THE COAL INDUSTRY OF BRAZIL
Part 2. Technology of Mining and Preparation

TECHNICAL PAPER 713
THE COAL INDUSTRY OF BRAZIL
(In Two Parts)

Part II. Technology of Mining and Preparation

By

JOHN E. GOOD, ALVARO ABREU, AND THOMAS FRASER
FOREWORD

During the last war close cooperation was established between the National Department of Mineral Production (Departamento Nacional da Produção Mineral) and the American counterparts, the Bureau of Mines and the Geological Survey, U. S. Department of the Interior, in order to study mining, geological, and technological problems of mutual interest to Brazil and the United States.

The results of most of these studies have been published, and many works of joint authorship by technicians of both countries now enrich the scientific literature of the Americas on a variety of subjects, such as quartz, beryl, manganese, scheelite, tantalite, mica, nickel, and iron.

It is well known that the important part played in the First World War by Brazilian manganese ore was duplicated during World War II by many strategic minerals such as quartz, tantalite, beryl, and mica. American technical aid was of paramount importance in the production of these minerals.

Fortunately, both countries recognized that no program for expansion of mineral production in Brazil could be effective without consideration of coal production in southern Brazil. For this reason a brilliant team of experts was sent to Brazil to increase production, to rationalize mining, and to study geological and technological problems related to coal. The work of these men was excellent and is gratefully acknowledged here: Russell Fleming, John E. Good, William Fourquarean, Thomas Fraser, Mackenzie Gordon, and Anton A. Brumfield. All have been excellent ambassadors of their country.

In regard to coal the cooperation was carried out through the Bureau of Mines, and it may be said that these engineers have contributed materially to the increase in production and better knowledge of Santa Catarina coal.

The work published by Thomas Fraser and Dr. Alvaro Abreu on the washability of Brazilian coals (Bulletin 13, Laboratory of Mineral Production) has become a classic in its field.

A further result of the cooperation initiated in 1941 is the present paper on Brazilian coals written by the American engineers John E. Good and Thomas Fraser and their Brazilian colleague Alvaro de Paiva Abreu.

In part I of The Coal Industry of Brazil the authors describe the general economy, production, and marketing of Brazilian coal. In this, the second part, they analyze mining and technological aspects of coal mining in Brazil.

This is the first time that an over-all picture has been drawn of the Brazilian coal problems, and the reader can see not only the many difficulties that confront both the producers and the consumers of a coal whose known reserves are inadequate and of poor quality but also the possibility of improvement.

Unfortunately, there has been a lack of comprehension in Brazil as to the importance of coal in modern technology. The attention of
almost everyone has been drawn to petroleum, but the importance of coal as a primary source of energy has been overlooked. The present paper, I am sure, will prove an excellent reference point for reactivation of interest in coal.

I hope that the spirit of comprehension and friendship with which this work has been completed will always be characteristic of the cooperation between the technicians of the two countries.

MARIO DA SILVA PINTO,
General Director,
National Department of Mineral Production.

RIO DE JANEIRO, BRAZIL.
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THE COAL INDUSTRY OF BRAZIL

(In Two Parts)

Part II. Technology of Mining and Preparation

By John E. Good, Alvaro Abreu, and Thomas Fraser

INTRODUCTION

This bulletin is a comprehensive over-all study of the coal industry of Brazil. Part I, entitled "General Economy, Production, and Marketing," was published as Bureau of Mines Technical Paper 713 in 1949. Part II completes the publication with a general description and analysis of the technology of coal production, coal preparation, and the movement of domestic coal supplies in Brazil.

The coal-producing industry of Brazil is active in the three southernmost States of that country—Rio Grande do Sul, Santa Catarina, and Paraná. The State of São Paulo has produced small quantities from time to time, but the known reserves there are so limited that this State is not generally considered to be a potential coal producer.

