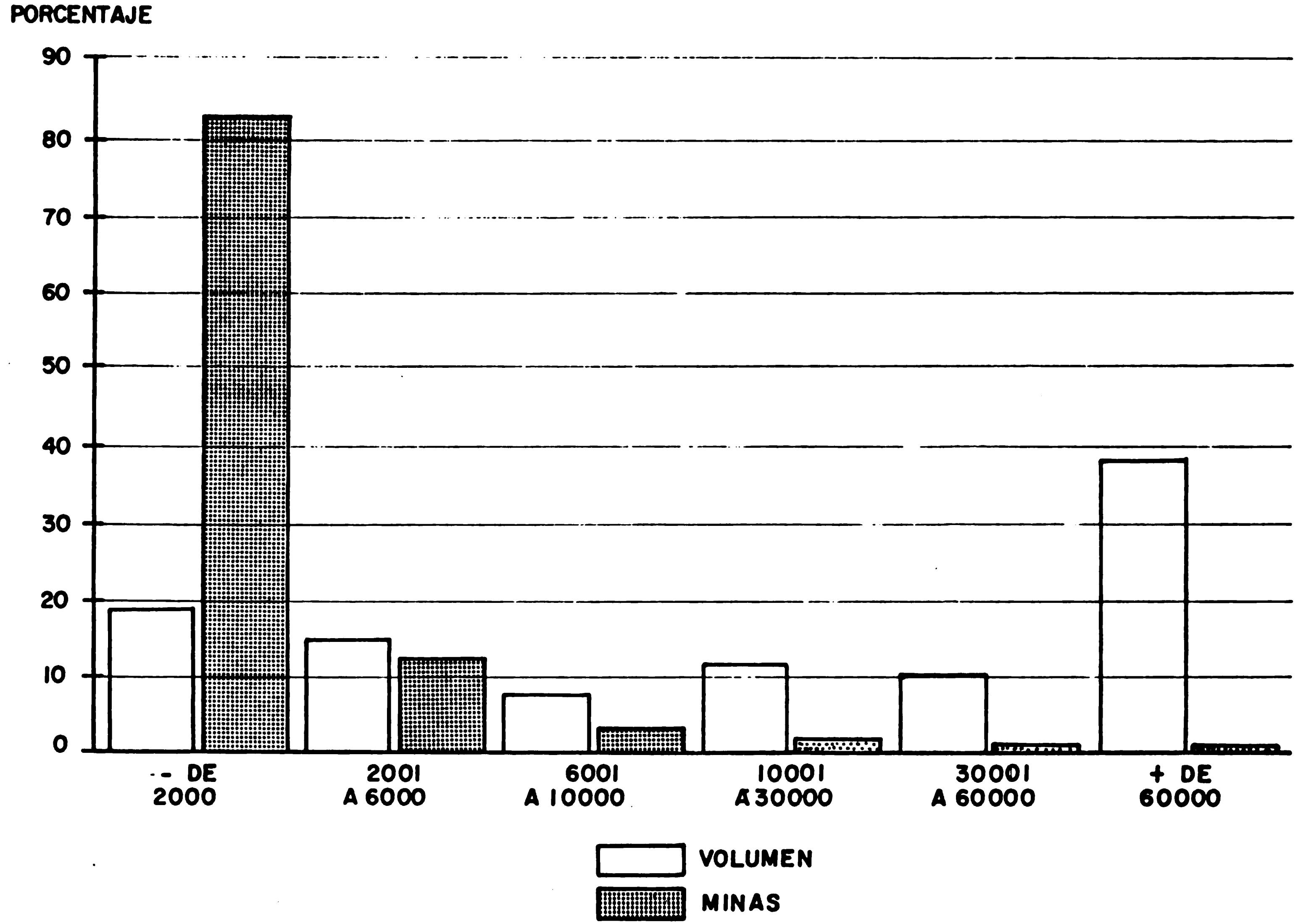
Regiones	- De 2000	2001 A 6000	6001 A 10000	10001 A 30000	30001 A 60000	+ De 60001	Total
BOYACA							
Volumen	345.183	104.599	35.871	56.000	33.299	416.051	951.003
Minas	587	30	5	3	1	1	627
CUNDINAMARCA							
Volumen	232.700	324.130	143.519	232.100	31.000	0.000	963.749
Minas	320	86	18	12	1	0	437
ANTIOQUIA							
Volumen	46.754	53.473	57.080	63.277	0.000	327.600	548.184
Minas	77	15	7	4	0	2	105
VALLE Y CAUCA							
Volumen	52.973	48.770	31.200	67.240	231.659	143.604	575.446
Minas	61	12	4	3	5	2	87
N. DE SANTANDER							
Volumen	30.310	49.293	13.517	24.000	94.293	0.000	211.413
Minas	41	13	2	1	2	0	59
RESTO DEL PAIS							
Volumen	3.920	5.200	0.000	0.000	0.000	570.000	579.120
Minas	11	3	0	0	0	2	16
TOTAL							
Volumen	711.840	585.465	281.187	442.917	390.251	1457.255	3368.915
Minas	1097	159	36	23	9	7	1331

CUADRO No. 4 A

COLOMBIA
DISTRIBUCION PORCENTUAL DE LA PRODUCCION Y DEL NUMERO DE MINAS
SEGUN NIVELES
1983

Regiones	TONELADAS - De 2000	2001 A 6000	6001 A 10000	10001 A 30000	30001 A 60000	+ De 60001	Total
BOYACA							
Volumen	34.7	10.6	3.6	5.7	3.4	42.0	100.0
Minas	93.5	4.8	0.8	0.5	0.2	0.2	100.0
CUNDINAMARCA							
Volumen	24.1	33.7	14.9	24.1	3.2	0.0	100.0
Minas	73.3	19.7	4.1	2.7	0.2	0.0	100.0
ANTIOQUIA							
Volumen	8.5	9.8	10.4	11.5	0.0	59.8	100.0
Minas	73.3	14.3	6.7	3.8	0.0	1.9	100.0
VALLE Y CAUCA							
Volumen	9.2	8.5	5.4	11.7	40.2	25.0	100.0
Minas	70.2	13.8	4.6	3.4	5.7	2.3	100.0
N. DE SANTANDER							
Volumen	14.3	23.3	6.4	11.4	44.6	0.0	100.0
Minas	69.5	22.0	3.4	1.7	3.4	0.0	100.0
RESTO DEL PAIS							
Volumen	0.7	0.9	0.0	0.0	0.0	98.4	100.0
Minas	68.7	18.9	0.0	0.0	0.0	12.5	100.0
IMPORTANCIA RELATIVA (%)							
Volumen	18.4	15.1	7.3	11.4	10.1	37.7	100.0
Minas	82.4	11.9	2.7	1.7	0.7	0.6	100.0

GRAFICA Nº 5



COLOMBIA - 1983 - COMPARACION DE LAS DISTRIBUCIONES PORCENTUALES EN LOS NIVELES nería en el sector carbón del país.

En un nivel de observación más desagredado se aprecia una diferente composición de la producción entre regiones. En Boyacá y Cundinamarca en un extremo, las minas con escala de producción inferior a 2.000 toneladas-año aportan el 35% y 24% respectivamente del volumen regional (Véase cuadro No.4A) en Antioquia, por el contrario, las minas con escala de producción superior a las 60.000 toneladas- año contribuyen con el 60% de la producción. La región comprendida por el Valle del Cauca y el Cauca constituye un caso intermedio en el cual las minas entre las 10.000 y 60.000 toneladas-año suministran el 52% de la producción. En el resto del país (especialmente en el caso de El Cerrejón) una cantidad mínimas de minas (2) aportan más del 99% de la producción regional.

En cuanto a la producción de carbón coquizable, nuevamente el mayor número de dichas minas (105 o sea el 65%) se localiza en niveles de producción inferiores a 2.000 toneladas-año; así mismo, tan solo 9 minas de este tipo se encuentran en rangos superiores a las 10.000 toneladas-año, aportando el 58% del volumen de carbón coquizable del país.

1.3. Los sistemas de explotación

La explotación subterránea es el tipo de minería predominante en el país (Véase cuadro No.5) siendo la escogida por el 99% de las minas. Solo existen 7 minas que cuentan con explotación a cielo abierto y 2 minas que cuentan con explotación subterránea y explotación de superficie simultáneamente.

En la minería subterránea el sistema de explotación imperante es el de cámaras y pilares, el cual alcanza un nivel del 65% (Véase Cuadro No.6) En Cundinamarca y los Santanderes el sistema de tambores paralelos ocupa el segundo lugar en importancia. El sistema de cámaras y pilares es aquel que divide el yacimiento en bloques para luego ser preparados teniendo en cuenta la inclinación del manto; el sistema de tambores paralelos desarrolla dos vías principales, siguiendo la dirección del manto, las cuales se van uniendo luego por medio de tambores (raises) paralelos entre sí; los otros sistemas reunen un número importante de minas y constituyen básicamente, variaciones a los sistemas comunes de explotación.

1.4. Los niveles de tecnificación y rendimiento

El nivel de tecnificación de la minería en Colombia es rudimentario, hecho que se deduce a partir de algunos de los resultados del cuadro No.7. Como ejemplo , en la etapa de arranque, es decir para la labor sistemática de desprendimiento del material, la utilización de martillos neumáticos o de explosivos es inferior al 5% y al 8% respectivamente;

CUADRO No. 5

COLOMBIA
MINAS ACTIVAS SEGUN TIPO DE MINERIA
1983

Regiones	De superficie	Subterránea	Con ambos Tipos
Boyacá	3	672	1
Cundinamarca	0	474	0
Antioquia	0	118	1
Valle y Cauca	0	92	0
Norte de Santander	2	61	0
Resto del país	3	15	0
Total	8	1432	2

Minas sin información: 7

CUADRO No. 6

COLOMBIA
MINAS SUBTERRANEA SEGUN SISTEMA DE EXPLOTACION
1983

Sistema	Utilizan Absoluto	Relativo (%)
Cámaras y pilares	1014	64.9
Escalones invertidos	23	1.5
Tajo largo	70	4.5
Tambores paralelos	165	10.6
Otros sistemas	289	18.5
Total (1)	1559	100.0

Minas sin información: 27

(1) El número de respuestas no coincide con el total de minas subterráneas, dado que una misma mina puede utilizar más de un sistema.

CUADRO No. 7

COLOMBIA
MINAS SUBTERRANEA SEGUN ELEMENTOS DE EXPLOTACION
1983

	Utilizan Absoluto	Relativo %
1. Arranque		
Pica	1299	88.0
Martillo	63	4.3
Explosivos	113	7.7
Total	1475	100.0
2. Ventilación		
Nautral	1292	84.3
Mecanizada	124	8.1
Otros	117	7.6
Total	1533	100.0
3. Desagüe		
Natural	607	45.1
Mecanizada	541	40.3
Otros	196	14.6
Total	1344	100.0
4. Iluminación		
Eléctrica	164	10.5
Lámparas portatiles	1295	82.8
Otros	105	6.7
Total	1564	100.0

Minas sin información para:

1. Arranque	64
2. Ventilación	6
3. Desagüe	56
4. Iluminación	11

adicionalmente, los sistemas de ventilación mecanizada, no alcanzan a ser empleados sino por el 8% de las minas.

La disponibilidad de energía eléctrica en las minas activas es un indicador de la precaria infraestructura circundante a ellas. En Colombia, solo el 24% de las minas (Véase Cuadro No.8) disponen de energía eléctrica, siendo esta importancia, adicionalmente, independiente de la importancia carbonífera de los municipios. Regionalmente, este indicador marca en cierto sentido las ventajas comparativas en el desarrollo minero. Mientras que en Antioquia más del 50% de las minas disponen del servicio y en Cundinamarca el 36%, en las demás regiones este porcentaje desciende a valores entre el 11% y el 18%.

La producción de carbón es lograda mediante la vinculación de 16.294 personas en las diferentes labores de la minería (Véase Cuadro No.9) De este total el 76% (más de 12.000 personas) ejercen su labor en el subsuelo. Por supuesto, los departamentos de Boyacá y Cundinamarca, concentran el mayor número de trabajadores; conjuntamente, estos dos departamentos reunen cerca de dos tercios de la población minera del carbón en el país.

Por municipios sobresalen, por su generación de empleos mineros, los de Guachetá, Cucunubá, Lenguazaque y Sutatausa en Cundinamarca y Samacá, Socha, Sogamoso y Tópaga en Boyacá. Otra contribución notoria

CUADRO No. 8

COLOMBIA
MINAS ACTIVAS CON DISPONIBILIDAD DE ENERGIA ELECTRICA
1983

Regiones	Disponen	Total
Boyacá	76	674
Cundinamarca	173	476
Antioquia	65	120
Valle y Cauca	14	91
Norte de Santander	11	65
Resto del país	6	16
	345	1442
Importancia relativa (%)	23.9	100.0

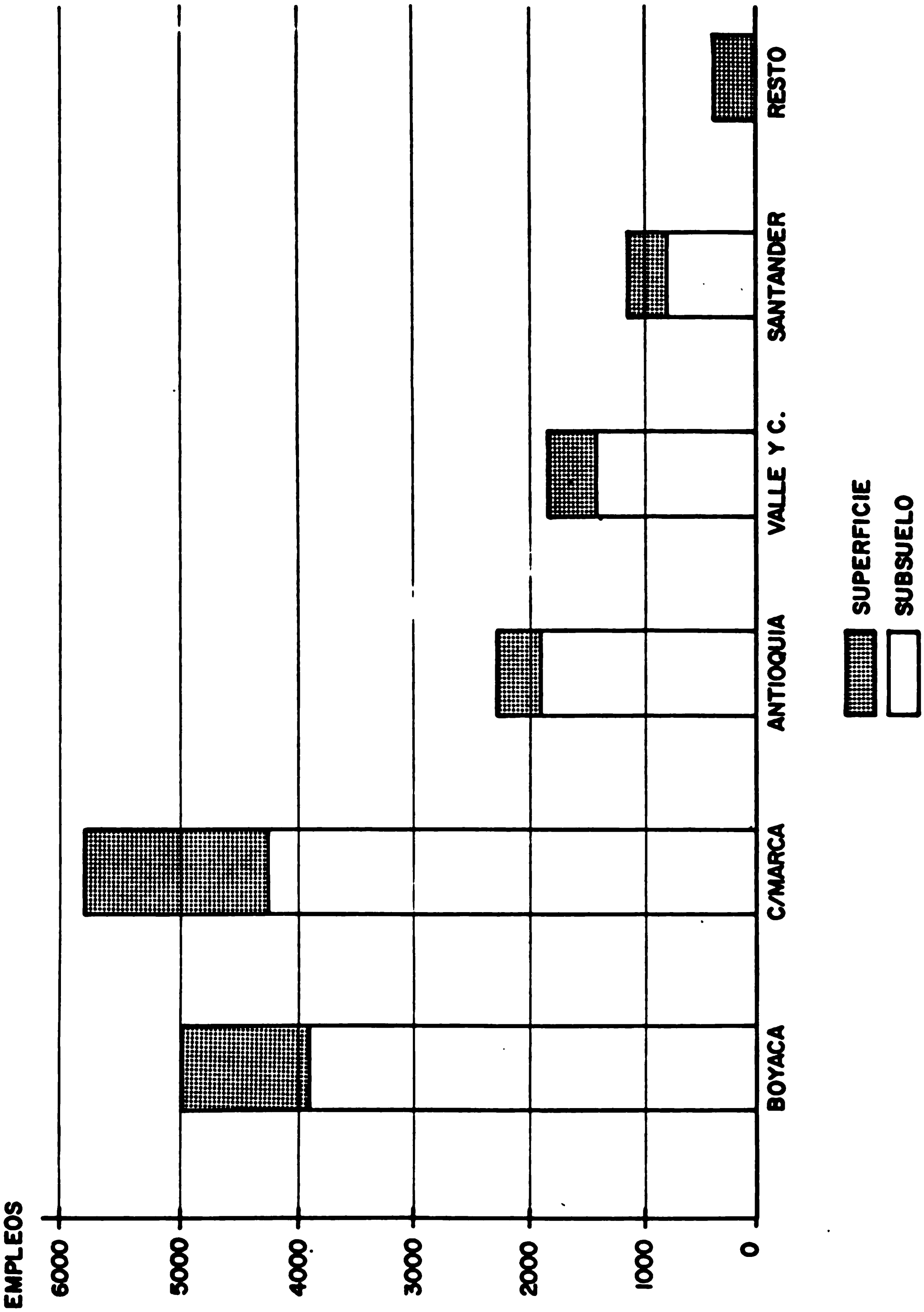
Minas sin información: 7

CUADRO No. 9

COLOMBIA
PERSONAL EMPLEADO EN LAS MINAS ACTIVAS SEGUN LUGAR DE OPERACION
1983

Regiones	En Subterránea	En Superficie	Total	Importancia Relativa (%)
Boyaca	3.899	1.065	4.964	30.5
Cundinamarca	4.249	1.534	5.783	35.4
Antioquia	1.915	345	2.260	13.9
Valle y Cauca	1.429	368	1.797	11.0
Norte de Santander	756	319	1075	6.6
Resto del país	80	335	415	2.6
Total	12.328	3.966	16.294	100.0
Minas sin información: 8				
Importancia relativa (%)	75.7	24.3	100.0	

GRAFICA Nº 6



COLOMBIA - 1.983 - PERSONAL EMPLEADO EN EL SECTOR SEGUN SU LUGAR DE OPERACION al total de empleos generados la hacen los municipios de Cali en el Valle y Amagá en Antioquia.

La relación producción a empleo aumenta considerablemente con el nivel de extracción (Véase Cuadro No. 10) no obstante, para las minas con producción superior a las 60.000 toneladas-año se percibe una caida en el indicador. Es de anotar que la variabilidad presentada por esta medida es alta, principalmente para Antioquia en el nivel de 10.000 a 30.000 toneladas-año.

Como puede apreciarse (Véase Cuadro No. 10) los rendimientos van desde 0,35 toneladas por hombre-turno en minería subterránea de baja producción hasta 5,73 toneladas por hombre-turno en las minas mecanizadas con sistemas de explotación a cielo abierto.

1.5. Las cooperativas y la producción de carbón

Hace escasos 20 años se inició el sistema cooperativo en la explotación de carbón en Colombia. En 1984 casi una tercera parte (449) de las 1449 minas activas se encontraban cooperadas (Véase Cuadro No. 11.) a través de 12 organizaciones regionales.

Estas 12 cooperativas controlan el 27.5% de la producción destinada al mercado interno (cerca de 1'300.000 toneladas por año) al cual se han dedicado con exclusividad desde su creación.

CUADRO No. 10

COLOMBIA
PRODUCTIVIDAD PROMEDIO EN LAS MINAS ACTIVAS SEGUN NIVELES
1983

TONELADAS/EMPLEO/AÑO

Regiones	-De 2000	2001 A 6000	6001 A10000	10001 A30000	30001 A60000	+ De 60001	Total
Boyacá	131	274	311	586	178	614	143
Cundinamarca	104	255	407	513	352	0	159
Antioquia	120	210	507	1.759	0	634	237
Valle y Cauca	200	448	271	399	1.375	409	321
Norte de Santander	105	240	387	304	1.219	0	188
Resto del país	91	248	0	0	0	1719	401
Total	125	267	397	715	1.094	877	172
Minas con información							
	1.042	159	36	23	9	7	1.276

CUADRO No. 11

COLOMBIA
MINAS ACTIVAS COOPERADAS
1984

Región	Cooperadas	Total	Cooperativas en la Región
Boyacá	193	676	4
Cundinamarca	156	478	2
Antioquia	0	120	0
Valle	60	92	5
Norte de Santander	40	67	1
Resto del País	0	16	0
Total	449	1449	12
Importancia relativa (%)	30.98	100.0	

El resto de la producción es generado por mineros independientes con operaciones intensivas en mano de obra (un 30%) y por productores que trabajan con sistemas mecanizados de alta tecnología que, generalmente, extraen el carbón para su propio consumo (caso de Acerías Paz del Río, Cementos del Valle, Cementos El Cairo, Coltejer, etc).

Existe, pues, un equilibrio muy marcado entre los productores independientes y los cooperados en lo que hace relación con la producción de carbón, más no así con el número de minas trabajadas por cada uno de ellos. Lo anterior debido al hecho de que las cooperativas han logrado mejorar sensiblemente el grado de mecanización y los rendimientos de las minas de sus cooperados utilizando para ello créditos de los consumidores y fondos propios retenidos de las ventas de carbón.

Ultimamente, Carbones de Colombia S.A.- Carbocol, ha acometido un programa de apoyo a la pequeña y mediana minería del carbón iniciando por la resolución del problema jurídico de la titularidad de las minas y paralelamente, a través del establecimiento de cinco estaciones regionales de capacitación y puntos de salvamento para minería subterránea situados en cada una de las zonas carboníferas actualmente en explotación.

Es indudable que el sistema cooperativo debe ser el más conveniente para orientar una sana política de apoyo a la pequeña y mediana minería del carbón porque a través de él es posible resolver, en forma masiva, los problemas jurídicos; los crediticios y de asistencia técnica; los de seguridad minera; los de mercadeo del producto; los de unificación de equipos, maquinaria y herramientas, en fin, todos aquellos que tienen que ver con esta actividad.

A título simplemente informativo, veamos cuales son los problemas principales que han mantenido al sector con tan bajo nivel de desarrollo:

1- Carencia absoluta de financiación o dicho de otra manera inexistencia de crédito adecuado para atender las necesidades del minero colombiano productor de carbón.

2- Falta casi absoluta de garantías que le permitan al minero acceder a una de las líneas crediticas de las existentes en el mercado de capitales.

3- Imposibilidad de poder cubrir el costo de una asistencia técnica adecuada por el bajo precio que ha tenido el carbón en el mercado interno.

4- Carencia casi absoluta de infraestructura física que le permita extraer, en mejor forma, su producto de las entrañas de la tierra (electrificación, túneles adecuados, mejor ventilación, etc) y de su mina hacia el mercado (vías de acceso y comunicación con las carreteras troncales).

5- Escasa preparación física (sin control de su salud) y nivel de capacitación tecnológica muy precario o de simple obrero raso.