Coal furnishes only a relatively small proportion of the total energy consumed in the nation; the largest load is carried by wood, as in most of the South American countries. In any sustained expansion of industrial activity in Brazil on a substantial scale the increase in total energy must necessarily be supplied very largely by coal. Firewood production is generally considered to have reached the maximum, and in some localities where the railways have depended for many years on firewood for locomotive fuel the supply is becoming scarce and costly. There are tremendous water-power potentials in Brazil, but for many years to come the nation's industries and its railway transportation system will be so widely separated that the capital investment required to serve these energy users with central-station electrical energy would be prohibitive. Hence, a dependable source of coal supply in gradually increasing quantities is very important to the future development of the economy of Brazil.

SUMMARY

The coal needs of the nation have for a long time been supplied from domestic and imported sources roughly in equal proportions, although this ratio varies from time to time as the supply of foreign sources

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1 Work on manuscript completed June 1950.
3 Mining engineer, Departamento Nacional da Produção Mineral, Rio de Janeiro, Brazil.
of coal has varied. Table 1 summarizes the available statistical data on the consumption of coal in recent years by foreign and domestic sources.

**Table 1.—Brazilian coal production and imports, 1940–46, metric tons**

<table>
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<tr>
<th>Year</th>
<th>Brazilian production</th>
<th>Imports</th>
<th>Total</th>
<th>Coke imports</th>
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</thead>
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<tr>
<td>1940</td>
<td>1,048,533</td>
<td>1,185,904</td>
<td>2,234,437</td>
<td>25,338</td>
</tr>
<tr>
<td>1941</td>
<td>1,109,853</td>
<td>1,093,323</td>
<td>2,196,182</td>
<td>24,623</td>
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<tr>
<td>1942</td>
<td>1,354,089</td>
<td>592,761</td>
<td>1,946,850</td>
<td>23,277</td>
</tr>
<tr>
<td>1943</td>
<td>1,537,423</td>
<td>712,562</td>
<td>2,249,994</td>
<td>52,239</td>
</tr>
<tr>
<td>1944</td>
<td>1,414,667</td>
<td>709,957</td>
<td>2,124,624</td>
<td>12,208</td>
</tr>
<tr>
<td>1945</td>
<td>1,489,666</td>
<td>956,980</td>
<td>2,446,646</td>
<td>17,920</td>
</tr>
<tr>
<td>1946</td>
<td>1,273,708</td>
<td>1,002,620</td>
<td>2,276,328</td>
<td>11,506</td>
</tr>
</tbody>
</table>

1 Cleaned coal available to consumers.

**RESERVES**

In some of the established producing areas parts of the field have been explored by means of drill holes and exploratory openings; these data form the basis of estimates of known reserves ranging variously from 380 to 650 million metric tons. The data given in table 2 broken down by States are considered to be conservative.5

**Table 2.—Estimate of coal reserves of Brazil, metric tons**

<table>
<thead>
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<th>State</th>
<th>Reserves (metric tons)</th>
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<tr>
<td>Rio Grande do Sul</td>
<td>60,000,000</td>
</tr>
<tr>
<td>Santa Catarina</td>
<td>400,000,000</td>
</tr>
<tr>
<td>Paraná</td>
<td>20,000,000</td>
</tr>
<tr>
<td>São Paulo</td>
<td>500,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>480,500,000</strong></td>
</tr>
</tbody>
</table>

The data for the State of Santa Catarina refer only to the coal known to exist in the Barro Branco bed; no estimates are included for the Rio Bonito bed or for possible extensions of the Barro Branco bed beyond the areas explored by present producing companies. Estimates for Rio Grande do Sul likewise contain only the relatively well-known areas; very probably, the conservative figure given here would be greatly expanded if exploration work were continued in the Rio Negro field near Bagé and in the Condeota Valley.

**RIO GRANDE DO SUL**

Brazil has one of the oldest coal-mining industries in South America, dating back to the opening of a small mine in São Jeronimo County in the State of Rio Grande do Sul in 1853; a coal-mining activity has been carried on intermittently in that area till the present time. At the beginning of the Second World War there were two well-organized, sound mining operations in that field, one at the original mine location of Arróio dos Ratos and the other at Butiá.

Both operations are administered by the Consórcio Administrador das Empresas de Mineracão (CADEM), which was organized in 1916.

These are the largest coal-mining operations in Brazil. The two mines are relatively near together in the eastern extremity of the crescent-shaped field just west of the city of Porto Alegre. In that locality the coal beds are not continuous, but the deposits occur in a series of isolated basins that attain a thickness of 5 to 9 feet in the central part but thin out toward the edges.

Development plan.—The deposits are opened by shafts and slopes, and all the coal is produced in underground mining operations.

At Butiá the room-and-pillar mining system is used with some modifications. The use of mechanical mining equipment is limited to pneumatic puncher-type cutting machines and pick hammers. The cutting machines are generally used only in driving narrow work, while the pick hammers are employed in rooms as well as development headings. Endless-rope haulage systems are used for underground transportation on the main haulage roads and the principal secondary roads. Loaded and empty cars are hand-trammed between collecting points and the face.

A modified longwall panel mining system is employed at the Arróio dos Ratos mine. The mechanical equipment underground is similar to that at Butiá except that electric trolley locomotives are used on the main haulage roads. The mine workings at both properties are ventilated by exhaust fans of the centrifugal type.

Surface plant.—On the surface both these mining properties have modern American coal-preparation plants designed and built by the McNally-Pittsburg Manufacturing Corp. Both plants are combination picking-table and Baum-jig washery plants adapted to prepare railway fuel and to make a secondary coal, which is delivered to the utilities company in Porto Alegre for use as power-plant fuel on chain-grate stokers and in pulverized-fuel burners.

Power for the productive operations and transportation facilities is supplied by thermoelectric generating plants at each of the mines. The larger of the two plants, at Arróio dos Ratos, furnishes power to the municipality of São Jeronimo and to the port of Charqueadas.

At each property there are general machine shops, blacksmith shops, foundry, carpenter shops, electrical repair shops, and repair shops for rolling stock of the mine transportation system. At Butiá repair work also is done on railway rolling stock.

Black powder, the explosive normally used in the mining operations, is manufactured in company-owned factories at the two mines. Normal consumption is at the rate of about 2,640 pounds of powder per day at each mine. The productive capacity of each plant is about 6,600 pounds of black powder in 8 hours.

The company also operates a railway to the port of Charqueadas on the Jacuí River and has loading facilities there by which coal is loaded into barges and transported to Porto Alegre, whence it is shipped by sea to other consuming areas of Brazil. Surface facilities of the Butiá property include a 3,600-meter aerial tramway across the Jacuí River at Conde. This tramway is used to deliver railway fuel to the State railways of Rio Grande do Sul.

The company has initiated an advanced program of social benefits for the working people, which includes adequate hospital facilities,
schools, and housing accommodations. Under the national labor code the mine operates a 5-day week, with four 6-hour shifts each working day.

For many years these two mines furnished the bulk of the domestic coal production; they reached a peak production record in 1943, when 1,346,269 metric tons was shipped. Since then the production rate has decreased materially, owing in part to the fact that the working areas have advanced into sections of the beds where mining conditions are less favorable and in part to the shortened work shifts, coupled with a shortage of permanent labor.

State mines.—To compensate for the threatened shortage of railway and industrial fuel in the State and for the rising costs of fuel, the government of the State of Rio Grande do Sul in 1947 established a State agency, the Departamento Autonomo de Carvão Mineral, under the direction of Dr. Jose Borges de Leão, to promote the production of coal on State-owned mining properties. This State agency is organizing a comprehensive program to develop the mining property of Leão in the same general area as the properties of CADEM and is also vigorously prosecuting the exploration of coal deposits in other parts of the State.