II - LA COMERCIALIZACION DEL CARBON

Aunque el carbón en Colombia se ha venido comercializando desde hace más de 100 años, la evolución de los sistemas de mercadeo ha sido sumamente lenta y se encuentra aún a niveles de la época de 1850 en los demás mercados internacionales. En efecto, el carbón colombiano siempra ha tenido un precio de venta diferente en cada uno de los centros de consumo (Bogotá, Medellín, Cali, etc) no pudiéndose hablar por tanto, de un mercado nacional del carbón, pues este no existe en sentido económico; la discriminación de precios no obedece ni ha obedecido a la calidad ni a la distancia de los centros de producción siempre ha sido causado por la desigualdad de condiciones en que se encuentra los productores frente a las grandes industrias consumidoras.

En general, puede decirse, que el precio ha sido fijado en su gran mayoría por los consumidores, con una ingerencia un poco mayor en los últimos años por parte de los productores agremiados. Más aún a pesar del alza notoria del precio en los últimos años, su valor ha disminuido en pesos constantes y apenas hoy si está alcanzando el mismo precio que tenía en 1960 en dólares equivalentes y, por ello, continúa siendo aún el combustible más barato vendido en el mundo entero.

Los mercados regionales del área de Norte de Santander, el de Boyacá, Cundinamarca, Antioquia y Valle se encuentran en un radio no mayor de 120 kilómetros de los centros de consumo razón por la cual el sistema de transporte no constituye ningún impedimento para la buena atención a los potenciales consumidores. Estos consumidores inicialmente acudían al sistema de facilitar créditos en herramientas y elementos de minería (picas, palas, rieles, carburo, etc) que debían ser pagados en el futuro mediante carbón en especie, razón por la cual el precio en vez de incrementarse bajaba continuamente.

Posteriormente a mediados del presente siglo con la creación de las cooperativas se vino a establecer una fuerza un poco más coherente que obligó a la suscripción de contratos en los cuales se establecían condiciones mínimas tales como: una duración de un año de suministro con un aumento en el precio después del primer semestre y se establecía por lo menos una limitante en la cantidad de humedad con que debía ser recibido el carbón existiendo además, un premio por la cantidad de calorías contenidas en el material suministrado.

Hasta ahora no ha sido posible establecer en Colombia contratos de suministro a largo plazo que son los más recomendables dentro de la industria y que, desde el punto de vista práctico este tipo de contratos constituyen un acuerdo firme y obligatorio para el suministro y compra de cantidades específicas de carbón durante un período generalmente de 10 años o más. La duración es especialmente importante para el productor dentro del contexto de la minería colombiana porque se está involucrando, desde ya, la preparación y explotación de nuevos frentes de trabajo y muy posiblemente la infraestructura relacionada; sinembargo también lo es para el comprador deseoso de asegurarse el suminis tro a largo plazo bajo condiciones conocidas y apropiadas durante el mayor tiempo posible permitiéndole realizar la planificación y financiamiento a largo plazo de su producción.

Existe, sin duda, una mutua desconfianza entre productores y consumidores debido, principalmente, a que los intermediarios que manejan gran parte del mercado son los que se han encargado de hacer que cuando se acuerda un precio o unas condiciones contractuales vengan a ofrecer condiciones inferiores de venta porque ellos tienen todo el margen para movilizarse dentro del sector sin que resulten lesionados sus intereses económicos pues ellos simplemente se limitan a pagarle menos al pequeño productor del que adquieren su producción. Debe si anotarse que en los últimos 5 años las cooperativas han suscrito contratos bastante satisfactorios en los cuales se involucran factores tales como cantidad mínima a entregar mensualmente, variaciones en la cantidad y calidad, bonificaciones y multas en las cuales aparecen involucradas especificaciones tales como la humedad total descontándose aquella cantidad de agua que supere la humedad inherente más la superficial, la cantidad de cenizas, la cantidad de azufre, la cantidad de materia volátil, el índice de hinchamiento, cuando va destinado a el sistema siderúrgico y el tamaño sobre todo para algunos consumidores que así lo requieren; obviamente que cuando se sobrepasan o se mejoran uno cualquiera de estos valores se presentan las multas o las bonificaciones respectivas tal y como están pactadas en cada uno de los contratos. Ya en Colombia se tienen contratos establecidos a cinco años con algunas de las cooperativas mineras del centro del país con for mulas de reajuste que están ligadas a los costos de producción de las minas en cuanto a mano de obra, herramientas combustibles, electricidad, dinamita, etc, etc existiendo además un precio base el cual es estudiado por las partes cada 6 meses para ver que no se haya excedido en la fórmula o se esté muy por debajo de los costos reales de explotación el costo básico pactado inicialmente el cual es afectado obviamente durante cada entrega por los precios o las multas y además, por una fórmula que tiene que ver con la cantidad de calorías entregadas durante el mes respectivo.

Una de las maneras de llegar a tener un verdadero mercadeo en el sentido económico de la palabra del carbón colombiano sería el de la eliminación de los intermediarios que lo único que hacen es reducir sustancialmente los ingresos del pequeño minero lo que conlleva a un trabajo cada vez más artesanal y más rudimentario que va en detrimento de las reservas de carbón del país. Debería, entonces, promoverse una verdadera acción de cooperativisación de estas personas para que se encamine todo su esfuerzo comercial a través de ella y perciban así mejores ingresos y puedan mejorar sus condiciones de vida y las condiciones de minería en sus yacimientos; de igual forma el sector productor tendría mucha mayor fuerza para negociar en mejores condiciones sus contratos con la industria que es lo que no sucede hoy y que a veces es utilizado por las empresas para hacer reducir los precios con el natural detrimento en las condiciones de los mineros y de la minería colombiana del carbón en general.

Por último cabe destacar que una buena proporción de las minas activas vende su carbón a través del sistema cooperativo (un 24,4% de la producción total) Los intermediarios son el grupo con el cual más minas hacen su comercialización directa alcanzando una participación del 46% del total de las minas con un aporte del 33,3% de la producción, el resto (42,3% de la producción total) pertenece a "mercados cautivos" (Véase Cuadro No. 12) en los cuales las mismas Empresas, producen el carbón que necesitan sus plantas como ocurre con Acerías Paz del Río, Coltejer, Fabricato, Cementos del Valle, Cementos Cairo y otras más.

2.1. Destino de la producción

La mayor parte de la producción de carbón es hoy consumida por un número muy limitado de industrias dentro de un mercado que ha estado sujeto a la competencia subsidiada de otras formas de energía cuyo precio había permanecido estático hasta hace muy pocos años. Como sólo la producción con fines coquizables resultaba insustituible, ha sido la industria siderúrgica y de fundición la que ha venido forzando las alzas de precios y el desarrollo de la industria hasta 1974, año a partir del cual el panorama ha dado un vuelco total apareciendo los programas de generación de energía térmica de gestores del nuevo auge esperado del sector.

CUADRO No. 12

LA COMERCIALIZACION DEL CARBON EN COLOMBIA
(Miles de Tons/año)

Regiones	Cooperativas	Otros	Grandes	Total
Boyacá	142	284	183	609
Cundinamarca	116	390	207	713 (T)
	45	82	123	250 (C)
Antioquia		158	390	548
Valle y Cauca	303	30	242	575
Santanderes	104	24	84	212
Totales	710	968	1'229	2'907
%	24,4%	33,3%	42,3%	

El resto de la producción corresponde a "producción para consumo propio" ó "mercados cautivos" de las grandes industrias (Paz del Río, Coltejer, Fabricato, Cementos Cairo, Cementos del Valle, Anchicayá, etc).

Acerías Paz del Río consume el 12% del total del carbón producido en el país, siguiendo en orden de importancia empresarial las Centrales Térmicas de Zipaquirá, Paipa, Anchicayá, Coltejer y Fabricato y las empresas de Cemento tales como Cementos del Valle, Cairo, Boyacá Diamante y Caldas. Otros consumidores importantes son Cartón de Colombia, Propal, Celanese, Planta de Soda, Bavaria, Andina, Cervecería Unión, Peldar, las ladrilleras y los ingenios azucareros.

Sectorialmente el consumo interno del país se distribuye así:

Industria	Del Consumo %
Energía Térmica	35%
Siderúrgica y fundición	15%
Cemento	12%
Ladrillera	10%
Papel	8%
Textil	8%
Soda cáustica	2%
Vidrio	2%
Otros (incluye exportaciones)	8%

De todo el carbón producido, sólo un escaso 6% es utilizado para atender mercados externos de carbón o coque metalúrgico.

A partir de 1985 esta cifra se incrementará notablemente hasta llegar en 1990 a más de un 50% del total del carbón producido por el país.

III- LA SUSTITUCION DE COMBUSTIBLES EN COLOMBIA

Por ser este tema el que ha servido de marco para la organización de este Seminario, haré una muy breve enunciación de "las opciones" que tiene Colombia en este campo, pudiendo llegar a ampliar cualquiera de ellas si la organización y los asistentes así lo desean.

Es bien sabido que Colombia tiene una dotación relativamente privilegiada de recursos energéticos, tanto en lo que hace a su variedad como en cuanto ocurre con la magnitud de algunos de ellos. Esta situación afortunada multiplica las opciones de política y hace más difícil de seleccionar la estrategia a seguir hacia el futuro. En efecto, para llegar a tener la solución más conveniente, en términos económicos y sociales, de sus necesidades energéticas, el país cuenta con una gama muy variada de políticas que puede adoptar sobre todo en un campo tan vasto como es el de la sustitución de combustibles.

Es por ello que resulta conveniente y necesario identificar LAS OPCIONES que tiene Colombia para sustituir el uso de energéticos más costosos y menos abundantes (caso de los hidrocarburos) por otros más baratos y que el país tenga en mayor cantidad (caso del carbón) situación ésta que se presenta en los siguientes sectores principales de uso final de nuestros recursos energéticos:

a) En el sector residencial

En este sector es posible realizar la sustitución del uso de energía eléctrica y gas propano por aplicaciones directas de energía solar para calentamiento de agua como lo han hecho el ICT y el BCH en ciudades como Medellín y Bogotá; igualmente, es posible sustituir cocinol, que es esencialmente gasolina, por electricidad, gas propano o briquetas de carbón en usos de cocción.

b) En el sector industrial

En este sector económico del país es posible llevar a cabo la sustitución de derivados del petróleo por carbón, gas o electricidad en los siguientes subsectores: cemento, alimentos y bebidas, vidrio, papel, hospitales, hoteles, etc.

c) En el sector transporte

Aquí es posible realizar programas de sustitución de uso de gasolina por ACPM, intensificando los programas de dieselización del transporte de carga implantando un programa de desarrollo intensivo de los sistemas de trolley-buses en las principales ciudades, o de transporte rápido masivo en algunas de ellas (casos de Medellín y Bogotá), dándole un mayor desarrollo al transporte fluvial y por ferrocarril ahorrando, así, energía en el transporte de carga y disminuyendo sustancialmente sus crecientes costos lo que de por sí justificaría llevar a cabo una remodelación completa de estos dos sistemas de transporte que el país ha mantenido abandonados desde hace muchos años.

Por último, bien vale la pena iniciar en este sector el programa de utilización de gas como combustible en los vehículos de transporte público empezando esta sustitución en la costa Atlántica.

d) En el sector de generación de energía eléctrica

Es indudable que para Colombia representa una excelente inversión hacia el futuro programar todos los desarrollos térmicos nuevos que se instalen en el país con base en la utilización de carbón como materia prima para la operación de estas plantas.

Alternativas para generar electricidad con fuentes diferentes a las que hoy se están utilizando como ocurre, por ejemplo, en el sistema de Corelca (que opera casi exclusivamente con gas natural) dependerán en el futuro de las políticas de precios de los recursos energéticos que adopte el Gobierno Nacional.

Como puede apreciarse, la tarea de sugerir en dónde se debe hacer una sustitución o en dónde se debe mantener un determinado consumo energético no es sencilla, por cuanto al sector, es en general muy complejo; más aún, debido al gran número de opciones de política, a la considerable interrelación que existe entre las distintas partes del sistema energético con el resto de la economía, y al hecho de que la adopción de una de-terminada política energética tiene incidencias complejas en varios subsectores del mismo sector energético y en la economía en general, hacen que cualquier planteamiento que se haga resulte complejo y difícil de sustentar.

Existen, sinembargo, algunos programas que son mucho más viables que otros y para impulsarlos, muchos países han utilizado diferentes caminos obteniendo resultados alentadores como puede apreciarse en la Figura No.2.

PROGRAMAS DE IMPLEMENTACION DE LA SUSTITUCION

DE ENERGIA, EN LA INDUSTRIA, EN PAISES DESARROLLADOS

PAISES	INCENTIVOS FISCALES O FINANCIEROS			INFORMACION Y ASISTENCIA TECNICA			OTRAS MEDIDAS			NOTAS
	Subsidios	Préstamos	Incentivos en Impuestos	Publicaciones	Conferenc. y Seminarios	Cuerpos Consultor	Prohibición de otros Combustibl.	Ordenes para usuarios del Gobierno	Prohibición discreta de otros combusti.	
ESTADOS UNIDOS			X				X		X	
FRANCIA	X									Derivados del petróleo son gravados con impuestos
ALEMANIA	X			X	X	X	X			
ITALIA				X	X					
GRAN BRETAÑA	X									El fuel oil es gravado
AUSTRALIA			X		X	X				
JAPON		X								

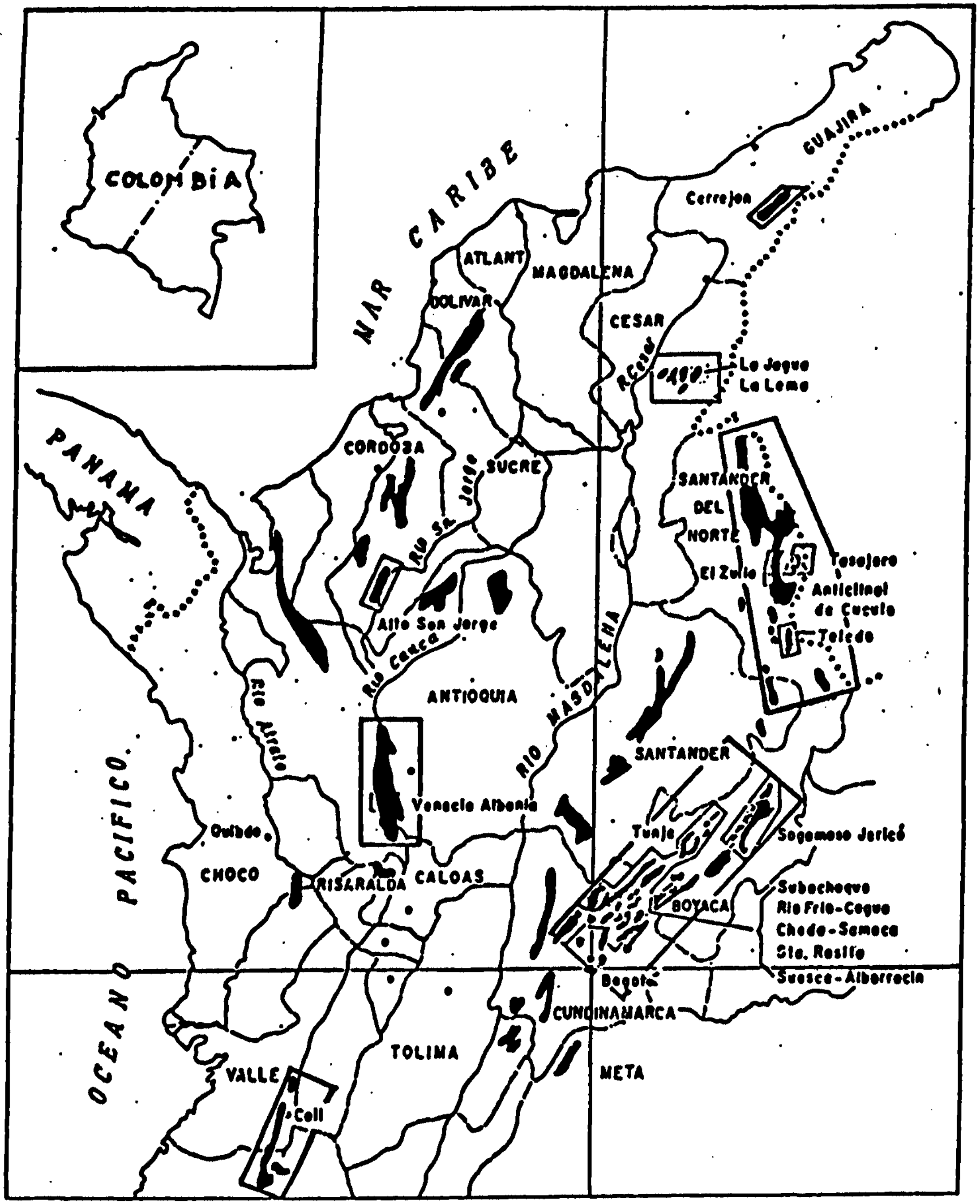
X : MEDIDAS PUESTAS EN PRACTICA

FUENTE: "Coal Industry Advisory Board", Mayo/82

FIGURA Nº 2

LOCALIZACION DE LAS ZONAS CARBONIFERAS

1984



50 0 50 100 Km.
Escala.

CONVENCIONES

Limite Internacional.
Limite Departamental.
Rios
Cuencas o Zonas

Figura No. 3

MERCADO PARA EL CARBON PERUANO
(ECUADORIANO, BOLIVIANO)

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Smith-Gruner
Ponca City, Oklahoma

June 1985

MERCADO PARA EL CARBON PERUANO (ECUADORIANO, BOLIVIANO)

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2. SCENARIO DEL MERCADO PARA CARBONES
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4. MERCADO REGIONAL - SUR AMERICA
5. MERCADO LOCAL - PERU, ECUADOR, BOLIVIA
6. RECOMENDACIONES

INTRODUCCION

El suscrito trabajó como gerente de operaciones para Acerias Paz Del Rio en Colombia durante 1961 - 1965. Subsequentemente se dedicó a "Valorizaciónes de Yacimientos" mundialmente para "The American Appraisal Company"(4 años) y Gerente de Ventas para Joy International en Latino America y el mundo entero.

Desde 1974 está en el negocio de Asesoria y Consulta en todos los Estado Unidos y Canada. INTERAMERICA Marketing fué formado recientemente y esta patronizado por cuatro companias. Un reciente viaje por Colombia, Perú, Chile y Brasil en Abril/Mayo del año y trabajos como asesor contratado por El Banco Mundial el año pasado y varios asignaciones de ingenieria además de las experiencias en casi todas las áreas carboníferas en Latino America, los Estados Unidos, Canada y Alemania formaron la base para este informe.

Agradezco a PROCARBON y al NATIONAL RESEARCH COUNCIL por el material f ornecido y esta oportunidad.

Bruno A. Fichna, P.E.

MERCADO PARA EL CARBON PERUANO (ECUADORIANO, BOLIVIANO)

1. UNA PROFESION CON MUCHOS RIESGOS - PREDECIR MERCADOS PARA CARBON

Como la mayoría de los minerales, carbon es una comodidad limitada a su demanda. En el mundo entero, la disponibilidad de carbones excede sus demandas. Esta situación (más disponibilidad que demanda) está cambiada y influenciada por trés grupos de factores:

1.1 Economias etre combustibles o fuentes de energia.

Carbones estan en competencia con otros fuentes de energia como uranio, fuerza hidroelectrica, viento, esquisto bituminoso, leña, energia solar y una cantidad de otros fuentes de energia.

1.2 Competencia entre otros carbones y mesclas de carbones.

Calidades de carbones son muy variables. Factores como valor termal, coquibilidad, ceniza, azufre y muchos otros determinan la utilidad de una u otra clase de carbon. Tmaño, distribución de tamaños, dureza y composición son factores físicas que determinan e influyen mercados.

1.3 Choques energeticos

Durante el embargo de petroleo en el 1973/74, la alza de precios para petroleo resulto en alzas de precios para carbones. Una escasez repentino de carbones, además, resultó en una carrera hacia nuevos yacimientos. Compañia de petroleo compraron yacimientos de carbon. Plantas industriales cambiaron sus calderas para utilización de carbon. Usinas electricas iniciaron su programa de cambio desde petroleo hacia carbón. El gobierno de los Estados Unidos formo su Departamento de Energia. Este creó su programa de combustible sintetico. Los politicos hablaron del "Proyecto de Independencia". El resultado de estos desarrollos fue la abertura de nuevas reservas y minas de carbon en los Estados Unidos y otroas partes del mundo.

El segundo choque de energia, una abundancia de petroleo, durante 1979/80 resultó en una reducción drastica de precios para carbones. Ningun politica habla más sobre el "Proyecto de Independencia". El programa de combustible sintetico desapareció. El Departamento de Energia esta moribundo y "todos los yacimientos de carbon y tadas las compañias carboniferos de los Estados Unidos" esta para vender.

Para dramatizar la situación en el carbon del mayor mercado interno, mundial, los Estados Unidos, un ejecutivo de una compañia carbonífera mayor dijo en un discurso: "Todo relacionado al carbon esta para venta: los yacimientos, las minas, las vias de transporte, las plantas y todas las casas con la excepcion de mi propia casa".

Como conclusión podemos decir que economias entre combustibles, competencia entre carbones y choques energeticos cambian drasticamente mercados para carbones. PREDECIR MERCADOS PARA CARBONES es verdaderamente UNA PROFESION CON MUCHOS RIESGOS.

2. SCENARIO DEL MERCADO PARA CARBONES

Las consideraciones presentadas en el capitulo precedente entran en mercados locales, regionales y mundiales con varios impactos. La ilustración siguinte (SCENARIO DEL MERCADO PARA CARBONES) indica los varios impactos dentro de los varios mercados. Como mercado local consideramos el Perú (o Ecuador o Bolivia). Como mercado regional consideramos Sur-America. Como mercado mundial consideramos los importadores de carbones. Se puede diferenciar más entre estos mercados, pero eso complicaria la presentacion:

CARBON

Mercado Local
Perú, Ecuador, Bolivia

Factores:
1. Precio de venta local;
2. Precio artificial ?
3. Subsidio ?
4. Flete;
5. Tipo de transacción;
6. Tipo de contratos largo o corto plazo ?
7. Arreglos comerciales;
8. Comerciante intermedio o final del productor al consumidor ?
9. Compra al precio o oligopolia o monopolia?