SANTA CATARINA

The coal deposits of Santa Catarina, unlike those in Rio Grande do Sul, are persistent over large areas. The Barro Branco bed is mined extensively in the Lauro Müller, Urussanga, Criciuma, and Sideropolis areas. The Rio Bonito bed below the Barro Branco has not been explored, but it is generally thought also to be persistent and substantially level.

The Barro Branco coal bed, in which nearly all the producing mines are working, is a high-rank, medium-volatile coking coal, but it is so intimately intermixed with shale and bony bands that the preparation of a usable coal is very difficult.

Coal has been mined in this field for many years, but until the national steel industry was established the production was relatively small compared to that of Rio Grande do Sul, which dominated the domestic coal-producing industry. During the period of development and construction of the Government-sponsored national steel industry a concerted effort was made to expand the production of coal in Santa Catarina, which is the only domestic source of metallurgical coal. The Brazilian National Government took many practical steps to support the coal industry in that area, and the United States Government, working first through the Board of Economic Warfare, then through the Foreign Economic Administration, and later through the Bureau of Mines, cooperated actively with the National Government in these efforts and assigned several technicians from the United States to the coal field during that period. Stimulated by these efforts and by the expanding coal market furnished by the national steel industry, the production of coal in Santa Catarina increased from 268,213 metric tons in 1940 to 980,000 metric tons in 1946.

Mine development.—In 1940 a number of relatively small drift mines were operated in the Criciuma area, and a few somewhat larger mines, some of which were opened by shafts and slopes, were worked in the Lauro Müller and Urussanga regions.
Throughout the area the coal is won by hand at the face and loaded into small cars of 600 to 900 kg. capacity and trammed by hand to the outside, except in two or three of the largest operations. Until very recently there were no central commercial power-generating stations from which the mines could purchase power, and only the largest operations had mine power plants. Because of an almost complete lack of mining machinery, machine shops are confined to a few of the largest central units, and repair or maintenance shops at the mine proper are limited to small blacksmith shops for repair of hand tools. At most of the operations the only surface structures are open sheds of timber construction to house the screening and hand-picking operations. However, there are mine preparation plants at the Lauro Müller property of the Companhia Nacional de Mineração de Carvão do Barro Branco at Lauro Müller and at the plant of the Companhia Carbonifera de Urussanga at Urussanga. The Lauro Müller plant is equipped with piston jigs and coal-washing tables, and the Urussanga plant, of German design, is equipped with Schuchterman and Kramer-Baum jigs in which feldspar is used in the boxes for cleaning the fines. Both these plants are small. The Companhia Brasileira Carbonifera de Araranguá and the Sociedade Carbonifera Prospera each operates one Deister table for cleaning fines, and there are several hand-jig plants scattered through the field to handle fines at the rate of 0.5 to 1 ton per hour.

In the hand-picking plants the coal is first screened by hand, then picked laboriously by hand on stationary tables, and then discharged to pit cars or bins, whence the coarse coal is hauled, usually by trucks, to railway sidings and again transferred by hand to railway cars. In the hand-preparation plants the coal is transferred from operating step to step by hand.

The total production of the field is gathered usually by trucks to sidings on the Dona Teresa Cristina Railway, which has branches to the three principal areas of the coal field, namely, Lauro Müller, Urussanga, and Criciuma; it is transferred by this railway to the twin seaports of Imbituba and Laguna, whence it goes to market by sea.

This was substantially the physical condition of the Santa Catarina coal industry when the National Government sponsored the development of the steel industry in 1940.

National Steel Company.—As a part of the steel-industry development program the Government empowered the National Steel Company to purchase all the coal produced in the Santa Catarina field or such part of it as might be needed, and it established by decree a uniform price schedule that would insure profitable operation to the industry and encourage expansion of production; it empowered the National Steel Company itself to acquire mining property and develop coal-producing enterprises; and it authorized the Departamento Nacional da Produção Mineral to carry on extensive technical investigations in the Santa Catarina coal field, to establish working regulations and direct the use of employment in the area, and to construct waterworks and an experiment station in the municipality of Criciuma. The Government of the United States assigned mining engineers and other technicians to cooperate with the Departamento Nacional in this
program to stimulate the production of metallurgical coal for the steel industry.