Mercado Regional
Sur-America

1. Brazil utilizando su propio carbon metalurgico con 17 % de ceniza y buena coquibilidad necesita carbon con poca ceniza (6%) para mezclar.
2. Los desarrollos del norte del Brazil necesitan mucha energia. Hay planos para plantas hidro-electricas y leña. Carbon puede reemplazar leña como combustible para usinas electricas.

Mercado Mundial
Importadores del Carbon como Japon

Factores:
1. Continuidad;
2. Presiones de grupos ambientales (azufre)
3. Vias de transporte;
4. Puertos;
5. Interrupciones;
6. Huelgas.

La confianza en una sola fuente de energia y una sola fuente de carbon puede ser costoso.

COMPETENCIA

- entre otros cobustibles y fuentes de energia →

← - entre carbones →

← - CHOQUES ENERGETICOS

CHOQUES ENERGETICOS - mayor impacto en el mercado mundial.

COMPETENCIA - mayor impacto entre mercados locales y regionales.

Una discusión sobre esto abrirá más impactos. Interrelación de impactos adicionales siguen en los capitulos siguientes.

3. MACRO ECONOMIA - MERCADO MUNDIAL

3.1 Carbon Termal Para Generación de Energia Electrica

El mercado del mayor volumen en el mundo es carbon termal. El alto volumen de este mercado requiere una planeación de consumo de energia electrica a largo plazo. En retorno requiere una planeación de minas grandes de carbon a largo plazo. Cambios y preferencias de ciertos fornecedores de carbon dependen de factores siguientes:

- Seguridad de materia prima - confianza continua (Mercado: Japon)
- Presión de grupos ambientales (Mercado: Europa)
- Economia entre combustibles diferentes (Francia y Estados Unidos)
- Inversiones grandes de capital (La demanda para energia electrica y para carbon en los Estados Unidos fué sobre estimado. El resultado fue sobre capacidad y sobre inversiones de capital tanto en usinas como minas de carbon).
- Presión de grupos ambientales (Minas de carbon en el estado de Ohio casi desaparecieron por su azufre).
- Monopolia de ferrocarriles (El buen y barato carbon del Oeste de los Estados Unidos ya no tiene mercado en el Este por la monopolia de transporte por ferrocarriles).
- Muchos otros factores.

3.2 Carbones para Plantas de Cementos

Contrario al carbon termal, plantas de cementos pueden utilizar una variabilidad de carbones y otros combustibles. Además, plantas de cementos tienen mayores tolerancias de azufre y ceniza.

3.3 Demanda Industrial

La demanda industrial se puede derivar de consumo o conversiones de plantas de papel, plantas quimicas, plantas para comestibles etc. La evaluación del sector industrial es mucho más dificil porque pequeñas calderas a veces pueden aceptar una variedad de combustibles como varios carbones, leña, basura y papel desgastado.

3.4 Resumen sobre el Mercado de Carbones Termales

La proyección para demanda total de carbones termales es relativamente facil. La selección de carbones es relativamente dificil, porque paises de exportaciónes de carbon como los Estados Unidos, Canada, sur Africa, China, Rusia, Polonia, Colombia, Australia e Indonesia tienen factores diferentes con respecto a calidades de carbones y su seguridad de fornecimiento continuo.

Además de los choques de petroleo de 1974 y 1980 y los factores ya mencionados, consumidores (mercados) de combustibles realizaron que

- confianza en petroleo puede ser muy costoso (1974;
- Por este motivo determinaron a desviar de este fuente de energia para energia nuclear y de carbon para generación de energia electrica.
- Ahora - con sobre abastecimiento de petroleo mundial - la tendencia sigue hacia la diversificación de generación de energia a base de petroleo, uranio y carbon.
- Importadores en particular estan convencidos que no pueden contar ni con fornecimiento de una sola fuente de energia, ni con estabilidad de precios ni confiar en una sola fuente de carbon.
- Importadores tampoco pueden confiar en una sola ruta de infraestructura del carbon de la mina para el puerto y hasta el consumidor. La confianza en una monopòlia de infraestructura puede ser muy costoso y sujecto a interrupciónes.
- Otros riesgos para mercados e importadores de carbones son:
  * huelgas en los Estados Unidos y Australia;
  * demoras excesivas en puertos;
  * transporte de carbon con baja prioridad en vias de ferrocarriles;
  * escalación de precios de cadenas de transporte.

Como ejemplo, el mayor mercado de importación de carbon del mundo- Japon - cambió su tendencia de compras en favor a los Estados Unidos desde Australia por motivos de huelgas en Australia.

IMPORTACIONES DE CARBON ~~TERMAL~~ AL JAPON (porcentajes)

Fuente	1980	1981	1990 proyectado
Australia	67.6	47.5	30 - 40
U.S.A.	5.5	17.7	30 - 40
Canada	6.3	10.6	10 - 20
S. Africa	4.6	12.7	5 - 10
China	11.7	10.3	10 - 20
U.S.S.R.	4.3	0.5	5 - 10
Otros	-	0.7	10 - 0
Total	100	100	100

Estas estimaciones tienen confianza solamente para plantas electricas presentes. En case que la segunda generación de usinas electricas de carbon pueden consumir mas variedades de carbones, la divercificación para otros fornecedores puede incluir carbones de Colombia y Perú. La posibilidad de liquifacción en el Japon amplifica aun mas la selección entre fornecedores de carbones.

3.5 Carbon Metalurgico

Mercados para carbones metalurgicos siguen a los productores de acero. Otra vez, el Japon es el importador principal del mundo. Los Japoneses desarrollaron tecnologias para mezclar carbones de baja calidad con carbones de coque. En el momento pueden utilizar hasta 40 % carbon con caracteristicas bajas de coquibilidad.
El motivo para estas mezclas son precios altos de carbones de coque del este de los Estados Unidos, en particular, precios altos de carbones con bajos volatiles.
Otros mercados de carbones metalurgicos internacionales son Korea, Taiwan, Belgica, Francia, España y Brazil. Este ultimo pais consideramos como mercado regional. El analisis del mercado regional o mercado de Sur America sigue.

4. MERCADO REGIONAL - SUR AMERICA

4.1 BRASIL

4.1.1 Mercado para Carbon Metalurgico

Hasta 1974, plantas de acero del Brasil utilizaron pocas cantidades del propio carbon Brasilero debido a su mala calidad (17 a 18.5 % de ceniza; 1.8 % de azufre; 35 % volátiles). La expansion de la industria de acero en el Brasil y al mismo tiempo la escasez de carbon en el mercado mundial durante el "choque de energia" motivo la industria Brasilera utilizar mas carbon local. Desde hace 1975, las trés mayores plantas de acero en el Brasil utilizam mas que 40 % de carbon Brasilero en vez de 25 % antes consumido. Las trés compañias de acero CSN, COSIPA y USIMINAS consumen alrededor de 1 million de toneladas de producción domestica y más que dos milliones de carbon metalurgico importado. Debido al alto porcentaje de ceniza (17 a 18.5%), azufre (1.8 %) y volatiles (35 %) del carbon metalurgico domestico, Brasil tiene que importar carbones de baja ceniza y bajo azufre y volátiles. Casi todas las importaciones de carbon para el mercado metalurgico Brasilero venieron de los Estados Unidos, Polonia y del Canada.

Además de puras importaciones, Brazil esta haciendo esfuerzos de trueques con Polonia, Canada y los Estados Unidos. Conversaciones sobre inversiones en otros paises para producción de carbon metalurgico se llevaron a cabo con Australia, Colombia, Polonia, Canada y los Estados Unidos. Es interesante que los Brasileros rechazaron Colombia como fornecedor de carbon metalurgico. Aunque Colombia tiene reservas de calidades metalurgicos, sus caracteristicas geologicas y locacion en el interior fueron razones de clasificar los carbones "no economicamente explotables".

4.1.2 Mercado para Carbon Termico - un Desafio

Solamente 4 % de la de la generación de energia en el Brasil es a base de carbon, comparado con 30 % a base de leña y carbón vegetal. Debido al bajo valor termal del propio carbón Brasilero (3,200 calorias/kg o 5,800 Btu/libra), se olvido el desarrollo de carbón durante precios bajos de petroleo anter de 1974 y en vista de energia hidroelectrica. El aumento de precios para petroleo importado

motivo el desarrollo de minas adicionales de carbon.
Los trés estados del sur contienen la mayoria de las reservas de carbón Brasilero. Dos de estos estados cuentan con la mayoria de la producción, Santa Catarina y Rio Grande do Sul, mientras que Parana solamente produce carbon termal en pequeñas cantidades. Algunos oficiales del Brasil reportan "reservas extensos" en los estados de Para y Amazonia, pero no se hizo investigaciones hasta la fecha.
El norte del Brasil con muchos desarrollos mineros de hierro, bauxita, manganeso y otros requiere mucha energia electrica. Usinas electricas a base de leña resultan en el agotamiento extenso de selvas. En el momento solamente hay comentarios de habitantes locales sobre este asunto, sin movimiento de grupos ambientales. El verdadero desafio esta en el futuro, reemplazar leña con otros fuentes de energia. Una de estos fuentes puede ser carbón. La tarea mas dificil en la creación de mercados es cambiar costumbres. Deforestación en largo plazo resulta en la erosion del suelo. Pero quien esta pensando en largo plazo ? Aun empresas en paises desarrollados piensan no en resultados durante años sino en resultados durante cuartales. Como podemes esperar que paises en desarrollo piensan en largo plazo ? Deforestación occurrio en los Estados Unidos y esta occurriendo en el Brasil debido a la utilización de leña. La solución es despacio y a largo plazo, nuevamente ilustrando un posible mercado para carbón.

4.2 VENEZUELA

Aunque Venezuela tiene su propio cabón, incluyendo una mina desarrollada (Naricual) y otras minas en producción, tiene que importar carbon metalurgico para su industria de acero cerca de Puerto Ordaz. Esfuerzos de utilizar carbones de Tachira (Lobatera) para la reducción de mineral de hierro tenian exito parcial. El carbon de Lobatera es coquzable, pero el coque no tiene la dureza necesaria para el alto horno. Colombia exporto carbon metalurgico a Venezuela desde Santander del Norte en pocas cantidades. El transporte terrestre sobre una distancia mayor que mil kilometros por camion talvez resulto mas caro que el transporte marítimo desde los Estador Unidos. Otros factores come especificación exacta, confianza de la fuente del carbon y relaciones comerciales limitaron este mercado dentro de Sur America.

4.3 ARGENTINA

Los dos productores de acero en la Argentina, Altos Hornos Zapla y Somisa uilizan carbones de leña y carbon importado. Propio carbon de Rio Turbio no tiene las caracteristicas metalurgicas necesarias, pero este carbón sirve para mezclas. Altos Hornos Zapla, además utiliza un sistema auxiliar de reducción con petroleo, que esta inyectado en el alto horno en adición con so carbon vegetal. Nuevos decubrimientos de carbones en Cordoba en una profundidad de alrededor de 800 metros requiere una catidad de capital, que no es disponible para su desarrollo. Esta situación puede eliminar este yaciniento de la clasificación "reserva economica". El desafio de reemplazar carbón vegetal con carbón metalurgico es el mismo como fue mencionado en relación con Brasil.

4.4 OTROS MERCADOS EN SUR AMERICA

Chile produce su propio carbon en Lota Schwager. Compañia de Acero del Pacifico consume carbon Chileno con pocas cantidades importados para mezclas. La tendencia presente en Chile es menos protección del productor interno que en otros paises Suramericanos. Esta tendencia puede abrir un mercado para carbon metalurcico importado o tambien la importacion de acero en vez de la propia produccion, o sea la eliminación de mercado para carbón metalurgico. Este ejemplo nuevamente soporta la "volatilidad" de mercado para carbón.

5. MERCADO LOCAL - PERU, ECUADOR, BOLIVIA

5.1 Motivación para Crear un Mercado

Deforestación dentro de paises en desarrollo, debido a la populación creciente, recibe una aumentada preocupación. Demanda para tierra a cultivar para agricultura y demanda para leña de cocina resulta en deforestación. La utilizacion de leña es ineficiente. Hay bastante literatura para mejorar el diseño de estufas de cocina y al mismo tiempo mejorar sus eficiencias. Deforestación resulta en la erosión de suelos y al mismo tiempo agrava la disponibilidad para tierra agraria.

Consequentemente hay una necesidad intensa para encontrar un convenient y factible reemplazo para leña.

5.2 Mayor Dificultad - Desarrollo del Mercado

Cambiar costumbres es dificil tato en paises desarrollados como en paises en desarrollo. Quien puede convencer el Norteamericano de abandonar su "fireplace" de leña y reemplazarlo por una estufa de carbon ? Esfuerzos dentro de los Estados Unidos fracasaron aun en vista de la "crisis de energia" durante los setentas.

La intruducción exitoso de reemplazo de leña como combustible con estufas de carbon resulta en problemas tremendas de desarrollo de mercado tanto en los Estados Unidos como en paises en desarrollo como en el resto del mundo.

Problemas técnicas no existen. Hay considerable experiencia industrial disponible para la solución de quemar cualquier carbon. Problemas de mercado son de naturaleza social y envueltan tradiciones y costumbres.

Otro problema es la determinación de precios. La materia prima de leña, en muchos casos, no "cuesta nada". Hay que medir el costo en terminos de esfuerzo humano requerido a recoger la leña. Comparación de valor monetario con valor de esfuerzo es particularmente dificil en paises en desarrollo, porque hay escasez de moneda y mano de obra abundante.

5.3 Mercado de Hogar

Paises con reservas abundantes de carbon cerca a hogares domesticos siempre quemaron carbon para calefacción de hogares. En Colombia, especialmente en la ciudad de Bogotá hay un mercado ~~para~~ carbon grueso. Que es carbon grueso ? Es el carbon que queda encima de una pala-tenedor con la que se carga a mano un camion, un método barato y efectivo para clasificar el tamaño de carbon. Uno de mis antiguos colegas tiene trés minas de carbon de ésta categoria, barato, efectivo y sin inversiones mayores de capital. El unico problema es la venta de carbon fine, lo que cae entre las agujas de la pala tenedos. Se vende este carbon para fabricas de cemento de Bogotá con un precio muy reducido.

5.4 "Regreso al Carbon" - Mercado Industrial - Usinas Electricas

La industria carbonífera en los Estados Unidos con su grupo grupo propagandista la "National Coal Associatión" en sus esfuerzos en Washington para amplificar el mercado para carbon dentro de los Estados Unidos tenia exito muy limitado. El dicho "El carbón podria convertirse en una poderosa fuente de energia" tenia peso durante escasez de petroleo en 1974. Hoy en dia, la contribución monetaria de productores de carbon en los Estados Unidos ha creado el proyecto "Coalition", un proyecto educativo para convencer el publico de favorecer el carbon. Advertencias de un minuto en la televisión nacional de "Coalition" aparecen durante programas nacionales como cambionatos de deporte. El éxito de desarrollar mercado por convencer el pueblo y politicos en los Estados Unidos fue muy limitado.

En Alemania estan hablando de reemplazar petroleo por carbon y regresar "zur guten alten Kohle" desde hace cuarenta años. Durante el mismo tiempo, hogares de carbon convertieron a gas o petroleo, plantas industriales convertieron a petroleo y la producción de carbon en Alemania cayo de 125 milliones de toneladas a 80 milliones de toneladas.

Esta dramatización de reducción de mercado o dificultades para utilizar mas carbón en paises desarrolladas esta mencionado aqui para anticipar y resolver las problemas que se puede encontrar en el desarrollo de un mercado en el Peru, Ecuador y Bolivia.

Hay una discrepancia tremenda entre "lo que se puede sustituir en petroleo por carbón" y "lo que se sustituye".

El factor mas sgnificante de frenar el mercado de carbon, se dice, son grupos de presión a mantener un ambiente limpio. Esto llegó al extremo en la Republica Federal de Alemania, donde "Die Grünen", "los verdes" formaron un partido politico y estan representado en el congreso Aleman (Im Bundestag).

En conclusion: Desarrollar mercados de carbon envuelta mas problemas politicas, tradiciones y costumbres que problemas técnicas.

5.5 Precios, Competencia Local, Asuntos Comerciales etc. como Elementos del Mercado

5.5.1 Precio de Venta Local

En Colombia, la mina subterranea más grande del pais "La Chapa" de la compañia Acerias Paz Del Rio esta designado para cerrar en el futuro cercano. La segunda mina de Acerias, Samacá, ya esta cerrado. Productores de minitas chiquitas podian vender carbon para Acerias con precios más bajos que la propia prducción lo que resultó en el cierre de las minas - el problema inherente de carbon - más capacidad que demanda.

5.5.2 Precio Artificial

Precios artificiales como existen en Alemania - protección de productor mantienen el mercado y eliminan competencia, tambien con precios artificiales en forma de recargos aduaneros.

5.5.3 Subsidio

Subsidios para fomento de mercado para carbon pueden tener varias formas. Impuestos y recargo al precio de fuentes de energia alternativa es un subsidio "escondido". Perdidas en la venta de carbon en Alemania, donde el precio de venta en menor que los costos de producción estan compensados por el estado. Algunos politicos consideran este hecho como "premio de seguro" contra la alza de precios para petroleo importado. En el Perú , kerosene como combustible esta subvencionado por el Estado.

5.5.4 Flete

Mercados locales estan limitados por su infraestructura o fletes desde el productor al mercado.

5.5.5 Tipo de Transacción

En las pequeñas minas de Colombia, el liente paga el minero en moneda efectiva antes de cargar su camion o volqueta, una tranacción de costo bajo, pero limitado a cantidades pequeñas.

5.5.6 Tipo de Contratos, largo o corto Plazo ?

Termoelectricas, tradicionalmente hacen contratos de muchos años.

Plantas metalurgicas y termoelecricas necesitan confianza en su fornecedor de carbones especificos y en retorno son mercados estables. Por ejemplo, si CENTROMIN pudiera reemplazar so carbon importado de 35,000 toneladas por año, hay que averiguar si Perú tiene un carbón util para CENTROMIN. También hay que investigar de que consiste el contrato vigente.

5.5.7 Arreglos Comerciales

En minas pequeñas de carbón en Colombia, el comprador llega a la mina, paga por su carbon en efectivo, carga su camion con pala cargador y el arreglo comercial esta terminado- no costo administrativo. La clasificacion de tamaño esta hecho con la pala tenedor de agujas. Lo que queda encima de la pala es carbón grueso y vendible para el mercado domestico de hogar. Lo que cae entre las agujas de la pala es carbon fino y sirve para el mercado de cemento con menor precio.

5.5.8 Comerciante Intermedio o Final del Productor al Consumidor ?

Para organizar un mercado para un grupo de minas, el comerciante intermedio tiene su lugar. Contratos grandes, en general, estan hechos directamente entre el productor y el consumidor.

5.5.9 Compra al Precio o Oligopolia o Monopolia

Finalmente, abundancia de carbon hace dificil la formación de monopolia o oligopolia, como OPEP en en petroleo. Sin embargo, existen organismos similares, como el Alemania, donde el consumidor tiene que comprar su carbon Aleman con precios artificialmente altos. En el resto del mundo, en general, el comprador compra al precio competitivo. Este punto esta enfocado en el capitulo siguiente - recomendaciónes.

6. RECOMENDACIONES

Si el termino "Economia del Productor" (Supply Side Economics) tiene merito, la aplicación para desarrollar un mercado para carbón es la más clasica.

Literatura sobre Peru indica la ausencia de un mercado seguro. Al mismo tiempo mencionan "intenciónes de fábricas al uso de carbón a reducir los costos de sus productos, otra vez "Economia del Productor." En este sentido recomendamos la rebaja de costos de producción en vista de errores frequentemente hechos en las categorias siguientes.

6.1 Exploración

En yacimientos de carbon con afloramiento en "condiciones inapropiados", la mejor exploración es la explotación. Averiguación del techo y del piso y espesores de los mantos, tendencia de fallas es más importante que calculo de reservas.

Al contrario, en yacimientos con buenas condiciones y en anticipación de una produccion alta y a largo plazo, definición y calculo de reservas es el factor más importante.

6.2 Alternativas

Cuándo se contrata un ingeniero Americano o Aleman o Canadiense o Ruso o Polaco o Sur Africano con "la ultima experiencia" en el diseño de minas para un nuevo yacimiento, el resultado son seis diseños diferentes. Cabe la buena posibilidad que ninguno de éstos ingenieros ha considerado alternativas de diseños de mina y alternativas de métodos de explotación. Como sabe, si el diseño presentado es el mejor con el costo de explotación más bajo ?

6.3 Gasta su Tiempo donde esta el Dinero

Muchos estudios de mineria enfocan, por ejemplo en procesos de beneficiamiento, que tiene un costo menor en el costo total, mientras la maniobra de materiales - con el mayor costo - no recibe atención.

6.4 Queda dentro de sus Limites

Limites pueden ser "capital" o "mano de obra".

En yacimientos como Alto Chicama en el Peru, donde ocurren mantos de 1.50 m de espesores y 65° de busamiento, la mano de obra barata es el mejor ingrediente. Peritos del Brasil, donde estas condiciones estan desconocidos, consideraron yacimientos similares de Colombia "inexplotables". En los Estados Unidos, estos recursos no son reservas economicas. En Alemania después de la segunda guerra mundial cuando no habia maquinaria, esta clase de mantos tenia el más alto rendimiento y el más bajo coste, porque los mineros no necesitaban palas. El carbón salió del frente por gravedad.

Mantos planos y con excelentes condiciones geologicas come en los Estados Unidos no sirven para la explotación manual.

Limites de la disponibilidad de capital en muy importante para Sur-america. El diseño de minas y de métodos de mineria debe estar dentro de estos limites.

6.5 Briquetes de Carbón

En varios paises de desarrollo, como Perú, Pakistan, Indonesia, Tanzania y Malavi, ya se ha estudiado la fabricación de briquetes para el desarrollo de mercado domestica para carbon. En Alemania, hace más que 50 años, briquetes fueron usados ampliamente en estufas de hogar. Indústrias ya existen en India y Korea para la calefacción espacial. En Pakistan hay demanda potencial para calefacción de hogares como ya existe en Korea.

La comercialización de comprimidos o briquetes de carbón sin humo como sustituto de leña y kerosene puede crear un mayor mercado en áreas rurales. Existen proyectos para instalar industrias locales en los alrededores de las minas, allí se podrían utilizar el polvo y residuos para mezclarlos con ciertos aglutinantes (brea, asfalto líquido, arcilla, etc.Al comprimirse esta masa con prensas especiales se obtienen pastillas ovoides de 45 a 50 gramos aproximadamente, para uso doméstico (vea "Regreso al Carbon" página 31).

6.7 Conclusión

En palabras cortas:

El mercado de carbones de Perú, Ecuador y Bolivia esta limitado solamente por:

- bajos costos de producción;
- movimientos politicos;
- tradiciónes y
- costumbres.

COAL COMBUSTION TECHNOLOGIES BECOME AN IMPORTANT CONSIDERATION IN COAL MINING AND MARKETING

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COAL COMBUSTION TECHNOLOGIES BECOME AN IMPORTANT CONSIDERATION IN COAL MINING AND MARKETING

ABSTRACT

Combustion of coal and the resulting ash characteristics in coal-fired furnaces have become an increasing concern for coal companies who market blends of coal from different depositional environments. Deterministics formulas and relationships have been developed to predict the combustion characteristics of various coal blends. These relationships have been programmed into computers to develop multiple alternatives for burnability and compatibility of various coal blends.

The general application of these predictive methods should better enable coal producers to identify potential markets for blended products and determine potential coal blends to utilize coal seams which have previously been rejected as unusuable products.

INTRODUCTION

In the past, most marketing efforts by mining companies have been based on BTU, ash, moisture, sulfur, grindability and ash fusion temperature. Custormers who are primarily power producers with large coal-fired boilers have selected the lowest price coals, with known combustion characteristics, that were proven compatible with existing boiler design. This had, in fact, tended to regionalize the marketing strategy of coal producers, since the electric industry preferred coal from specific depositional environments.

However, in the past few years there have been several changes in the scenario for coal marketing strategy. Some of these changes are:

A. Changes in economics making low-BTU western coals available to additional markets through unit rail transportation;

B. Increased price of eastern coals through higher labor costs and lower productivity;

C. A landslide of environmental laws and regulations, many based on sulfur content, affecting the production and burning of coal, i.e.:
   - Clean Air Acts Amendment of 1977
   - Resource Conservation & Recovery Act of 1976
   - Toxic Substances Control Act
   - Surface Mining Control and Reclamation Act of 1977
   - Clean Water Act of 1977
   - National Environmental & Policy Act of 1969

D. An awareness of the micro-economics involved with determining the optimum coal, transportation, and burnability for coal-fired boilers.

This new scenario has not only made a multiplicity of coals available from many new regions, but it has also introduced burning compatibility problems for certain blended coals and for specific boiler designs. The majority of the coal-fired boilers have been designed to use high-fusion-temperature coals that would produce a dry ash when burned. However, the introduction of high-sodium, low-fusion coals, such as Powder River Basin Coals, has created the need for designed blending to obtain a product whose ash-fusion characteristics will not require that the boiler be derated.

Thus, the coal producer and purchaser must be aware of the implications of burning coals from different depositional environments. The marketing strategist must analyze the economical advantages of purchasing low-BTU, high-ash/high-moisture, low-fusion, and other low sulfur coals vs. high-BTU, low-ash/low-moisture, high-fusion and high in sulfur coals. Specific consideration in this synergistic evaluation include:

A. FOB mine cost per million BTU;
B. Transportation cost per million BTU;

C. Combustion characteristics of coal in large utility boilers (derating or slagging characteristics); and

D. Environmental advantages of each burn.

Of these variables, the ones that have had least consideration in the past have been the coal ash-fusion properties and the burning characteristics. Since the utilities burning lower BTU coals have had to face the problem of derating boilers, handling large amounts of slag, and minimizing increases in the generating costs, all available technology must be utilized to insure maximum generating capability at the lowest cost. This paper will focus on the important consideration of the behavior of coal in large boiler furnaces and how this knowledge can be utilized by the coal producer and the coal buyer.

Problems in burning pulverized coal involve mainly furnace temperatures and ash-fusion. Since the heat release rate establishes furnace temperature and is a function of the heating value of the coal, the furnace dimensions and the firing rate, it is the ash-fusion characteristics that determine the maximum available rating for a given coal.

Research on the behavior of coal ash at furnace temperatures was carried on by the U.S. Bureau of Mines beginning in the 1930's. That research, plus continuing efforts by the boiler manufacturers and the coal industry, provides a fund of information that is widely use today in selecting coals for steam generation.

UTILIZATION OF INFORMATION

The problem of compatibility of coal blends may be critical to the producer, marketing agent and/or user. The producer or mining company must be assured that the product can be efficiently burned by the user without slagging or fouling problems. Instances exist where boilers were slagged, or "thought to be slagged", by a coal from a certain company, resulting in expensive slag removal fees imposed upon the producer. Such problems may or may not be a result of the coal combustion characteristics of the particular producer when examined in the technology of blended coals.

Marketing agents and power producers must utilize all information possible to insure coal can be sold or purchased for the optimal price. Many times, industrial and electric consumers burn a multiplicity of coals that must be compatible on a blended basis. Thus, it is in the best interest of all parties to be confident in advance of test burns that certain coal can be successfully burned on a blended basis.

ASH SLAGGING AND FOULING CORRELATIONS

The design of large pulverized-coal-fired boiler furnaces is established largely by the fusion characteristics of coal ash. The volume of the furnace must be sufficient to allow adequate space for burning the combustible matter in the coal, but the burner location, the shape of the flame envelope, the amount of heat-receiving surface in the furnace, and the location and design of connective tube banks for superheaters and reheaters is fixed by ash properties. Further, operating conditions and maintenance programs are affected more by ash than by other characteristics of the coal.

The magnitude of these differences can be judged from the amount of heat-absorbing surface that must be provided in large steam generators with different fuels. The maximim heat transfer rate to clean surfaces in a boiler, which is established by water conditions inside the boiler tube, is about 175,000 BTU/ft^2hr., and in burning natural gas, this rate can be attained. With oil firing, the rate may be 135,000 BTU/ft^2hr. With coal having an ash-fusion softening temperature above 2400^oF, the rate may be 100,000 BTU/ft^2hr. Lower ash-fusion Pennsylvania coals may lower this to 90,000; Illinois No. 6 coals may be limited to 80,000; and high-sodium lignites may permit no more than 45,000 BTU/ft^2hr. Since the size of the boiler furnace for a given output of steam depends upon this rate of heat transfer, it is evident that a boiler furnace to burn high-sodium, badly fouling coals would be roughly twice as big as a furnace burning an Eastern bituminous coal.

It is evident, then, that careful consideration must be given to the quality of the ash in the coal, as well as the quantity, in assessing the suitability of any given coal for steam generation in large central-station boiler furnaces.

Over the past half century, since pulverized-coal firing has largely taken over this field, many correlations have been developed to predict ash behavior from the chemical composition of the ash or from such laboratory measurements of melting characteristics as the ASTM cone fusion determination.

The correlation methods discussed here for assessing the behavior of the ash are those most commonly accepted. All these methods can be related to the chemical composition of the coal ash. Different interpretations and varying importance are placed on some of the compositional variables, but generally there is a broad agreement on the factors that lead to operational problems.

Silica Percentage

This is the earliest of the correlation methods, coming from the U.S. Bureau of Mines in the late 1930's; the "silica percentage" is the SiO_2 in a coal-ash analysis reclaculated so that $SiO_2 + Fe_2O_3 + CaO + MgO =$ 100 percent. It is an indication of viscosity at

2600°F, used originally for predicting flow of slag from slag-tap furnaces, but now applied widely in estimating ash behavior at temperatures higher than about 2000°F. The correlation applies for wide variations in iron oxide, lime and magnesia and for nominal levels of the alkalies. Viscosity varies exponentially with silica percentage, from 1 poise at 2600°F for a silica percentage of 30 to 1000 poises for a silica percentage of 82. These are the nominal limits for most coals. For slag-tap furnaces, a viscosity of 10 poises assures easy slag removal; for cyclone furnaces, the viscosity must not be more than 250 poises for satisfactory slag flow. As for fouling, there is no specific limit of silica percentage for non-fouling coals; the maximum level will depend on furnace design. Arbitrarily, a silica percentage of 50 (10 poises viscosity) is probably the lower limit, with 75 (400 poises) or higher, a likely indicator of little slagging or fouling in dry-bottom furnaces. Means are available for converting viscosity at 2600°F to slag viscosity at higher and lower temperatures.

Base-Acid Ratio

This correlation method was devised in the late 1950's by Babcock & Wilcox. It is another method of predicting slag viscosity from chemical composition, using the ratio of the bases (Fe_2O_3 + CaO + MgO + K_2O + Na_2O) to the acids (SiO_2 + Al_2O_3 + TiO_2). The useful limits of the ratio are 0.1 and 1.0. For dry-bottom pulverized-coal-fired boiler furnaces, the base-acid ratio should not be greater than about 0.5; for slag-tap units the ratio should be more than 0.27. The base-acid ratio is widely applied because of its simplicity and general usefulness, but it is less precise than the silica percentage for predicting slag viscosity. Its greatest use has been for estimating the temperature at which a slag has a viscosity of 250 poises (T_{250}). Slags with a higher viscosity at furnace temperatures will not flow satisfactorily from cyclone furnaces, but such furnaces are not being built today.

(Ash fusion temps)

Cone Fusion Temperature

The ASTM cone fusion determination is an empirical test devised by the U.S. Bureau of Mines in 1915 to indicate the behavior of coal at furnace temperatures. Four stages of melting of the 3/4 inch-high triangular-based cones of coal ash are observed at a constant heating rate of 15°F per minute: as the tip of the cones become rounded (I.T.); as the cones melt to a flattened sphere with the height equal to the width (H.T.); and finally as the cones melt completely (F.T.). Cone fusion temperatures are only broadly useful since the conditions of the test, particularly the heating rate, differ so greatly from an actual furnace environment. The softening temperature (S.T.) is most widely used. Small changes in S.T. are not significant. Mostly, coal ash is classed as low melting if the S.T. falls between 1800°F and 2200°F; as moderately fusible between 2200°F and 2600°F; and as a refractory ash above 2600°F.

Temperature of Critical Viscosity (T_{CV})

This parameter also was developed by the U.S. Bureau of Mines. It identifies the temperature where, by cooling, a coal ash slag changes from a viscous "glass" to a pseudo-plastic "solid", thus radically affecting slag movement on furnace walls. Although T_{CV} has strong support on a theoretical basis and has been the subject of extensive investigation in the laboratory, it has not been applied practically in the field. Involved mathematical calculations can predict T_{CV} from ash composition, but is more common to be T_{CV} on the cone fusion H.T. plus 200°F. Viscosity predictions have little value below T_{CV}.

T_{250}

This parameter has already been mentioned; it is the temperature where a coal-ash slag has a viscosity of 250 poises under mildly reducing conditions, as is required for tapping the slag from a cyclone furnace.

It can be calculated from the silica percentage or from the base-acid ratio.

Slagging Factor R_s

Although developed for "Eastern" coals, and having little theoretical basis, R_s has been used with some success to predict slagging in dry-bottom furnaces. It is calculated as the base-acid ratio times the sulfur content of the dry coal. For R_s less than 0.6, slagging is "minimal"; between 0.6 and 2.0, slagging is "medium"; between 2.0 and 2.6, "high"; and greater than 2.6, "severe". Application of R_s to "Western" coals with low pyritic sulfur content is unreliable, but is often used.

Fouling Factors, R_f and $R^1{}_f$

These parameters, developed empirically, are intended to predict fouling of superheaters and reheaters as a function of ash composition. Both were developed for "Eastern" coals (where the Fe_2O_3 content is greater than the CaO + MgO), but $R^1{}_f$ is seldom used because it is based on low-temperature ashing of the coal, a technique requiring highly specialized equipment and long ashing periods. When the fouling factor R_f is less than 0.2, fouling is low; between 0.2 and 0.5, fouling is medium; between 0.5 and 1.0, high; and above 1.0, severe. Methods to calculate R_f and $R^1{}_f$ are shown in Appendix A.

Alkalies

"Sodium" (Na_2O) is used in calculating the R_f fouling factor, but K_2O also is present in many coals, on the average about equal percentagewise to Na_2O. Because of the different molecular weights, K_2O times 0.659 is equivalent to Na_2O, hence the total alkalies are often expressed as $Na_2O + 0.659K_2O$. These alkalies are a major factor in fouling because they lead to the presence of a "sticky" layer on tube surfaces, as well as lowering the temperature where ash particles will sinter and thereby agglomerate to form massive deposits. And since it is the alkalies in the coal that are really important, because some alkalies are volatized during ashing, alkalies in coal are more meaningful than alkalies in ash. Reliable data is not available as yet on the tendency of alkalies in "Western" coal to cause fouling, hence the role of alkalies must be deduced from experience with "Eastern" coals (with Fe_2O_3 greater than CaO + MgO). For alkalies less than 0.3 percent in the coal, fouling is low; between 0.3 and 0.45 fouling is medium; between 0.45 and 0.6, high; and above 0.6, severe. At present, this is one of the most powerful of the fouling predictors.

A further yardstick is the "sodium/ash yield ratio" used with great success in Australia to predict fouling. The critical value of this ratio falls between 0.035 and 0.040; fouling increases rapidly at higher ratios of sodium to ash yield. More simply, alkalies in ash amounting to more than 4 percent can be expected to cause troubles.

Ash Content

Obviously, the greater the amount of ash in coal, the higher will be the tendency to foul, simply because there will be more ash suspended in the furnace gases. Complex relationships have been developed empirically to relate fouling to ash content, but these correlations rely heavily on furnace design and operation.

One major Midwest utility has developed such a correlation for the coals available to it and burned in its furnaces. Their "slagging index" modifies the "slagging factor, R_s" by multiplying $(R_s)^2$ by the pounds of ash per million BTU, and dividing this product by the square root of the ash softening temperature (S.T.). The resulting slagging index is a good measure of the problems they experience with slagging. When the index is lower than 0.24, slagging is low; between 0.24 and 0.52, slagging is average; between 0.52 and 0.65, slagging is high; and above 0.65 it is severe.

There is no theoretical basis for such a correlation, which was developed from manipulating slagging data over long periods with coals that were roughly similar.

Potential Capture of SO_2 in Fly Ash

Flue gas desulfurization by the alkaline constituents of fly ash formed from burning western coal has been observed both in laboratory studies (see Ness, Sondreal and Tufte, "Symposium on Flue Gas Desulfurization", March 1976, EPA-600/2-76-B6a) and in full-scale boiler furnace operations. In these latter tests, flue gas scrubbers installed primarily to control particulate emissions also removed appreciable amounts of SO_2.

Capture of SO_2 from flue gas by alkaline constituents in the fly ash is accomplished by the following reactions:

$$CaO + SO_2 + 1/2\ O_2 \longrightarrow CaSO_4$$
$$MgO + SO_2 + 1/2\ O_2 \longrightarrow MgSO_4$$

Although Na_2O and K_2O might also be considered potentially reactive material in the flue gas. If their levels are low, CaO + MgO can be used reliably as a measure of alkalinity.

The formula developed for this assessment assumes a one-to-one mole ratio for sulfur to calcium or magnesium. Therefore, 64 pounds of SO_2 would be captured by 56 pounds of CaO, or by 40.32 pounds of MgO. This assumption represents the theoretical maximum amount of SO_2 that could be captured by the alkaline earths in a given coal. Therefore:

$$\text{Maximum } SO_2 \text{ consumed} = \frac{(64)}{(56)} \frac{(\text{lbs ash})}{(\text{million BTU})} \frac{(\%\ CaO)}{(100)} \frac{(100-\%SO_3)}{(100)}$$

$$+ \frac{(64)}{(40.32)} \frac{(\text{lbs ash})}{(\text{million BTU})} \frac{(\%MgO)}{(100)} \frac{(100-\%SO_3)}{(100)}$$

$$= (0.01143)(\%CaO) + (0.01587)(\%MgO)(\text{ash burden}) \frac{(100-\%SO_3)}{(100)}$$

The final quantity in the above expression restates the percentage CaO or MgO on an SO_3-free basis. The entire expression must be multiplied by 0.8 for dry bottom furnaces, because about 80 percent of the total ash burden is carried up the stack as fly ash, whereas the remaining 20 percent remains in the furnace as bottom ash where temperatures are high enough to prevent formation of sulfates.

APPENDIX A

CALCULATION METHODS AND USEFUL LIMITS FOR ASH PARAMETERS

- Silica Percentage = $100 \left(\frac{SiO_2}{SiO_2 + Fe_2O_3 + CaO - MgO} \right)$ all in percent

  Low 30 (viscosity about 1 poise)

  High 82 (viscosity about 1000 poises)

- Viscosity, poise at 2600°F

  Log viscosity = (0.06674 x Silica Percentage) - 2.4367 + 1

- Total alkalies

  - in ash = $Na_2O + 0.659\ K_2O$
  - in coal = (% ash, dry basis) ($Na_2O + 0.659\ K_2O$)

  Alkalies in coal, fouling tendency:

Low	0.3
Medium	0.3 - 0.45
High	0.45 - 0.6
Severe	0.6

- Base/acid ratio = $\frac{Fe_2O_3 + CaO + MgO + Na_2O + K_2O}{SiO_2 + Al_2O_3 + TiO_2}$ all in percent

Low	0.0 - 0.5 for dry-bottom furnaces
High	1.0 - 0.27 for slag-tap furnaces

- Slagging factor, R_s = (base/acid ratio) (% sulfur, dry basis)

Minimal	0.6
Medium	0.6 - 2.0
High	2.0 - 2.6
Severe	2.6

- Fouling Factor, R_f = (base/acid ratio) ($Na_2O + 0.659\ K_2O$ in ash, percent)

Low	0.2
Medium	0.2 - 0.5
High	0.5 - 1.0
Severe	1.0

7. Ash burden = $\dfrac{(\%\ \text{Ash, dry basis})\ (1{,}000{,}000)}{(100)\ (\text{Heating value, BTU per pound, dry basis})}$

Low 5 lb/million BTU
High 25 lb/million BTU

8. Pounds SO_2 per million BTU, as fired

$$= \frac{(20{,}000)\ (\text{percent sulfur, dry basis})}{(\text{Heating value, BTU per pound, dry basis})}$$

9. Pounds So_2 captured in fly ash, per million BTU

$$= \frac{(64)}{56}\ (\text{ash burden, lbs/million BTU})\ \frac{(\%MgO)}{100}\ \frac{(100 - \%SO_3)}{100}$$

$$+ \frac{(\ 64\ )}{40.32}\ (\text{ash burden, lbs/million BTU})\ \frac{(\%MgO)}{100}\ \frac{(100 - \%SO_3)}{100}$$

multiplied by 0.8 for dry-bottom surfaces;

multiplied by 0.5 for slag-tap furnaces.

10. Pounds SO_2 remaining in flue gas per million BTU

(Pounds SO_2 per million BTU as fired) - (Pounds captured in fly ash, per million BTU)

NOTE: The material in this appendix is summarized in part from information in "External Deposits and Corrosion: Boiler and Gas Turbines" by W.T. Reid, Elsevier Press, New York, 1971.

UTILIZACIÓN DEL CARBÓN
EN LA INDUSTRIA DEL CEMENTO

Ing. Rubén Céspedes B.
Antofagasta, Chile
June 1985

UTILIZACION DEL CARBON EN LA INDUSTRIA DEL CEMENTO

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- CARACTERISTICA DE ALGUNOS CARBONES CHILENOS.

ANEXO - 2

- ESQUEMA DE INSTALACION PLANTA ANTOFAGASTA.

ANEXO - 3

- CUIDADOS Y RECOMENDACIONES EN EL MANEJO, PREPARACION Y USO DEL CARBON EN POLVO.

BIBLIOGRAFIA.

UTILIZACION DEL CARBON

EN LA INDUSTRIA DEL CEMENTO

INTRODUCCION

El costo de la energía en general y de los combustibles en particular expresados en moneda de valor constante, se ha cuadruplicado en los últimos años. Esto ha significado que en muchas industrias el costo de la energía involucrada en el proceso se ha transformado en un factor de mucha importancia.

En algunos casos la energía ha llegado a ser del orden del 40% al 50% de los costos directos de producción.

A partir del embargo del petróleo en 1973-1974, se inició en los países desarrollados la preocupación de buscar en forma intensa, nuevas formas de producir energía de manera de independizarse de tan necesario elemento.

Es un hecho indiscutible que esta preocupación hoy día no debe de ser solo en los países industrializados, dado que dentro del contexto global de crecimiento de un país en vías de desarrollo, estos aspectos no pueden pasar inadvertidos y más aún deberían considerarse con urgencia, con la finalidad de conseguir un óptimo aprovechamiento de los recursos naturales y económicos disponibles.

De acuerdo con cifras proporcionadas por firmas responsables, las reservas probadas de petróleo en el mundo permitirían abastecerse al actual ritmo de demanda solo por unos 34 años más.

Una parte importante de la energía es consumida en la industria, en procesos que perfectamente podrían emplearse otros tipos de combustibles o fuentes alternativas disponibles en abundancia.

EL CARBON COMO ALTERNATIVA

El carbón ha sido un combustible normalmente utilizado en la industria del cemento, prueba de ello es que actualmente exiten en el mundo numerosas instalaciones que lo utilizan como fuente de energía calorífica y otras que se encuentran preparadas para el uso alternativo o combinado de carbón y fuel-oil o gas.

Repartición porcentual de los combustibles en la industria del cemento entre 1960 y 1980 en Alemania

	Carbón	Gas	Fuel
1960	80 %	-	20 %
1965	48 %	-	52 %
1970	10 %	15 %	75 %
1973	3 %	25 %	72 %
1975	6 %	22 %	72 %
1977	10 %	24 %	66 %
1980	40 %	10 %	50 %

Las previsiones actuales son indicativas que hay necesidad de diversificar fuentes energéticas imponiéndose como solución una conversión de petróleo a carbón en la industria cementera.