As a result of these measures, new mines were opened, and production was greatly increased, especially in the Crimiuma area. Power plants, mostly of portable Diesel-driven type with compressors, were installed at some of the mines, and pick hammers were introduced in the underground work to speed up the production of coal and the extension of development work. Many improvements in details of coal-handling operations were made to increase the productivity per man, especially among surface workers. An experimental hand-picking plant was erected by the Departamento at the Bainha mine, and substantial improvements were introduced to eliminate hand methods of transporting from unit to unit.

**Sideropolis stripping operation.**—After extensive exploration work in the vicinity of the town of Beluno the National Steel Company acquired property there, which contains large areas of Barro Branco coal adapted to open-cut mining; it then developed the Sideropolis mine, which now produces approximately 10 percent of the total output of the Santa Catarina field. A large part of this tonnage is produced by strip-mining methods with mechanical equipment obtained in the United States. Some underground operations are also being developed, and a surface preparation plant with large-capacity storage bins and some mechanical aids to the worker have substantially increased production per man as compared with the more primitive mine preparation plants described briefly above.

**Capivarí washery.**—Early in the development program the National Steel Company sampled the run-of-mine Barro Branco coal from the several coal-producing districts and sent a test lot of some 50 tons to the United States for washing tests and coking tests.

Based on the test data obtained in the United States, the steel company erected a central coal-preparation plant in the railroad yard near Tubarão to prepare the Santa Catarina coal to make metallurgical fuel. This plant site is near the junction point of the branch lines of the Dona Cristina Railway, which connects the coal-producing area with the Atlantic coast ports of Imbituba and Laguna. Here the steel company erected a 400-ton-per-hour washing plant of American design, furnished by the McNally-Pittsburg Manufacturing Corp.

The Capivarí washery is a combination Baum-jig and Rheolaveur plant housed in a modern reinforced-concrete structure.

Raw coal obtained by purchase from the various producers in the Santa Catarina field is stored in a series of raw-coal storage bins in the receiving yards. Besides serving as storage bins to furnish a continuous flow of raw material to the preparation plant, these bins must also serve as separate storage bins for the different producers in order to facilitate fiscalization of the business. There is also a central power-generating station at Capivarí to produce power for use in the preparation plant and for the coal producers in the Santa Catarina field. This plant is adapted to use secondary coal from the washing plant.

The Barro Branco coal, though of a very good coking quality, is extremely difficult to wash, and the yield of metallurgical coal is small. Therefore, it is necessary to make a three-product separation
and to dispose of a large part of the product as a general-purpose fuel of relatively higher ash content and lower heating value than the first-grade coal, which goes to the coke ovens of the steel plant at Volta Redonda.

The problem of preparing this coal for metallurgical use is very difficult. Currently, the Capivarí washery is producing a metallurgical-grade coal of about 22 percent ash content and is obtaining a yield of this grade of around 30 percent. Also, a product amounting to 30 to 40 percent of the raw coal is used in the power plant or shipped to market for industrial purposes. At the Volta Redonda plant the Santa Catarina coal is blended usually with around 50 percent of high-volatile imported coal, drawn from the eastern United States or Britain. Although this blend yields a coke of relatively high ash content, it nevertheless is well-adapted for use in the blast-furnace plant at Volta Redonda because the iron ore for this plant is obtained from the Minas Gerais iron range and has a very high iron content; it is therefore desirable to have an adequate volume of coke ash to slag off the sulfur.