CONVERSION DE PETROLEO A CARBON

Un estudio de factibilidad técnico-económico debería indicarnos la rentabilidad del cambio, considerando la fuerte inversión que requiere la transformación y los aspectos técnicos más importantes a considerarse, tales como:

- Características del carbón a utilizar.
- Innovaciones o nuevos equipos a montar.
- Influencia del uso del carbón en el proceso.

CARACTERISTICAS DEL CARBON PARA LA INDUSTRIA DEL CEMENTO

Será requisito primario que la fábrica tenga una disponibilidad segura de abastecimiento y de una exigente homogeneidad, para evitar alteraciones constantes en la dosificación del crudo con los consiguientes problemas en la conducción del horno y modificación en la calidad del clínquer.

Aunque no debe olvidarse que se han utilizado carbones muy variados en la industria del cemento, es aconsejable que además del grado de homogeneización citado, el carbón cumpla con un cierto grado de calidad.

ANALISIS DEL CARBON

Para clasificar los carbones se utilizan dos tipos de análisis:

a. El análisis aproximado, que comprende la determinación cuantitativa de la humedad, volátiles, carbono y cenizas. Este análisis sirve para la evaluación rápida, orientativa, de un un carbón.

b. El análisis elemental, se emplea para el cálculo exacto de los procesos de combustión y comprende la determinación de los siguientes componentes: humedad, carbono, hidrógeno, oxígeno, azufre, nitrógeno.

Estos últimos son los componentes combustibles del carbón.

Cuanto mayor es la proporción de estos componentes en el combustible, tanto más elevado es el calor de combustión. Cuando se valora un combustible únicamente se tiene en cuenta el carbono y el hidrógeno que contiene.

HUMEDAD BRUTA

El concepto humedau bruta nos indica la cantidad de agua física que se ha adherido al grano de carbón producto de su preparación, almacenamiento y/o transporte.

Incide notablemente en el consumo energético de la instalación, ya que se requieren como valor medio 1.500 kcal/kg. de agua evaporada.

El calor necesario para el secado puede provenir de un hogar auxiliar o de los gases de escape del horno o del enfriador de parrilla.

Cuando se emplean molinos tubulares para su refinación una humedad superior a 8% puede ser tolerada, a valores mayores será necesario un secado previo.

TRITURABILIDAD (Dureza)

Esta característica influye notablemente sobre la molturabilidad del carbón.

La dureza se expresa en índice Hardgrove siendo recomendable un mínimo de 55, y como ideal 70. En Chile se operan carbones con dureza 40-50 Hardgrove.

CALIBRE

La industria del carbón ofrece por lo general distintas bandas de granulometrías. La industria del cemento obligada a consumirlo en polvo puede aceptar valores como máximo de 40 mm., lo aconsejable entre 20 - 0 mm.

Como regla general, las bandas inferiores de granulometrías son las que se compran a menor precio/tonelada.

DISTRIBUCION GRANULOMETRICA USUAL EN CHILE, EN LA INDUSTRIA DEL CEMENTO (%)

MALLA	LOTA		CORONEL	
	% Parc.	% Acum.	% Parcial	% Acumul.
30 mm.	0	0	0	0
30 - 10 mm.	20	20	15	15
10 - 5 mm.	23	43	22	37
5 - 1 mm.	40	83	44	81
- 0 mm.	17	100	19	100

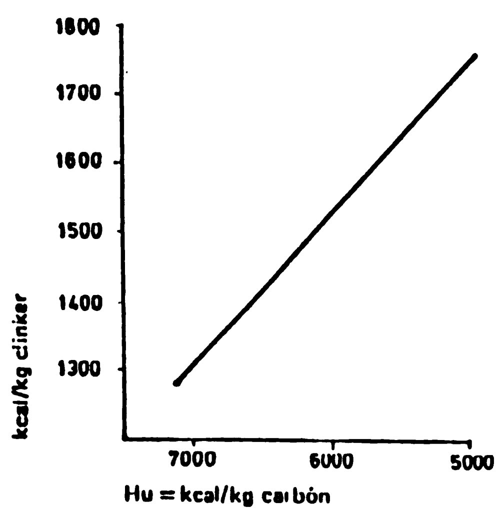
PODER CALORIFICO

Por definición, el poder calorífico representa la energía que se libera durante la combustión.

El poder calorífico aumenta con el mayor grado de carbonización (edad del carbón), es decir, desde turba pasando por lignitos hasta la antracita.

Naturalmente es deseable, si es posible, obtener un carbón con alto poder calorífico. Una explotación económica del horno exige un carbón con un poder calorífico aconsejable de 6.000 - 6.800 kcal/kg. (poder calorífico inferior).

Los carbones con poder calorífico bajo elevan el consumo específico de calor para la cocción de clínquer y rebajan el caudal del horno.



Consumo específico de calor para la cocción del clinker y poder calorífico del carbón aplicado.

COMPONENTES VOLATILES

Los carbones de formaciones geológicas más jóvenes contienen mayor proporción de oxígeno, hidrógeno y nitrógeno que los carbones de edades geológicas más antiguas.

Durante la combustión, esos elementos y sus combinaciones producen más componentes volátiles que los carbones de formaciones más antiguas.

El contenido de volátiles ejerce una gran influencia sobre la longitud de llama en el horno.

Los carbones pulverizados que poseen altos volátiles cuando se inyectan como polvo en el horno rotatorio, ya caliente tendrán tendencia a quemarse con llama corta, debido a que se descomponen a gran velocidad.

Los carbones que contienen bajos volátiles se descomponen lentamente cuando se insuflan a horno en forma de polvo, dando lugar a quemarse con llama larga.

El contenido óptimo de componentes volátiles para carbón pulverizado oscila entre 18-22% sin alargamiento de la llama respecto al uso de fuel-oil, no obstante con una molienda adecuadamente fina es posible utilizar provechosamente en el horno rotatorio carbones de hasta un 10%. Sobre el límite de 22% pueden producirse problemas de combustión espontánea en el acopio, en las instalaciones de molienda y en el almacenamiento de carbón en polvo.

En la actualidad se han desarrollado sistemas de inertización, fluidificación y protección contra incendios mediante la utilización del anhídrido carbónico (CO_2) en sus estados gaseoso y líquido.

CONTENIDO DE CENIZAS

Representa el residuo mineral de la combustión del carbón, formado principalmente por silicatos y aluminatos que introducen alteraciones en la homogeneización tan deseada del crudo alimentado en el horno.

Los componentes no deseados en el combustible carbón son las cenizas y la humedad, a las cuales se les llama componentes inertes. En el proceso de cocción el clínquer absorbe casi totalmente las cenizas, siendo un pequeño aporte en cantidad al material producido.

En caso de presencia alta de cenizas hay que corregir consecuentemente el diseño del crudo, es decir el standard de cal, elevándolo para obtener el grado de saturación correcto que permita neutralizar su presencia ácida en el sistema.

ANALISIS DE CENIZAS

CARBONES CHILENOS USADOS EN CEMENTO (%)

	LOTA	CORONEL	COCAR
SiO_2	49.00	44.00	42.00
$Al^2 O^3$	27.00	22.00	23.00
$Fe^2 O^3$	10.00	20.00	6.00
CaO	6.00	4.00	13.00
MgO	0.80	0.90	2.00
SO_3	4.40	4.00	7.00
Tº de fusión ºC	1.350	1.350	1.350

AZUFRE

El azufre en el carbón se presenta por lo general como súlfuro (pirita, galena, calcopirita, etc.). Durante la combustión del carbón se transforma el contenido azufre en SO_2 de alta oxidación. El dióxido de azufre a su vez reacciona con los óxidos alcalinos del crudo y/o propios del carbón y el oxígeno del ambiente, formando sulfatos alcalinos.

En el horno, puede formarse lo que se llama el ciclo de azufre, es decir, el SO_2 y/o SO_3 liberado de la zona caliente del horno se condensa de nuevo en las zonas más frías del mismo y vuelve a la zona de fuego.

Después de haberse formado los sulfatos alcalinos y debido a la escasa volatilización de los sulfatos, se incorporan una gran parte al clínquer y así saliendo del horno. Observado el fenómeno, en caso de altos contenidos de álcalis en el proceso y bajos contenidos de azufre, puede ser ventajoso llevar intencionalmente el contenido de azufre en el crudo y/o combustible, para que los álcalis se unan al clínquer como sulfatos.

En esta forma un ciclo de álcali alto en el horno podría ser manejado convenientemente.

Con todo lo dicho, se deberá cuidar que la circulación de azufre no aumente demasiado, ya que al fin tendrá influencia en la estabilidad de marcha del horno, de la calidad del clínquer y sobre la duración del revestimiento refractario.

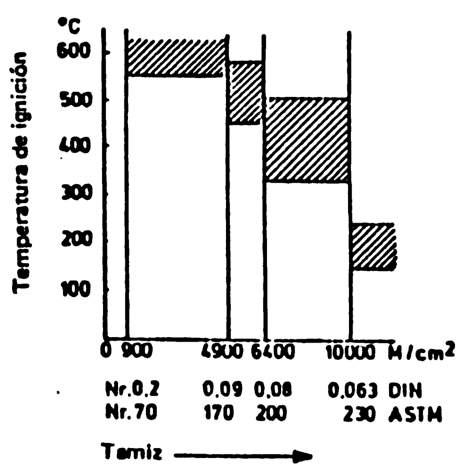
Valores entre 1.5 a 1.8% sobre muestra seca pueden ser tolerables.

En los carbones chilenos para cemento se toleran valores entre 1.5 a 2.0%.

TEMPERATURA DE IGNICION DEL CARBON

Se define como temperatura de ignición, la superficial de un combustible para la cual la reacción de combustión discurre con tal velocidad que da lugar a una combustión ininterrumpida. Para alcanzar la temperatura de ignición es menester cierto intervalo de tiempo, el tiempo de ignición. Este es el tiempo requerido para llevar la superficie del combustible a la temperatura de ignición; está determinado por el gradiente de temperatura y por las condiciones de transmisión del calor. De aquí se deduce que la temperatura de ignición está superficialmente condicionada; como la superficie del combustible depende del tamaño de sus partículas se obtiene que aquella depende del tamaño de las partículas, por lo tanto, de la finura de molienda del carbón.

En la figura siguiente se representa la dependencia de la temperatura de ignición en función de la finura de molienda del carbón. Los límites superiores valen para las antracitas; los inferiores para los carbones con alto contenido de volátiles.



Temperatura de ignición para el polvo de carbón.

En el diagrama se aprecia que la temperatura de ignición del polvo del carbón está situada entre 200 y 550º C. Además, puede observa-se que la finura de molienda es de mayor influencia que el contenido de volátiles.

TRANSMISION DEL CALOR EN LA LLAMA DEL POLVO DE CARBON

Los gases calientes de la llama ceden calor a su entorno de modo preponderante por radiación y solo una pequeña parte por contacto inmediato con el material que está reaccionando, es decir por convección.

El horno rotatorio está lleno de material en una pequeña fracción de su volumen (aprox. el 13%); por consiguiente, la mayor parte del calor se cede al revestimiento refractario del horno y una reducida fracción al material directamente.

La mayor parte de la transmisión de calor se realiza por radiación.

Las fracciones activas a efectos de la radiación en la llama de polvo de carbón son:

a) El contenido de CO^2 en los gases de la llama.

b) El contenido en H_2O en los gases de la llama.

c) El contenido de polvo en suspensión en los gases de la llama.

Para favorecer, entonces, la transmisión de calor por los gases en la zona de sinterización, se requiere:

1) Elevación de la temperatura de la llama.

2) Elevación de la concentración de CO^2 y del H^2O.

3) Llevar al máximo el diámetro del horno.

COMBUSTION

El polvo de carbón será insuflado dentro del horno mediante el aire primario aportado por un ventilador. El flujo y la velocidad de este aire primario son los factores más importantes para determinar la forma de la llama .

Su longitud depende de los siguientes factores:

a) Bondad de la mezcla de combustible, aire primario y/o medios de oxidación.

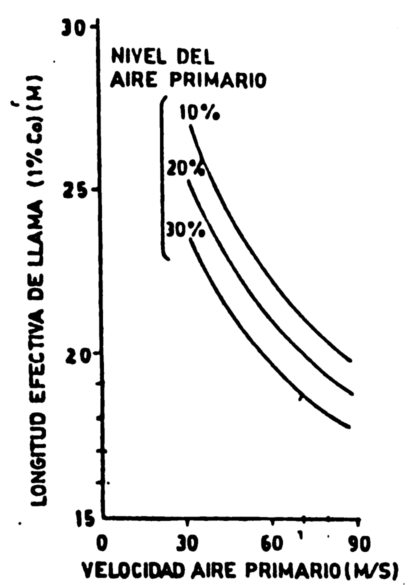
b) Grado de calentamiento.

c) Capacidad de reacción del combustible.

d) Finura de molienda del carbón.

Como regla general puede ceñirse al siguiente criterio:

Cuanto más antiguo es el carbón (edad geológica), más alto es el peso específico y el poder calorífico, pero más bajo el contenido en componentes volátiles. Si se quiere una llama lo más corta posible, hay que moler el carbón tanto más fino, cuanto más escaso sea el contenido en componentes volátiles.



Dependencia entre longitud de llama, contenido de aire primario y velocidad de aire primario (según Lowes y otros).

QUEMADOR O MECHERO

Los factores antes indicados son determinantes para la elección de una forma y medidas apropiadas para un quemador o mechero idóneo.

Un equipo de combustión a carbón debe tener un quemador que permita:

a) Regular la forma y longitud de la llama.

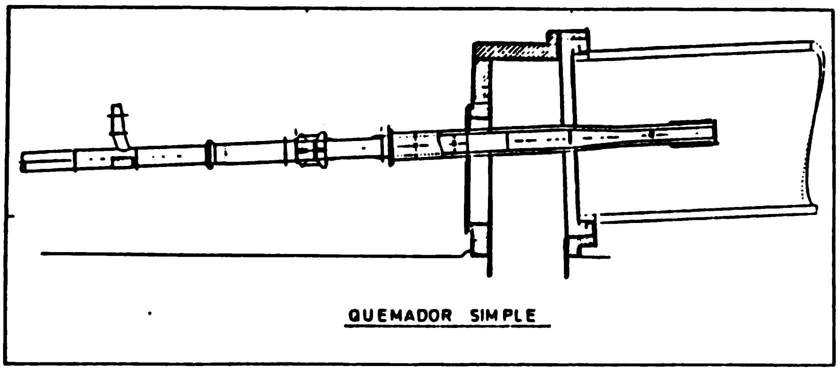
b) Permitir regular la penetración en el horno.

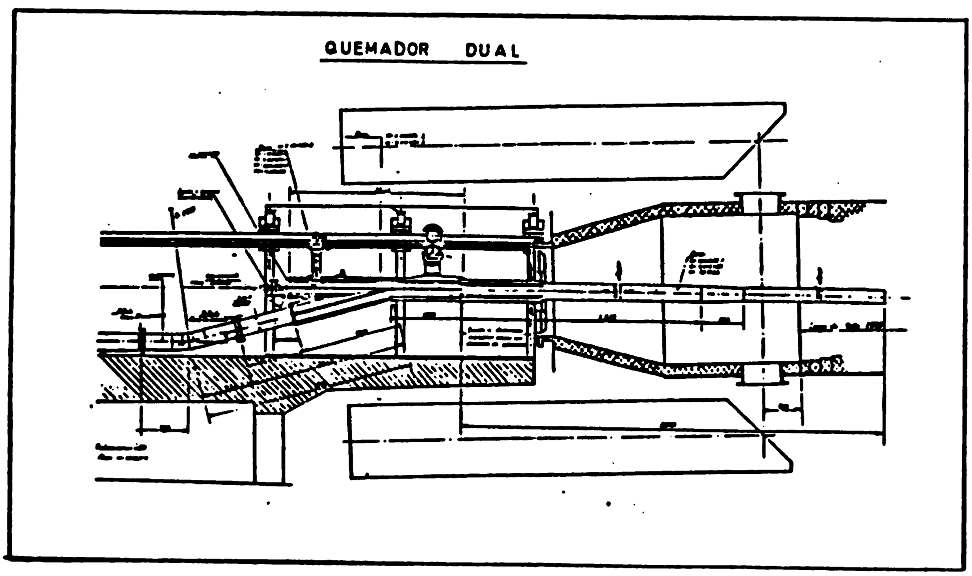
c) Dirigir la llama en la dirección deseada.

d) Permitir regular la temperatura del aire primario, para mejorar el rendimiento global.

e) Permitir el uso mixto (dual) de carbón y fuel-oil, con regulación de 0 - 100º de la mezcla.

f) Cambiar de combustible sin ningún desmontaje de la tobera.



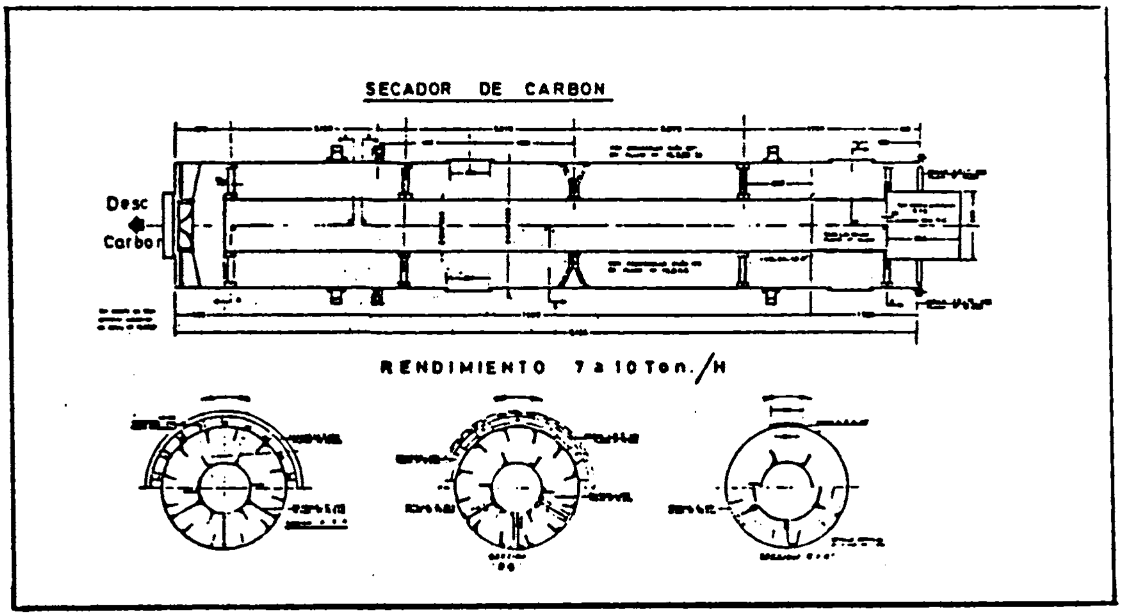


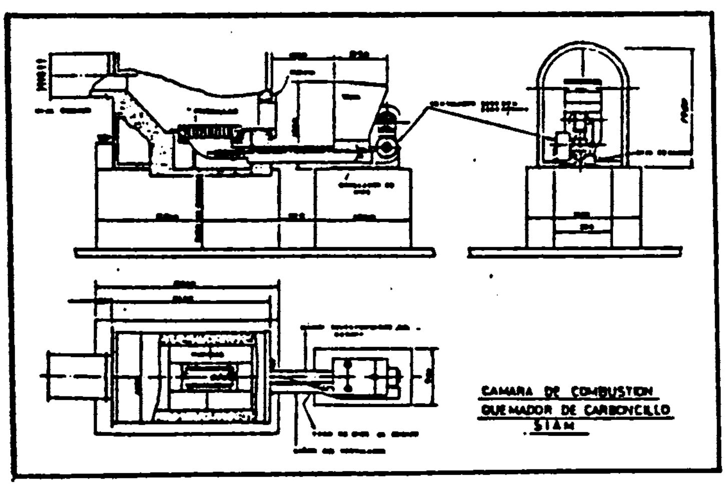
PROCESO DE SECADO DEL CARBON

Con este proceso se inicia la preparación del carbón para reducirlo al estado de polvo.

Para carbones con humedad superior al 12% se usan la mayoría de las veces secadores de tambor rotativos, similares a los que suelen usarse para las materias primas.

Son de diseño y manejo simple, acoplado a un hogar auxiliar que puede quemar carbón.





En este diseño de secador el carbón a secar no está en contacto con la llama del hogar, ya que el tambor central conduce los gases calientes y por el tambor externo concéntrico al primero circula el carbón. Solo al retorno de los gases se justan con el carbón avanzando cada uno a contra corriente hasta abandonar el secador, o sea el aire caliente recorre dos veces el largo del tambor.

El carbón seco se descarga a un sistema de transporte (sin fin), para llevarlo hasta la tolva del molino.

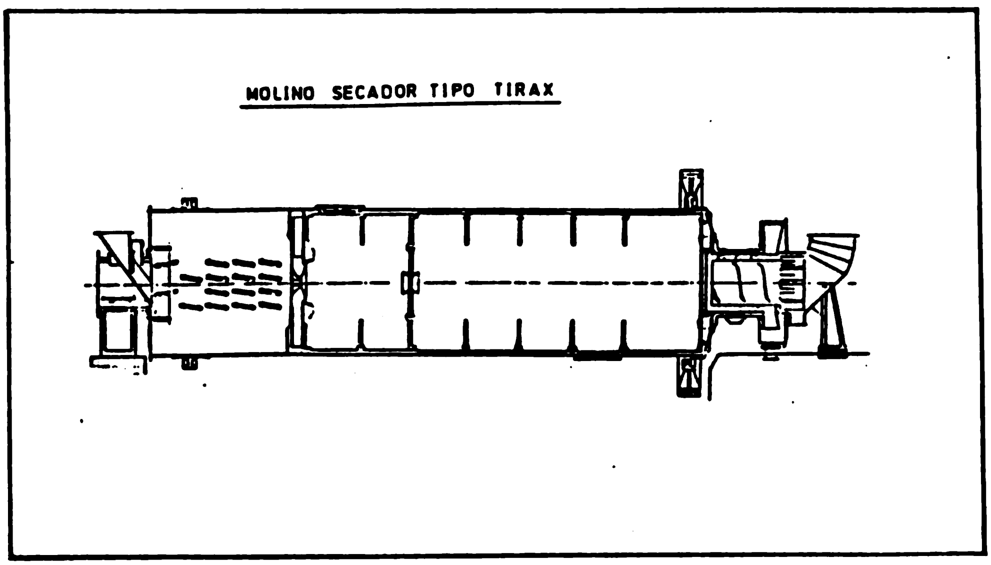
La temperatura de los gases que abandonan el sector debe ser, aproximadamente 120º C y la del carbón no más de 70º C, para evitar la inflamación de éste.

Los secadores son de diseño antiguo pero bastante útiles, permitiendo secar el carbón en forma totalmente separada del proceso de molienda.

SECADOR COMBINADO CON MOLIENDA

Existen equipos en que el secado se efectúa dentro del molino tubular con la ayuda de una corriente de gases calientes suministrados por un hogar auxiliar, o el calor residual de los enfriadores de parrilla.

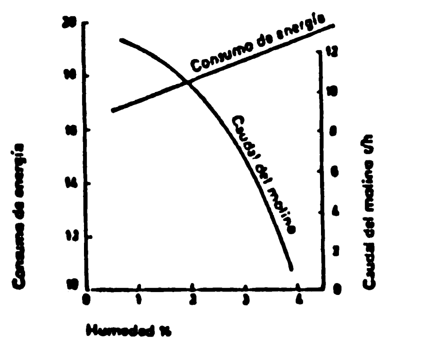
Hoy se ofrecen molinos tubulares para carbones con alta humedad (12%), en que la primera cámara del molino es un secador tubular, con paletas de levante para provocar un permanente movimiento de cascada del carbón a fin de ser penetrado por la corriente de gases que proviene de un hogar auxiliar. El carbón seco pasa a través de un tabique a una especial segunda cámara que trabaja como sección de trituración, la que entrega el carbón semi molido a través de un segundo tabique, a una tercera cámara que trabaja como refinadora.



Estos molinos secadores son, por lo general, de arrastre o barrido por aire (sistema Tirax).

La temperatura de los gases calientes que se utilicen en las instalaciones de molienda-secado de carbón debe ser como máximo de unos 350-400 C.

La humedad del carbón a moler tiene gran influencia sobre el rendimiento del molino. Con incremento de humedad de 1% al 3%, el rendimiento del molino desciende en aproximadamente 40%, con un aumento simultáneo del consumo de energía del orden del 10% para una misma granulometría.



Dependencia del caudal del molino y del consumo específico de energía en función de la humedad del carbón.

La humedad residual del carbón a la salida del molino debe ser aproximadamente de un valor entre 1 a 1,5%, pues se ha comprobado que esto favorece la combustión.

SECADO NATURAL

Bajo ciertas condiciones climáticas especiales, que se presentan en zonas desérticas, la ausencia de lluvias y la energía solar más la eólica, pueden ayudar en forma muy económica a secar el carbón desde humedades altas (12%), hasta valores de 2%, en un plazo razonable.

En la fábrica de Antofagasta se ocupa en acopio una superficie de unos diez mil metros cuadrados para almacenar hasta unas diez mil toneladas de carbón, distribuidas en cuatro pilas, ubicadas a buena distancia una de otra, a fin de tener acceso cómodo a ellas.

Cada pila deberá tener no más de 2,5 m. de altura y el carbón se compacta pisándolo con la ayuda de una máquina pesada (cargador frontal, por ejemplo), para evitar autocombustión.

La altura de cada pila estará en función inversa al porcentaje de contenidos volátiles del carbón. A valores altos de volátiles la pila debe tener una altura muy reducida.

En nuestro caso, el carbón posee 35-40% de volátiles, en la práctica con 2,5 m. de altura del acopio hemos tenido éxito.

Existen fábricas donde es menester controlar periódicamente la temperatura del material apilado, lo que se logra introduciendo un termómetro unos cincuenta centímetros cada tres a cuatro metros de separación entre punto y punto.

En nuestro caso no hemos necesitado esta precaución.

Para este tipo de acopio valen dos recomendaciones:

1). Evitar se boten basuras junto al carbón almacenado, tales como papeles, cartones, maderas, huaipe, restos de lubricantes, etc.

2) Entre una partida de carbón y otra, siempre se deberá usar la más antigua.

Esta rotación del stock evitará resecar el carbón y, por lo tanto, posibles incendios.

En climas lluviosos será preferible tener stock conveniente acopiado en canchas bajo techo.

MOLIENDA DE CARBON

TIPOS DE MOLINOS

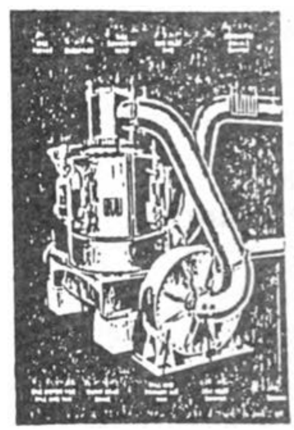
En función del tipo de construcción o diseño, se conocen principalmente dos tipos de molinos:

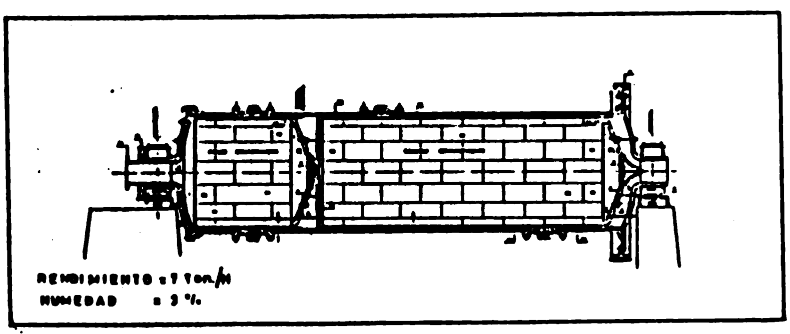
- Molinos horizontales,
- Molinos verticales.

En la industria cementera chilena se usan solo molinos horizontales, por la sencillez de su manejo y por la similitud con los molinos de harina cruda y/o cemento. La técnica de mantenimiento también es conocida por años por el personal.

La industria de la cal y de generación de vapor suele preferir los molinos verticales por las razones siguientes:

- Menor disponibilidad de espacio.
- La inversión global es más reducida.
- Menor nivel de ruido.
- Menor consumo de energía eléctrica.
- Pueden procesar carbones con mayor grado de humedad.





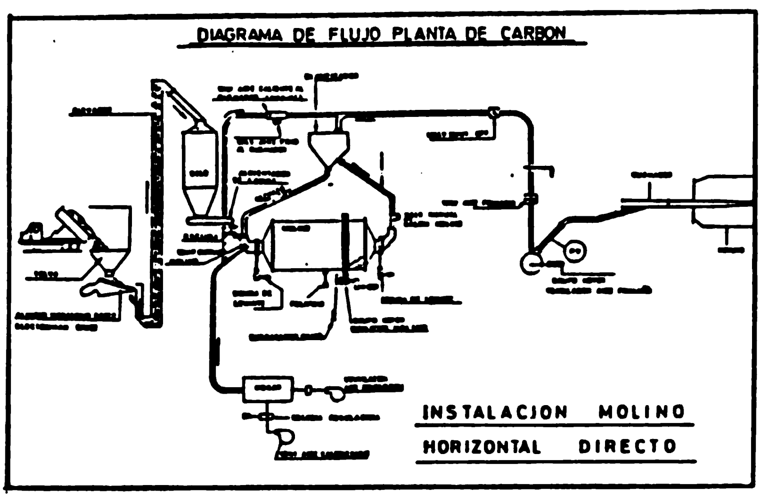
TECNICAS DE MOLIENDA

En cuanto a la compatibilidad de operar entre el horno rotatorio y el molino de carbón, existen fundamentalmente, distintos sistemas de operación:

- Sistema directo.
- Sistema semi-directo.
- Sistema indirecto.

SISTEMA DIRECTO

El molino trabaja conjuntamente con el horno rotatorio y se ajusta a sus demandas, usa gases calientes del enfriador de parrilla o de un hogar auxiliar.



El aire de arrastre es el propio aire primario de combustión y el secado y molienda se realiza simultaneamente.

Las ventajas principales del sistema directo son:

- Manejo muy simple.
- Menor inversión de la planta (40%).
- No hay riesgos de explosión por no necesitar depósito para almacenar carbón pulverizado.
- Planta limpia.

DESVENTAJAS

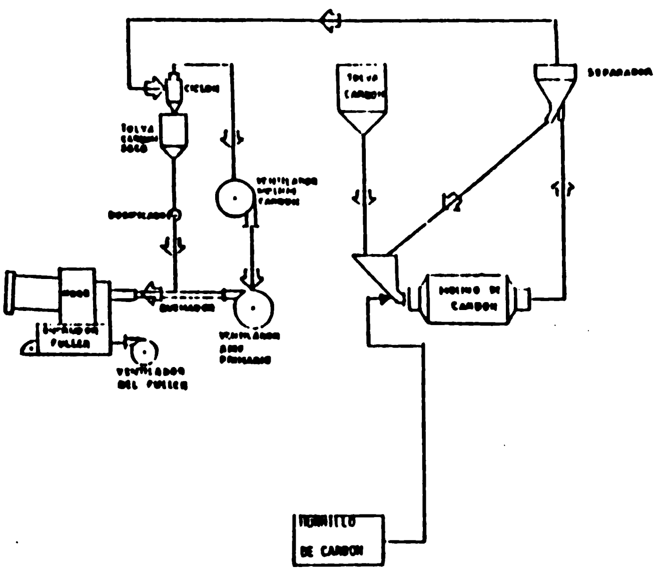
- Dependencia del horno a la marcha del molino.
- Dificultad para ajustar la cantidad de aire primario.
- Inyección del horno del vapor de agua de la humedad del carbón.

En nuestra planta de Antofagasta hemos preferido este sistema por razones de seguridad, evitando las posibles explosiones, ya que usamos un carbón de alto contenido de volátiles. Un separador estático completa la instalación.

SISTEMA SEMI-DIRECTO

Este sistema fue desarrollado para evitar las desventajas del sistema directo, manteniendo la seguridad y el bajo costo de inversión.

INSTALACION MOLINO HORIZONTAL SISTEMA SEMIDIRECTO



Este sistema difiere del directo en que posee dos ventiladores, uno que trabaja para el molino y el segundo que impulsa el aire primario. El primer ventilador alimenta al segundo.

El ventilador de tiro del molino arrastra el polvo de carbón y los gases y los conduce a través de un separador estático, donde se rechaza el material grueso, saliendo el fino y los gases en dirección a un ciclón, lugar donde el fino es retirado del circuito de gases, cayendo por gravedad a la tolva de acopio. Los gases impulsados por el mismo ventilador se convierten en la alimentación principal del ventilador de aire primario del horno.

El polvo de carbón acumulado en la tolva alimenta a la corriente de aire primario una vez controlado por un dosificador, para luego ser impulsado por el quemador al interior del horno.

Este sistema semi-directo lo usa una fábrica de cemento en Chile desde hace 24 años, sin mayores problemas.

VENTAJAS PRINCIPALES DEL SISTEMA SEMI-DIRECTO

- Independencia relativa del horno con el molino.
- Ambos ventiladores mantienen un equilibrio entre el aire y el material circulante.
- No obliga a trabajar con exceso de aire primario.

DESVENTAJAS

- Inyección al horno del vapor de agua de la humedad del en proceso.
- Obliga, la operación del molino a la marcha del ventilador de aire primario, con lo cual no se puede moler a horno detenido so pena de enfriarlo.

  Esta situación se hace más crítica en períodos de invierno en que el carbón está demasiado húmedo (12%).

SISTEMA INDIRECTO (Planta centralizada)

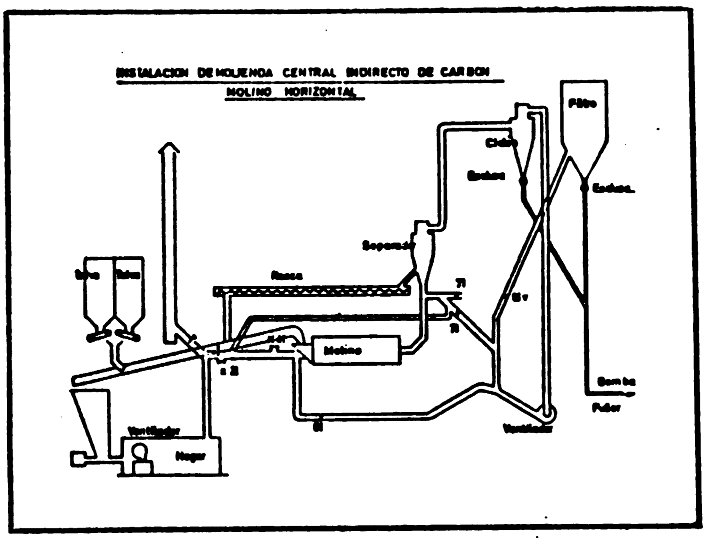
En este sistema el molino trabaja en forma totalmente independiente del horno.

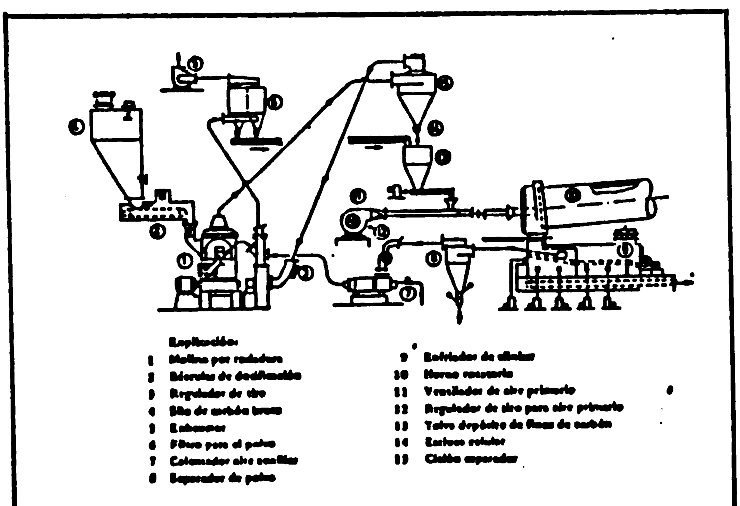
El rendimiento del molino es sustancialmente mayor que el consumo de carbón en el horno.

Por ello se dispone entre el horno y el molino del carbón, un depósito para carbón pulverizado.

Es el sistema ideal para fábricas en que funcionan varios hornos en forma simultánea a distancia.

El o los depósitos para acopio de polvo de carbón son de una capacidad tal que, dan al horno una autonomía de marcha que puede alcanzar varias horas.





INSTALACION DE MOLIENDA CENTRAL INDIRECTO DE CARBON

Esta planta tiene solo el ventilador de arrastre de polvos y gases del molino, pasándolas por el separador estático, los finos y los gases llegan al ciclón donde los finos se separan de los gases y caen a la tolva de acopio; los gases son descargados a un filtro que puede ser de mangas o electrostático, donde se precipitan las partículas más finas y escapan limpios los gases junto al vapor de agua.

VENTAJAS DEL SISTEMA INDIRECTO

- Independencia muy holgada del molino con el horno.
- Regulación exquisita del aire primario libre de vapor de agua.
- Puede trabajar estando el horno detenido.
- Un molino puede alimentar a varios hornos en forma rotativa.

DESVENTAJAS

- Mayor inversión.
- R gurosas medidas de seguridad cuando se opera con carbones altos en volátiles, por peligros de explosión.
- Dependencia total de la marcha del filtro electrostático.

LA FINURA DE MOLIENDA

La finura aconsejable del carbón a la salida del molino estará en relación indirecta con el contenido de componentes volátiles.

Es decir, a valores bajos de volátiles deberá aumentarse la finura, a fin de tener un tiempo relativamente corto de combustión de la partícula de carbón.

La finura del carbón a la salida del molino usada en Chile, es de 8-16% retenido en el tamiz 170.

Control debe ejercerse sobre este valor en consideración que una refinación excesiva innecesaria aumentará el costo por consumo de energía eléctrica/tonelada de carbón, produciendo además una llama demasiado corta que significará una zona de sinterización con una carga térmica muy concentrada.

COMO PLANTEARSE LA CONVERSION DE PETROLEO A CARBON

La conversión de petróleo a carbón por razones económicas deberá ser analizada a lo menos, bajo los siguientes aspectos:

1.- Cálculo comparativo del valor de la caloría entre el petróleo y el carbón.

2.- Disponibilidad fluida de un abastecimiento de carbón,

3.- Calidad y homogeneidad del carbón ofrecido.

4.- Estudio de ingeniería conceptual sobre los equipos necesarios e innovaciones a realizar en la fábrica.

5.- Estudios comparativos de las ofertas por equipos, en función del diseño y compatibilidad con los equipos existentes.

6.- Alternativas:

    6.1 Con equipos nuevos ofrecidos por el fabricante del horno.

    6.2 Con equipos nuevos ofrecidos por otros fabricantes.

    6.3 Con equipos de segundo uso existentes en el extranjero o en el propio país.

    6.4 Con equipos de segundo uso existentes en la propia fábrica.

7.- Asesoría Técnica.

8.- Repercusiones del uso del carbón en el proceso y en la calidad del producto terminado.

9.- Toma de decisión.

10.- Plazos - contrato por equipos y contrato por abastecimiento de carbón, comprometiendo garantías.

11.- Resultados.

RESULTADOS CASO INACESA

(Para un horno de 420 t/día).

CARACTERISTICAS DE LA PLANTA DE CARBON

Rendimiento (t/h)	2,8
Consumo específico de energía (kwh/t.)	40
Finura del carbón molido M-170 (%).	18
Humedades, (%)	
Recepción fábrica	6 - 10
Entrada a molino	2,0
Pérdida en cancha	4 - 8
Factor de marcha del molino (%).	99
Factor de marcha del horno (%)	97

La operación no necesitó más personal que el asignado al horno cuando usó petróleo.

- Ausencia total de explosiones.
- Planta ordenada y totalmente limpia.
- La inversión se pagó en 12 meses.
- El sistema dual nos permite volver a la opción petróleo en forma ocasional y/o permanente.
- Quemador dual, telescópico.

RESULTADOS ECONOMICOS

DE LA CONVERSION PETROLEO A CARBON

EN HORNO Y GENERACION TERMO-ELECTRICA.

ALTERNATIVA	PETROLEO	CARBON
COSTO DIRECTO/ton. cemento	70%	40%
INVERSION	1	5
AMORTIZACION	-	1 año
GENERACION TERMO-ELECTRICA	47%	30%

ANEXO 1

CARACTERISTICAS DE ALGUNOS CARBONES CHILENOS

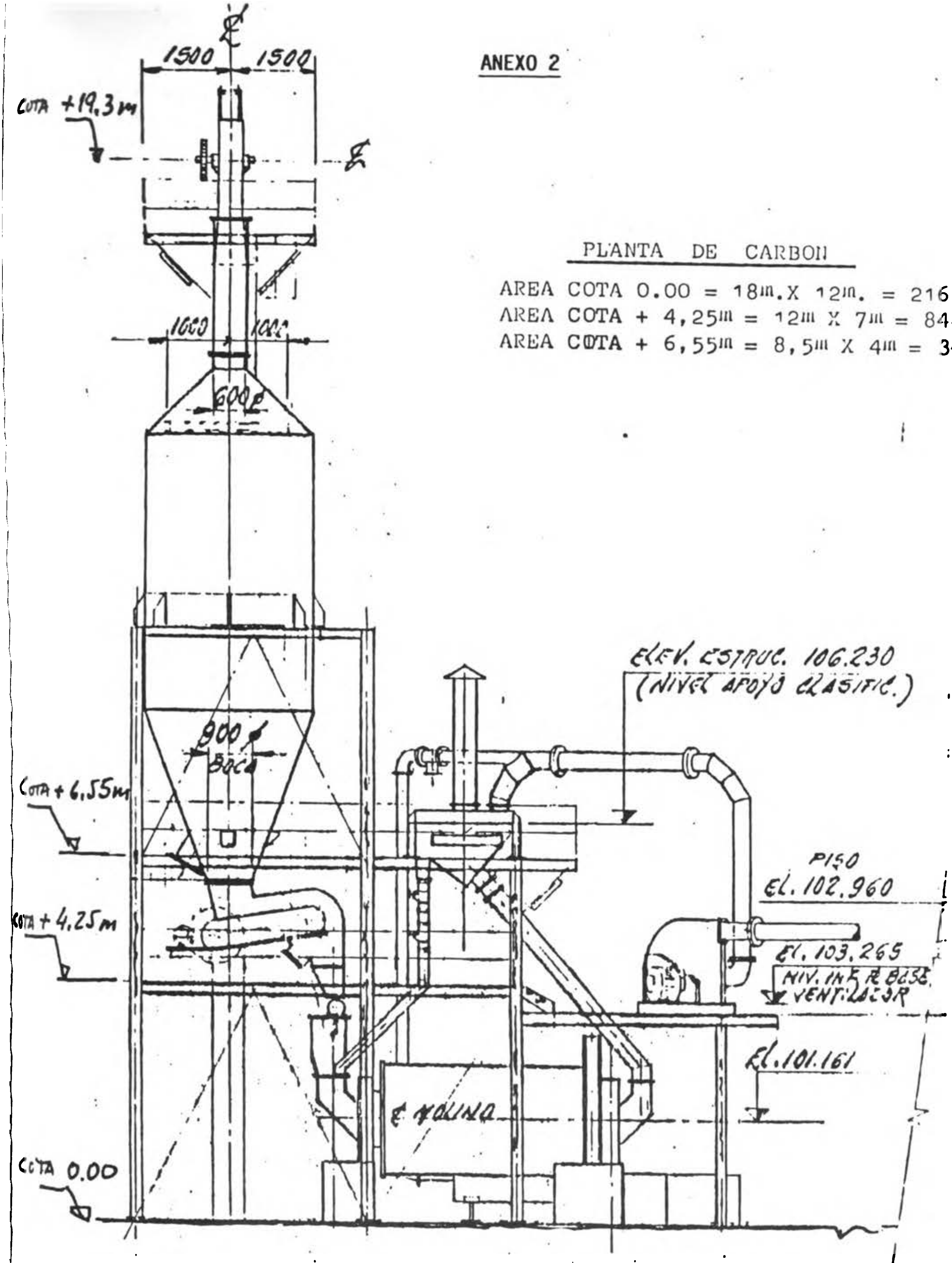
Usados en la Industria del Cemento

	ENACAR		SCHWAGER		COCAR
TIPO DE CARBON	CTN	CTE	CTN	CTE	PECKET
ANALISIS INMEDIATO, (%)					
- Humedad higroscópica	1-3	1,5-3	6-10	1,5-2,5	13-18
- Humedad superficial	6-7	6-7		5-7	7-9
- Cenizas base seca	15-17	12-14	16-18	10-15	14-23
- Volátiles base seca	40-42	38-43	33-38	40-44	33-37
- Azufre base seca	1,5-2,5	1,5-2,5	-	-	1,0-2,0
PODER CALORIFICO (Kcal/kg)					
- Superior base seca	6650-6850	6950-7100	-	7040-7550	-
- Superior como recibido	-	6250-6500	5900-6300	-	4200
INDICE DUREZA HARDGROVE	40-50	40-45	45-60	-	40-50
ANALISIS CENIZAS					
- Fusibilidad en atm. ox. (°C)					
Punto deformación inicial	1100-1250	1080-1200	1210-1300	1250-1320	1177-1356
Punto fusión	1300-1450	1300-1480	1330-1370	1270-1340	1290-1400
Punto fluidez	1400-1500	1350-1500	1360-1410	1280-1350	1310-1410
- Análisis químico, (%)					
SiO_2	49,3	42,7	44,0	38,0	41,8
Al_2O_3	27,0	28,5	22,0	18,0	23,4
TiO_2	-	1,1	1,0	0,8	1,2
Fe_2O_3	10,2	17,0	20,0	28,0	6,0
CaO	5,8	3,6	3,8	5,0	12,5
MgO	0,8	0,2	0,9	0,8	2,2
SO_3	4,4	3,7	4,0	6,0	7,4
$K_2O + Na_2O$	1,4	3,2	1,8	1,4	2,9
ANALISIS ELEMENTAL, (%)					
Carbono	65-69	78-82	59-65	69-77	58-62
Hidrógeno	5-6	6-7	4,3-4,9	5,1-5,9	4,1-4,6
Oxígeno	7,5-9,5	9-11	4,1-5,3	3,7-7,6	16-19
Nitrógeno	0,8-1,7	1-2	0,9-1,1	0,9-1,8	0,7-0,8
Azufre	0,4-3,3	0,5-4	2,7-3,7	1,8-3,0	0,1-0,8
GRANULOMETRIA					
Tamaño nominal, (mm)	0-20	0-20	0-19	0-19	-