Under the cooperative agreement between the Bureau of Mines, United States Department of the Interior, and the Departamento Nacional da Produção Mineral, extensive tests of the washing characteristics of the Barro Branco coal have been made throughout the field. These data have shown that the upper bench of that bed (above the middle bench, called the Barro Branco) is relatively cleaner and much easier to wash to metallurgical grade than the bottom bench. Operations at the Capivarí washery probably would be facilitated by mining the two benches of the Barro Branco bed separately, the top coal being used only for metallurgical use. In most underground operations the two benches of the bed are handled separately at the face, and it would not be impracticable to keep these two products separate where the mining and transportation are done by hand, as is still the prevailing practice.

Dona Teresa Cristina Railway.—Expansion of coal production in the Santa Catarina field required substantial improvements in transportation facilities. The Dona Teresa Cristina Railway line, which connects the coal field with the coast, was improved, and some new rolling stock was obtained; but the primary improvements that stepped up the capacity to haul coal were the modernization and expansion of the maintenance department so that the locomotives could be kept in service. Movement of coal also was facilitated by construction of a central railway loading bin in the railway yards at Criciúma, where raw coal may be loaded by gravity into railway cars.

Port facilities.—Loading facilities at the twin ports of Laguna and Imbituba also were greatly improved. A loading station at the Imbituba port, erected in 1940, consists of a series of bunkers adapted to load by gravity chutes directly to ocean-going vessels. Belt conveyors distribute the coal to the bunkers and transport the coal from the railway dump hopper to the distributing conveyors above the bunkers. The Laguna facilities consist of an open storage yard along the water front with a concrete sea wall and masonry quay upon which traveling cranes serve the boats alongside, loading coal from open storage behind the sea wall.
PARANÁ

Exploration work was carried out in the northeastern part of the State of Paraná during World War II, and a small production was developed to supply fuel for the Rêde Viação Paraná-Santa Catarina and for the industrial area of São Paulo. The Paraná coal beds lie in a number of small basins in the general area called the Rio do Peixe area, which is served by the Rio do Peixe branch of the above-mentioned railway. The coal beds vary greatly in thickness and quality, ranging from subbituminous to anthracitic; however, the principal operating mines are in bituminous coal. The mines are opened by drifts, but in the northeastern part of the field there are beds under about 330 feet of cover that would have to be opened by shafts.

During the development of these mines the Rio do Peixe branch of the railway was extended to Euzebio Oliveira, and it is proposed to extend this railhead to the center of the Rio do Peixe coal-producing area but construction work is not yet completed. Inadequate transportation facilities have limited coal-production capacity. All mining and mine transportation are carried on by hand, and preparation methods are very simple. Until 1946 virtually all the coal was screened to about 1½-inch size, and the screenings were discarded. In 1946 the Companhia Carbonífera Brasileira built a cleaning plant at its property and installed a modern stoker-fired boiler plant to generate power. The preparation plant with screens, picking tables, and Deister tables, to wash the slack, produces a coal containing around 14 to 18 percent ash.

The peak production was reached about 1945, when a total of 79,856 metric tons of coal was shipped out of the Paraná field. Virtually all this coal was used as locomotive fuel by the Rêde Viação Paraná-Santa Catarina and the Sorocabana Railway. Both these railways serve industrial areas that would be potential consumers of coal if adequate production and transportation facilities were available.

ORGANIZATION OF THE INDUSTRY

RIO GRANDE DO SUL

ARRÔIO DOS RATOS

The history of coal mining in São Jeronimo County, Rio Grande do Sul, began about 1800 with the discovery of coal at Curral Alto (then), County of Rio Pardo. From the time of discovery until 1851 various studies and investigations were carried on at intervals, all of which indicated that the quantity and quality of the coal reserves justified commercial development.

In 1853 an English engineer named James Johnson started development of a coal mine near the town of São Jeronimo, the beginning of the coal-mining industry in Rio Grande do Sul. Shortly thereafter, with English capital, the Imperial Brazilian Collieries Co., Ltd., was formed, and a railroad was built from the mines to the port of Pereira Cabral, near São Jeronimo, on the right bank of the Jacuí River.