ANEXO 2

PLANTA DE CARBON

AREA COTA 0.00 = 18m. X 12m. = 216 m²
AREA COTA + 4,25m = 12m X 7m = 84m²
AREA COTA + 6,55m = 8,5m X 4m = 34m²



ANEXO 3

CUIDADOS Y RECOMENDACIONES PARA EL MANEJO, PREPARACION Y USO DEL CARBON EN POLVO

PREPARACION DEL POLVO DE CARBON

La preparación del carbón para reducirlo al estado de polvo, exige medidas particulares y cuidadosas, para evitar explosiones.

La explosión se origina por la concurrencia de las tres condiciones siguientes :

1. Concentración de polvo de carbón en el aire, dentro de los límites de explosión.

2. Existencia de la fracción suficiente de oxígeno en la mezcla de gases presente.

3. Existencia de suficiente energía térmica para dar lugar a la explosión.

Para impedir teóricamente la explosión de polvo de carbón, basta con que se anule una de las tres condiciones. En la práctica, sin embargo, es aceptable que se eliminen dos y si fuera posible las tres condiciones.

CONCENTRACION DEL POLVO DE CARBON

Para los carbones minerales el intervalo de explosión está situado entre 150 g. (límite inferior) hasta aproximadamente 1500 g. de carbón (límite superior de explosión) por m3N de aire. Estos límites de concentración pueden variar según el contenido de volátiles y la finura del carbón. Esta debe corresponder a un residuo del 10 al 15 % al tamiz de 4900 mallas/cm2 (luz de 0,088 mm.)

El intervalo de concentración por debajo del límite inferior de explosión varía entre 0 - 150 g/m3N que es bastante corto. Por consiguiente este intervalo no puede utilizarse en la preparación de carbón, puesto que para ello se necesitan grandes cantidades de gases.

También se habrá de evitar el trabajo con una concentración de polvo de carbón que caiga dentro de los límites de explosión, es decir, entre los 150 y 1500 g/m3N, incluso en ausencia de los otros dos factores. La concentración de polvo de carbón por encima del límite superior de concentración para explosión es la única zona en que se puede trabajar en las instalaciones de molienda-secado de carbón.

OXIGENO EN LA MEZCLA DE GASES

El contenido de oxígeno, en el sistema de molienda-secado debe alcanzar, a lo sumo, el 14 %. Para conseguirlo se aprovecha la recirculación de una parte de los gases residuales para disminuir el contenido de oxígeno.

A veces el contenido de oxígeno puede dar lugar a situaciones peligrosas al poner en marcha las instalaciones de preparación. Rebajando el contenido de oxígeno se eleva el límite inferior de explosión y se rebaja el límite superior, con ello el intervalo entre ambos se hace sustancialmente más corto. Con esas medidas también se eleva la temperatura de inflamabilidad de la mezcla de gases.

ENERGIA TERMICA SUFICIENTE

La energía térmica necesaria para que se inicie una explosión puede ser originada por :

a. Autoencendido del carbón.
b. Sobrecalentamiento local del carbón, debido a gases de secado excesivamente calientes.
c. Por sobrecalentamiento de elementos de las máquinas que intervienen.

ALMACENAMIENTO DEL CARBON EN CANCHA

La capacidad mínima aconsejable en los parques de almacenamiento de carbón es la equivalente a dos meses del consumo en fábrica. Naturalmente, ésto será difícil de conseguir en algunas instalaciones, por lo que se verán obligadas a recurrir al fuel-oil o gas como combustibles de reserva ante una eventualidad en el suministro de carbón.

El mayor riesgo que presenta el parque se deriva de la posible combustión espontánea del carbón. Además de este fenómeno, en el carbón almacenado tienen lugar los siguientes: aumento de peso, de contenido de oxígeno y de su temperatura de ignición y disminución en el contenido de hidrógeno, en el poder calorífico y en el tamaño medio de la granulometría.

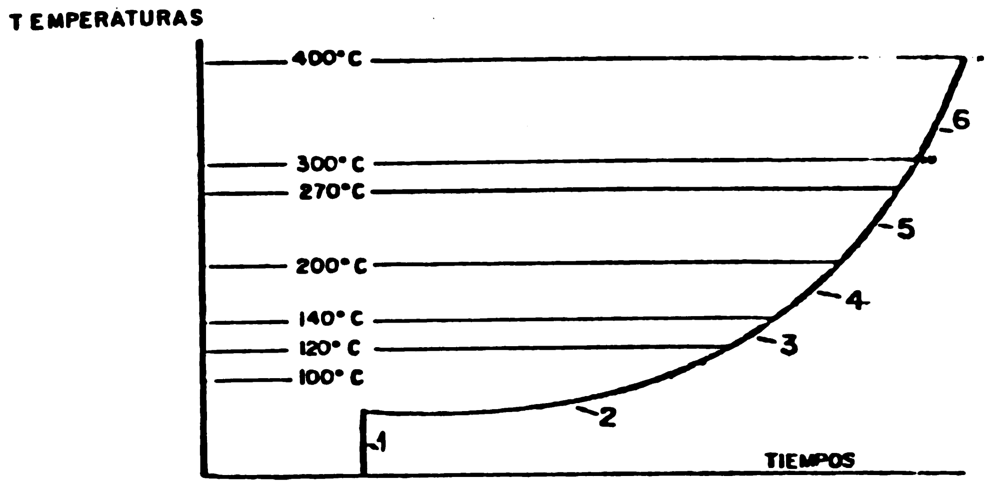
Las causas que producen todos estos problemas se pueden reducir a dos: las reacciones provocadas por la oxidación del carbón y los efectos de la humedad.

Un trozo de carbón expuesto al aire se combina con el oxígeno a una velocidad medible. De esta "combustión" a baja temperatura resultan los mismos productos que de una combustión ordinaria (anhídrido carbónico, óxido de carbono y vapor de agua).

La diferencia entre ambas combustiones estriba en que a bajas temperaturas la velocidad de combustión será menor y además aproximadamente la mitad del oxígeno permanece unido a la molécula del carbón, lo que origina un aumento de peso.

La velocidad de oxidación aumenta con la temperatura. Además, se ve influenciada por el tamaño de las partículas expuestas a la misma y por la concentración del oxígeno.

Estos fenómenos van acompañados de calor lo que hace aumentar la temperatura y con ello la velocidad de oxidación. Se trata por tanto de un proceso en cadena que puede terminar en la autoignición.



Zona 1. - Absorción de oxígeno.
2. - Zona peligrosa entre esos límites indicada por la elevación rápida de la temperatura.
3. - Desprendimiento notable de CO y CO2.
4. - Rápida elevación de temperatura.
5. - Se inicia el proceso.
6. - Se verifica el encendido.

Para que el autoencendido tenga lugar es preciso que la velocidad de calentamiento prevalezca sobre la de enfriamiento.

La temperatura a la que se puede producir la combustión espontánea se sitúa en el entorno de 70 - 80 °C.

Debe tenerse en cuenta que un carbón con gran cantidad de tamaños gruesos facilita el acceso de aire atmosférico en el interior y por el contrario si el número de finos es muy elevado aumenta la reactividad del carbón captando oxígeno de la atmósfera y formando gases.

El apilamiento en épocas o zonas geográficas con temperaturas elevadas, en donde el calor acumulado en las partes bajas de la pila puede ser otra causa de incendio. Para evitarlo, debe disponerse el carbón con su menor superficie dirigida hacia la dirección del viento predominante.

El efecto de superficie de contacto elevada tiene lugar también cuando existen "chimeneas" o canales en las pilas de carbón, por las que circula más intensamente el aire. Además de los tamaños gruesos este fenómeno puede ser debido a las impurezas del carbón (trozos de madera y/o grandes piedras).

Las conclusiones y recomendaciones de muchos autores, para evitar la combustión de carbones son las siguientes :

- El suelo sobre el que descansan las pilas debe estar bien nivelado, ser firme, no tener grietas y estar bien drenado.
- Cuanto menor sea la altura de las pilas tanto menor es el peligro de combustión ya que el calor se disipa más fácilmente, el carbón no tiene tanta tendencia a deshacerse en tamaños menores y es más fácil evitar o retirar los focos de calentamiento.
- Debe evitarse la separación natural por tamaños porque en las zonas de tamaños más gruesos se forman chimeneas que establecen "tiros" de aire en las pilas.
- Preferiblemente el carbón no debe apilarse durante un tiempo muy caluroso, ya que muchos incendios proceden de este hecho.
- Los carbones de distintas procedencias deben apilarse separadamente.
- Una carga de carbón demasiado húmedo no debe apilarse con otro más seco.

- Es muy importante la observación periódica de las pilas de carbón, máxime cuando exista peligro de incendio, con termómetros introducidos en el montón con separaciones de 3 ó 4 metros.

- La existencia de un foco con temperatura superior a 60 °C debe ser motivo para aislarle. Es peligroso usar un riego de agua.

- Procurar el libre acceso por todos los lados del almacén, de forma que, en caso de incendio, pueda entrarse a combatir el fuego.

- El apisonado con tongadas de poca altura que evite el paso del aire a través del carbón se ha probado como remedio muy eficaz para evitar la autocombustión.

- Debe tenerse en cuenta lo ya indicado de que el contenido de volátiles no es aconsejable que sobrepase el 22 %.

En el caso de almacenar grandes cantidades de carbón en fábrica, se dispondrá como precaución ante el autoencendido, dividir las existencias en dos almacenes : un almacén destinado a un largo período y un almacén pequeño para consumo.

En el almacén a largo plazo se tendrá en cuenta las recomendaciones anteriormente citadas, y además debe pensarse que por regla general un incendio se produce antes de los dos primeros meses de almacenamiento.

BIBLIOGRAFIA

1.- Cement Data Book - W.H.Duda (1978).

2.- Cement Manufacturer's Handbook - K.E. Peray (1979)

3.- Coal Technology And The Cement Industry - A review
A World Cement Publication (1985).

4.- Combustión con Carbón en los Hornos de Cemento
Artículo publicado por Didier Werke Ag.

5.- La Utilización Eficiente de los Combustibles -
Aguilar Ediciones (1949).

6.- North American Combustion Handbook (1978).

7.- Process Engineering of Size Reduction Ball Milling
L. Austin - L. Klimpel - P. Luckie (1948).

8.- Prontuario del Cemento. O. Labahn/B. Kohlhaas (1985).

9.- Rock Talk Manual - KVS - K1082 (1982).

10.- The Rotary Cement Kiln - K.E. Peray (1972).

11.- Trituración - Molienda y Separación de Minerales
N.P. Waganoff (1956).

12.- Utilización del Carbón en la Industria Cementera Española
M. Oliver - D.Alvarez Revista Cemento Hormigón (Dic. 1980).

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CARBON

OPORTUNIDAD DEL PERU

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1985

Publicacion de la Empresa Promotora del Carbon S.A.
PROCARBON Lima, Peru

COAL PRODUCTION

COAL PRODUCTION IN PERU HAS BEEN VERY IRREGULAR DURING THIS CENTURY AND THIS CAN BE ATTRIBUTED TO THE RELATIVELY SMALL LOCAL DEMAND.

THE MAIN LOCAL CONSUMERS HAVE TRADITIONALLY BEEN TWO STATE-OWNED COMPANIES: CENTROMIN PERU FOR ITS SMELTER AT LA OROYA AND SIDER PERU FOR ITS STEELMAKING PLANT AT CHIMBOTE, BOTH OF WHICH REQUIRE COKING COALS, WHICH ARE SCARCE IN THE COUNTRY.

CENTROMIN PERU'S COKING PLANT IS FED WITH COAL PRODUCED AT ITS GOYLLARISQUIZGA MINE, WHICH IS MIXED WITH BRADFORD COAL IMPORTED FROM THE U.S. AND SIDER PERU HAS ALWAYS IMPORTED COKE, UNTIL ITS BLAST FURNACE WAS STOPPED AND REPLACED BY ELECTRIC FURNACES, ALTHOUGH THE COMPANY IS NOW CONSIDERING PUTTING BACK INTO OPERATION ITS BLAST FURNACE, THUS RE-OPENING AN IMPORTANT LOCAL MARKET FOR COKE.

BESIDES THESE TWO LARGE CONSUMERS, THERE ARE OTHER SMALL INDUSTRIES WHICH CONSTITUTE A RELATIVELY STABLE MARKET FOR ANTHRACITE.

COAL MINING IN PERU IS CARRIED OUT AT A SMALL SCALE AND EMPLOYING A RELATIVELY SIMPLE TECHNOLOGY, BEING SOMETIMES A SEASONAL ACTIVITY.

CURRENT LOCAL COAL PRODUCTION IS ESTIMATED BETWEEN 50,000 AND 80,000T/Y, GOYLLARISQUIZGA BEING THE LARGEST OPERATING UNIT PRODUCING AROUND 17,000 T/Y.

PROCARBON

COAL CONSUMPTION

THE COUNTRY'S LOCAL COAL MARKET CAN BE DIVIDED INTO TWO DISTINCT GROUPS: CENTROMIN PERU AND SIDER PERU, BOTH REQUIRING COKING COAL AND THE REST OF THE USERS (SMALL SMELTERS, BRICK PLANTS, ETC), WHICH CONSTITUTE THE MARKET FOR ANTHRACITE. CENTROMIN PERU IMPORTS AN AVERAGE OF 35,000 T/Y OF BRADFORD COAL TO COVER ITS ANNUAL DEMAND OF 55,000 T/Y, WHICH REPRESENT AROUND 50% OF THE CURRENT COAL MARKET, THE REMAINING INDUSTRIES CONSUMING APPROXIMATELY 45,000 T/Y OF ANTHRACITE SUPPLIED BY LOCAL PRODUCERS, THIS MAKING AN OVERALL DOMESTIC MARKET OF AROUND 100,000 T/Y.

DESPITE THIS RELATIVELY SMALL MARKET, THERE ARE INDICATIONS THAT SOME IMPORTANT INDUSTRIES SUCH AS THE CEMENT PLANTS, ARE NOW CONSIDERING TO CONVERT THEIR INSTALLATIONS FROM OIL TO COAL, WHICH WOULD INCREASE THE LOCAL DEMAND BY 150,000 T/Y IN A VERY SHORT PERIOD IF THE CONVERSION OPERATION IS CARRIED OUT AS FAST AS EXPECTED.

PROCARBON

PRESENTATION

THIS BRIEF DOCUMENT HAS BEEN PREPARED BY EMPRESA PROMOTORA DEL CARBÓN S.A. (PROCARBON) AS A GENERAL GUIDE TO THE COAL SITUATION IN PERU.

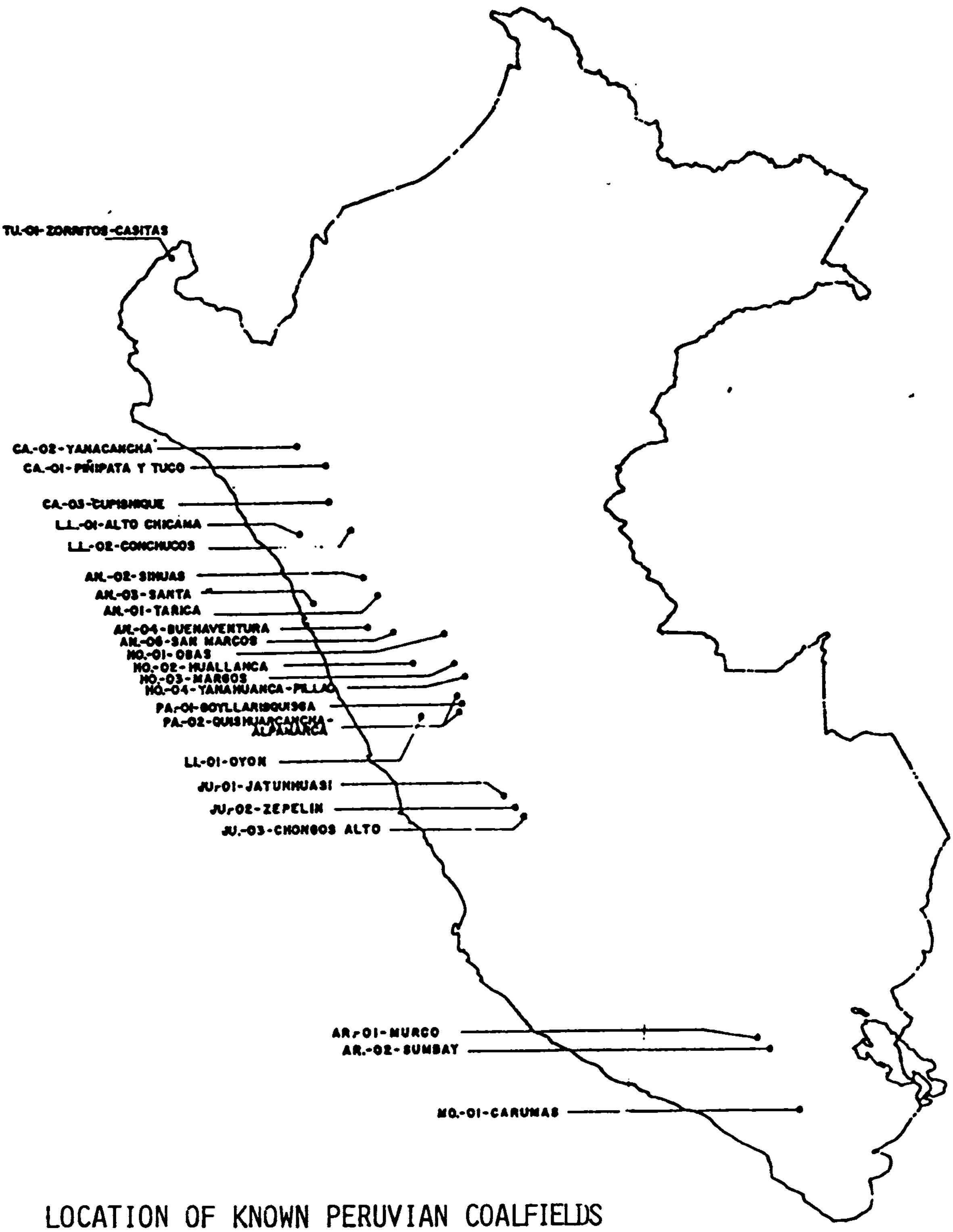
IT CONTAINS INFORMATION ON THE COUNTRY'S COAL PRODUCTION, CONSUMPTION AND POTENCIAL RESERVES (SEE TABLES 1 TO 6) PROVIDING AN OVERALL VIEW THE GEOGRAPHYCAL DISTRIBUTION OF THE KNOWN COALFIELDS AND THE TYPES OF COAL FOUND IN EACH OF THEM.

IT MUST BE STRESSED THAT MOST OF THE COAL RESERVES FIGURES QUOTED HERE, SHOULD BE CONSIDERED AS "SPECULATIVE RESERVES" UNDER THE COAL RESOURCE CLASSIFICATION SYSTEM SUGGESTED BY THE U.S. BUREAU OF MINES AND GEOLOGICAL SERVICE, BUT THIS IS MAINLY DUE TO THE FACT THAT NO SERIOUS EFFORT HAS BEEN MADE YET TO CARRY OUT A SYSTEMATIC COAL EXPLORATION WORK, EXCEPT FOR ONE OR TWO OF THE MOST OBVIOUS LARGE COALFIELDS, WHERE COAL SEAMS OUTCROP ALONG SEVERAL KILOMETRES AND SMALL MINING OPERATIONS HAD BEEN CARRIED OUT IN THE PAST, SOME OF WHICH BEING STILL ACTIVE TODAY.

WHAT IS CERTAINLY CLEAR IS THAT COAL RESERVES ARE IMPORTANT AND THAT THE COAL MARKET IS POTENTIALLY LARGE IF CONSUMERS DECIDE TO LOOK FOR AN ALTERNATIVE TO PETROLEUM FUELS.

PROCARBON

EMPRESA PROMOTORA DEL CARBON S.A.



LOCATION OF KNOWN PERUVIAN COALFIELDS

TABLE N°1: LOCATION OF MAIN PERUVIAN COALFIELDS

COALFIELDS	DEPARTMENT	PROVINCE	DISTRICT	TYPE OF COAL	ACCESS TO PORT
TUMBES	TUMBES	CMDTE. VILLAR	ZORRITOS-CASITAS	LIGNITE	150 KMS FROM TALARA
YANACANCHA	CAJAMARCA	CAJAMARCA	LA ENCAÑADA	ANTHRACITE	228 KMS FROM PACASMAYO
PIÑIPATA	CAJAMARCA	HUALGAYOC	HUALGAYOC	ANTHRACITE	310 KMS FROM PACASMAYO
CUPISNIQUE	CAJAMARCA	CONTUMAZÁ	TRINIDAD	ANTHRACITE	72 KMS FROM PACASMAYO
ALTO CHICAMA	LA LIBERTAD	OTUZCO Y STGO.DE CHUCO	USQUIL Y QUIRUVILCA	ANTHRACITE	160 KMS FROM SALAVERRY
SANTA					
LA GALGADA	ANCASH	PALLASCA	TAUCA	ANTHRACITE	114 KMS FROM CHIMBOTE
ANCOS	ANCASH	PALLASCA	TAUCA	ANTHRACITE	104 KMS FROM CHIMBOTE
LA LIMEÑA	ANCASH	PALLASCA	STA. ROSA	ANTHRACITE	103 KMS FROM CHIMBOTE
SAN CARLOS	ANCASH	PALLASCA	STA. ROSA	SEMI-ANTHRACITE	104 KMS FROM CHIMBOTE
BUEN AMIGO	ANCASH	CARAZ	CARAZ	ANTHRACITE	135 KMS FROM CHIMBOTE
TARICA	ANCASH	SIHUAS	SIHUAS	ANTHRACITE	191 KMS FROM CHIMBOTE
SIHUAS	ANCASH	SIHUAS	QUICHES	ANTHRACITE	213 KMS FROM CHIMBOTE
CONCHUCOS	ANCASH	PALLASCA	CONCHUCOS	ANTHRACITE	240 KMS FROM CHIMBOTE
SAN MARCOS	ANCASH	HUARI	SN.MARCOS-HUANTAR	ANTHRACITE	495 KMS FROM CALLAO
HUALLANCA	HUÁNUCO	DOS DE MAYO	HUALLANCA	ANTHRACITE	450 KMS FROM CALLAO
OBAS	HUÁNUCO	DOS DE MAYO	OBAS	BITUMINOUS	* 502 KMS FROM CALLAO
MARGOS	HUÁNUCO	HUÁNUCO	MARGOS	BITUMINOUS	* 455 KMS FROM CALLAO
GOYLLARISQUIZGA	PASCO	D.A. CARRIÓN	GOYLLARISQUIZGA	SUBBITUMINOUS	341 KMS FROM CALLAO
QUISHUARCANCHA	PASCO	D.A. CARRIÓN	VILCABAMBA	SUBBITUMINOUS	330 KMS FROM CALLAO
PILLAO	PASCO	D.A. CARRIÓN	S.P. CALLAO	SUBBITUMINOUS	375 KMS FROM CALLAO
YANAHUANCA	PASCO	D.A. CARRIÓN	YANAHUANCA	SEMI-ANTHRACITE	367 KMS FROM CALLAO
ALPAMARCA	PASCO	D.A. CARRIÓN	YANAHUANCA	SEMI-ANTHRACITE	342 KMS FROM CALLAO

TABLE N°1
PAGE 2

LOCATION OF MAIN PERUVIAN COALFIELDS......

OYON	DEPARTMENT	PROVINCE	DISTRICT	TYPE OF COAL	ACCESS TO PORT
PAMPAHUAY	LIMA	CAJATAMBO	OYON	BITUMINOUS	250 KMS FROM CALLAO
SAQUICOCHA	LIMA	CAJATAMBO	OYON	SUBBITUMINOUS	246 KMS FROM CALLAO
GAZUNA	LIMA	CAJATAMBO	OYON	ANTHRACITE	255 KMS FROM CALLAO
COCHAQUILLO	LIMA	CAJATAMBO	OYON	ANTHRACITE	274 KMS FROM CALLAO
MATICHACRA	LIMA	CAJATAMBO	OYON	ANTHRACITE	250 KMS FROM CALLAO
ATACOCHA	LIMA	CAJATAMBO	OYON	ANTHRACITE	250 KMS FROM CALLAO
PARQUIN	LIMA	CHANCAY	STA. LEONOR	ANTHRACITE	252 KMS FROM CALLAO
MARAY	LIMA	CHANCAY	STA. LEONOR	ANTHRACITE	255 KMS FROM CALLAO
JATUNHUASI					
CÉLICA-NEGRO BUENO	JUNÍN	CONCEPCIÓN	SN.J. DE QUERO	SUBBITUMINOUS	366 KMS FROM CALLAO
CACHI N Y S	JUNÍN	HUANCAYO	YANACANCHA	SUBBITUMINOUS	386 KMS FROM CALLAO
CHONGOS ALTO					
AMELIA	JUNÍN	HUANCAYO	CHONGOS ALTO	SUBBITUMINOUS	325 KMS FROM CALLAO
ZEPELIN	JUNÍN	HUANCAYO	CHONGOS ALTO	SUBBITUMINOUS	345 KMS FROM CALLAO
MURCO	AREQUIPA	CAYLLOMA	HUANCA	BITUMINOUS?	195 KMS FROM MOLLENDO
SUMBAY	AREQUIPA	AREQUIPA	YURA	BITUMINOUS?	210 KMS FROM MOLLENDO
CARUMAS	MOQUEGUA	MCAL. NIETO	CARUMAS	SEMÌ-ANTHRACITE	210 KMS TO ILO
PEBAS	LORETO	LORETO	INTUTO?	LIGNITE	?
CHAMBARA	LORETO	LORETO	INTUTO?	LIGNITE	?

* ROUTE: LIMA - LA OROYA - CERRO DE PASCO - HUÁNUCO

TABLE N°2: POTENTIAL COAL RESERVES OF KNOWN DEPOSITS

(IN METRIC TONS)

COAL FIELDS	TYPE OF COAL	DEGREE OF CERTAINTY: DEMONSTRATED	INFERRED	SPECULATIVE	TOTAL
TUMBES	LIGNITE	---	1'000,000	100'000,000	101'000,000
PIÑIPATA	ANTHRACITE	---	---	50'000,000	50'000,000
YANACANCHA	BITUMINOUS	---	---	25'000,000	25'000,000
CUPISNIQUE	ANTHRACITE	---	---	24'000,000	24'000,000
ALTO CHICAMA	ANTHRACITE	25'222,741	34'478,764	211'000,000	270'000,000
SANTA					
LA GALGADA	ANTHRACITE	800,000	---	4'000,000	4'800,000
ANCOS	ANTHRACITE	600,000	---	20'000,000	20'600,000
LA LIMEÑA	ANTHRACITE	500,000	---	21'000,000	21'500,000
SAN CARLOS		---	---	2'000,000	2'000,000
BUENAVENTURA	ANTHRACITE	18,000	15,000	15'300,000	15'000,000
TARICA	ANTHRACITE	---	---	27'000,000	27'000,000
SIHUAS	ANTHRACITE	---	---	27'000,000	27'000,000
CONCHUCOS	ANTHRACITE	---	---	26'000,000	26'000,000
SAN MARCOS	ANTHRACITE	---	---	25'000,000	25'000,000
HUALLANCA	ANTHRACITE	40,000	3'000,000	25'000,000	28'000,000
GOYLLARISQUIZGA	SUBBITUMINOUS	1'521,000	900,000	5'000,000	7'421,000
PILLAO	SUBBITUMINOUS	12,000	---	2'000,000	2'012,000
YANAHUANCA	SEMI-ANTHRACITE	4,000	20,000	500,000	524,000
QUISHUARCANCHA	SUBBITUMINOUS	20,000	15,000	2'000,000	2'035,000

POTENCIAL COAL RESERVES OF KNOWN DEPOSITS...

TABLE N°2

PAGE N°2

COAL FIELDS	TYPE OF COAL	DEGREE OF CERTAINTY: DEMONSTRATE	INFERRED	SPECULATIVE	TOTAL
OYON					
SAQUICOCHA	SUBBITUMINOUS	---	---	1'800,000	1'800,000
COCHAQUILLO	ANTHRACITE	---	---	20'250,000	20'000,000
GAZUNA	ANTHRACITE	---	26'000,000	82'000,000	108'000,000
PARQUIN	ANTHRACITE	---	---	4'000,000	4'000,000
PAMPAHUAY	BITUMINOUS	---	10'000,000	24'000,000	34'000,000
JATUNHUASI					
CÉLICA-NEGRO BUENO	SUBBITUMINOUS	703,000	----	30'000,000	30'703,000
CACHI N Y S	SUBBITUMINOUS	165,000	135,000	30'000,000	30'300,000
CHONGOS ALTO					
AMELIA	SUBBITUMINOUS	---	---	1'500,000	1'500,000
ZEPELIN	SUBBITUMINOUS	---	---	800,000	800,000
CARUMAS	SEMI-ANTHRACITE	---	---	3'000,000	3'000,000
		29'605,741	75'563,764	808'050,000	914'319,505

TABLE N°3: RESERVES BY TYPE AND QUALITY OF COAL

TYPE	DEGREE OF CERTAINTY: DEMONSTRATE	INFERRED	SPECULATIVE	TOTAL
LIGNITE	---	1'000,000	100'000,000	101'000,000
BITUMINOUS	2'421,000	11'050,000	122'100,000	135'571,000
ANTHRACITE	27'184,741	63'513,764	586'750,000	677,748,505
TOTAL	29'605,741	75'563,764	808'050,000	914'319,505

TYPE (BITUMINOUS AND SUB-BITUMINOUS)	DEMONSTRATE	INFERRED	SPECULATIVE	TOTAL
COKING COAL	2'256,000	10'915,000	64'800,000	77'971,000
NON-COKING COAL	165,000	135,000	57'300,000	57'600,000
TOTAL	2'421,000	11'050,000	122'100,000	135'571,000

TABLE N°4: PROXIMATE ANALYSES OF TYPICAL SAMPLES

COAL DEPOSIT	KNOWN SEAMS	MOISTURE CONTENT (%)	FIXED CARBON (%)	VOLATILE MATTER (%)	ASH (%)	SULPHUR (%)	CALORIFIC VALUE KCAL/KG	SWELLING INDEX
TUMBES	4	13.5	25.0	29.0	28.0	5.0	3,500	0
CUPISNIQUE	3	5.0	75.0	6.0	10.0	0.6	6,750	0
PIÑIPATA	5	4.3	68.4	5.7	20.7	-	7,000	0
YANACANCHA	-	10.0	45.0	29.0	11.0	1.5	7,000	0
ALTO CHICAMA	10	8.5	70.5	2.4	20.0	1.89	6,846	0
SANTA								
LA GALGADA	6	4.0	84.0	5.75	9.0	0.75	6,750	0
LA LIMEÑA	5	4.5	70.0	5.0	14.0	0.70	6,250	0
SAN CARLOS	6	4.5	82.5	3.5	9.5	0.6	6,750	0
BUENAVENTURA	1	4.5	85.0	3.5	8.5	0.8	6,750	0
TARICA-SIHUAS	2	5.5	-	5.0	10.0	-	6,650	0
GOYLLARISQUIZGA	4	-	45.0	27.0	31.0	3.0	6,100	3-7
QUISHUARCANCHA	2	-	22.8	29.3	47.8	2.8	3,500	?
OYON								
PAMPAHUAY	5	6.0	70.0	19.0	9.0	0.75	7,300	2.5-9.0
GAZUNA	5	6.0	77.5	10.0	7.5	0.75	7,300	0
JATUNHUASI								
CÉLICA-NEGRO BUENO	4	8.0	47.5	35.5	12.5	1.55	6,500	3.5-7.0
CACHI N Y S	4	5.5	47.7	29.3	23.0	6.0	6,500	1.0-1.5
CHONGOS ALTO								
AMELIA	3	-	44.5	32.1	23.9	1.5	5,060	-
ZEPELIN	2	-	44.4	35.4	20.4	0.6	5,380	-
CARUMAS	3	4.0	62.0	23.5	4.0	-	-	0

TABLE N°5: QUALITY OF PERUVIAN COALS

COMPARATIVE TABLE OF QUALITY WITH SOME COALS FORM OTHER COUNTRIES

COUNTRY	% IN WEIGHT				CALORIFIC VALUE	
	ASH	VOLATILE MATTER	SULPHUR	MOISTURE CONTENT	BTU/LB	KCAL/KG
AUSTRALIA	7-14	20-35	0.3-0.8	1-3	11,000 - 12,500	6,105 - 6,940
SUD-AFRICA	20-32	50-60	0.5-2.0	11-30	10,000 - 13,000	5,550 - 7,215
CANADA	8-20	20-35	0.3-0.8	6-8	11,500 - 14,000	6,382 - 7,770
COLOMBIA	8.5		0.6	9.3	11,800	6,549
PERUVIAN COALFIELDS						
ALTO CHICAMA	6-10	2-4	0.5-3.0	4-6	12,615 - 13,500	7,000 - 7,500
JATUNHUASI	9-16	34-37	0.6-2.5	5-6	10,800 - 12,615	6,000 - 7,000
OYON	6-12	16-22	0.5-1.0	6	12,615 - 13,700	7,000 - 7,600
DEL SANTA	6-12	5.6.5	0.5-1.0	4	10,800 - 13,500	6,000 - 7,500

TABLE N°6: MAIN PRODUCTIVE DEPOSITS - 1983 (*)

COAL DEPOSITS	DEPARTMENT	ANNUAL PRODUCTION (T.M.) (**)	PHYSICAL AND CHEMICAL CHARACTERISTICS					
			FIXED CARBON (%)	VOLATILE MATTER (%)	ASH (%)	MOISTURE CONTENT (%)	SULPHUR (%)	CALORIFIC VALUE KCAL/KG
GOYLLARISQUIZGA MINE	C. DE PASCO	90,000	45.0	27.0	31.0	-	2.0-3.0	6000-6500
ALTO CHICAMA MINES	LA LIBERTAD	27,000	70-75	2-3	25-30	8.0	0.5-3.0	7000-7500
OYON MINES	LIMA	16,000	70-80	12-22	6-12	6.0	0.5-1.0	7000-7500
SANTA MINES	ANCASH	12,000	70-82	5-7	6-12	4.0	0.5-1.0	6000-7500

* MOST OF THE MINES ARE SMALL PRODUCTION UNITS AND EMPLOY RUDIMENTARY MINING METHODS

** ESTIMATED PRODUCTION

OVERALL PERUVIAN COAL PRODUCTION (1979 - 1980)

(IN METRIC TONS)

YEAR	ANTHRACITE (WASHED)	BITUMINOUS COAL (R.O.M.)	TOTAL
1970	20,069	136,000	156,069
1971	16,259	--- (*)	16,259
1972	29,344	---	29,344
1973	10,220	---	10,220
1974	N.A.	---	
1975	22,929	---	22,929
1976	21,471	---	21,471
1977	29,352	---	29,352
1978	N.A.	---	
1979	34,300 (+)	6,000	40,300
1980	25,000	17,525	42,525

(*) GOYLLARISQUIZGA STOPPED PRODUCTION

(+) COMBUSTIBLES SÓLIDOS DEL PERÚ S.A. EXPORTED 21,700 MT

SOURCES: - ANUARIO MINERO DEL PERÚ (1970-1976) M.E.M.
- OTHER SOURCES

COAL PRODUCTION AT GOYLLARISQUIZGA

(IN METRIC TONS)

YEAR	PRODUCTION	CENTROMIN CONSUMPTION
1979	1,685	1,627
1980	17,526	15,684
1981	26,450	22,706
1982	17,114	19,807
1983	16,668	17,378

APPENDIX A

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APPENDIX B

SEMINARIO REGIONAL SOBRE LA UTILIZATION DEL CARBON COMO ALTERNATIVE A LOS COMBUSTIBLES DERIVADOS DEL PETROLEO BOLIVIA - ECUADOR - PERU

24-28 de Junio de 1985
Lima, Perú

PROGRAMA

LUNES 24 DE JUNIO

9:00 a.m.	Inscripción de los Participantes	
Sesión de Inauguración		
10:00 a.m.	Ing. Luis F. Morán President PROCARBON	
	Dr. Alberto Sabadell USAID Washington	
	Ing. Luis Chang Vice-Ministro de Energía, Perú	
	Dr. Ulrich Petersen Coordinator General del Seminario	
11:00 a.m.	Intermedio	
Sesión de la Mañana	**POLITICA ENERGETICA**	**Presidente:** Dr. Ulrich Petersen
11:15 a.m.	Política de petróleo y carbón	E. Thiers SRI International
11:45 a.m.	Política de desarrollo carbonífero el caso de Colombia	C. de Greiff Consultor Colombia
12:15 p.m.	Discusión	

Sesión de la Tarde	**IMPACTO SOCIAL DEL CARBON**	**Presidente:** Sr. Robert Mott
2:45 p.m.	Desarrollo carbonífero Impacto socio-económico	C. Harvey Economista Univ. Kentucky U.S.A.
3:30 p.m.	Impacto social del empleo del carbón en Corea	J.I. Yang KIER Corea
4:15 p.m.	Intermedio	
4:30 p.m.	Discusión	

MARTES 25 DE JUNIO

Sesión de la Mañana	**RECURSOS DE CARBON**	**Presidente:** Dr. Eugene Thiers
9:00 a.m.	Recursos carboníferos de Bolivia	M. Flores Servicio Geologico Bolivia
9:30 a.m.	Recursos carboníferos de Ecuador	J. Sosa D.G. de Geologia y Minas, Ecuador
10:00 a.m.	Recursos carboníferos del Perú	E. Dunin-Borkowski Univ. Nac. de Ingeniería, Peru
10:30 a.m.	Intermedio	
11:00 a.m.	Tecnología minera del carbón	A. Szwilski Universidad de Kentucky, U.S.A.
11:30 a.m.	Discusión	

Sesión de la Tarde	LAVADO, PREPARACION Y TRANSPORTE DEL CARBON	Presidente: Ing. Mario Flores
2:00 p.m.	Lavado y preparación del carbón	F. Karlson Electric Power Res. Int., U.S.A.
2:45 p.m.	Métodos de transporte del carbón	R. Mott Dames & Moore U.S.A.
3:30 p.m.	Intermedio	
3:45 p.m.	Utilización del carbón en la industria metalúrgica	E. Thiers SRI International U.S.A.
4:30 p.m.	Discusión	

MIERCOLES 26 DE JUNIO

Sesión de la Mañana	UTILIZATION DEL CARBON	Presidente: Dr. Juan Sosa
9:00 a.m.	Utilización del carbón como combustible doméstico en el Perú	C. Soldi Universidad Católica Perú
9:45 a.m.	Intermedio	
10:15 a.m.	Utilización del carbón para la generación de vapor y electricidad	B.F. Gilbert Florida Power & Light, U.S.A.
11:15 a.m.	Intermedio	
11:30 a.m.	Discusión	

Sesión de la Tarde	**MERCADEO DEL CARBON**	**Presidente:** Dr. Carlos de Greiff
2:00 p.m.	Mercado del carbón colombiano	J. Londoño Asoc. de Industriales y Mineros, Colombia
2:45 p.m.	Mercadeo internacional del carbón: mercados, tendencias y requerimientos	B. Fichna Consultor U.S.A.
3:30 p.m.	Intermedio	
4:00 p.m.	Tecnologías de combustión y mercadeo del carbón	G. Blacker Fluor Engineers, Inc. U.S.A.
4:45 p.m.	Discusión	

JUEVES 27 DE JUNIO

Sesión de la Mañana		**Presidente:** Ing. Benjamin Gilbert
9:00 a.m.	Utilización del carbón en la industria del cemento	R. Céspedes Ind. Nac. Cementos Chile
9:45 a.m.	Proyecto de conversión de Cementos Lima y Cemento Andino	R. Rizo Patrón A.R.P.L. Peru
10:30 a.m.	Intermedio	
10:45 a.m.	Programas de capacitación en energía convencional	S. Ebbin Inst. of International Education U.S.A.
11:15 a.m.	Planeamiento de política energética	A. Heyman Economista U.S.A.
12:00	Intermedio	
12:15 p.m.	Discusión	

<u>Sesión de la Tarde</u>	<u>SESION PLENARIA</u>	<u>Presidente</u>: Ing. Carlos Soldi
2:45 p.m.	Instalación de Sesión Plenaria	
3:00 p.m.	<u>Primera Parte</u> Minería y geología del carbón	
4:00 p.m.	Intermedio	
4:15 p.m.	<u>Segunda Parte</u> Tratamiento y utilización del carbón	
<u>VIERNES 28 DE JUNIO</u>	<u>SESION PLENARIA</u>	<u>Presidente</u>: Ing. Luis Morán
9:00 a.m.	Sesión Plenaria (Cont.)	
	<u>Tercera Parte</u> Transporte y mercadeo de carbón	
10:00 a.m.	Intermedio	
10:45 a.m.	Lectura y discusión de conclusiones de cada una de las partes de la Sesión Plenaria	
12:00	Sesión de Clausura	