The enterprise started by Johnson and his associates did not prosper and was finally abandoned. The mines were taken over successively by several other operators, and in 1916 the company was reorganized.
under the direction of Eugenio Honold, Octávio Reis, Miram Latif, and Luiz Betim Paes Leme. A new port was constructed at Charqueadas, on the Jacuí River, and linked to the mines by a railroad. This company extended on an industrial scale the development of the mines that are today known as Arróiô dos Ratos, or São Jeronimo.

BUTIÁ

The Butiá mines, situated in the third district of São Jeronimo County, were opened in 1881 by António Patrício de Azambuja, Gaspar de Menezes, and Nicácio Teixeira Machado. Machado played the same role in the development of Butiá that Johnson did at Arróiô dos Ratos.

After the first shaft was sunk to a depth of about 55 feet (16.70 meters) the operation was inactive until 1905, when Machado, despite numerous difficulties, succeeded in reorganizing the company under the name of Companhia Hulha Rio Grandense and extracted the first underground coal at Butiá in 1914. This activity again collapsed in 1915 but was reopened in 1917 by Buarque de Macedo, who formed the Companhia Carbonifera Rio Grandense. In 1918 the company obtained State funds to build a railroad branch from the mines to Entroncamento, a station on the Estrada de Ferro do Jacuí (railroad), which connects the Leão mines (formerly Jacuí mines) to the port of Conde on the Jacuí River. This railroad and the branch today are part of the Viação Ferrea do Rio Grande do Sul (railroad) system.

In 1925 direction of the company passed into the hands of the Martinelli group, finally remaining under the exclusive direction of the industrialist and engineer Roberto Cardoso, who is responsible for Butiá’s present state of prosperity.

In 1936, by mutual agreement between the mines of Butiá and those of Arróiô dos Ratos (or São Jeronimo), CADEM (Consórcio Administrador das Empresas de Mineração) was organized. Since then this organization has handled the administration of both the Butiá and the Arróiô dos Ratos mines.

JACIÊ (OR LEÃO)

Between 1916 and 1917 Frederico Horta Barbosa, Buarque de Macedo, Arraia Lisboa, and others organized the Cia. Minas de Carrão do Jacuí with the aid of the Federal Government, which retained half of the shares of the new company. A shaft about 475 feet (145 meters) deep was sunk, and the Estrada de Ferro do Jacuí (railroad) was built connecting the new mine to the port of Conde on the Jacuí River.

The Leão mining project failed in 1923 and remained idle until it was reorganized in 1942 under the name of Cia. Nacional de Mineração e Força. The company was formed with São Paulo capital and was under the technical direction of Horta Barbosa, who died a short time later. After many difficulties encountered in reopening the flooded galleries the mine was brought into limited production but was soon closed again to enter another period of inactivity. In 1948 the mine was purchased by the State of Rio Grande do Sul and turned over to a State government agency to be developed and operated.
The CADEM mines (Arróiio dos Ratos and Butiá) in Rio Grande do Sul are the largest coal mines in Brazil and for many years have represented the best, if not the only example, of a compact, coordinated, comparatively large-scale coal-mining organization in the country. Production is derived from two large mines in contrast to the many small producing units in Santa Catarina and Paraná, and the administrative and technical staff is competently organized. All drilling, exploration, mapping, mine planning, engineering control, cost control, and records are practiced to a much greater extent than in the other coal fields.

The two mines at Arróiio dos Ratos and Butiá together produce about 98 percent of all the coal mined in Rio Grande do Sul. In 1943, a peak production year, the Arróiio dos Ratos mine produced 676,455 metric tons of run-of-mine coal, and Butiá produced 664,196 metric tons. The production rate was approximately 2,500 tons per day for each mine, a sharp contrast to the low production rate of individual mines in Santa Catarina and Paraná.

ORGANIZATION OF STATE PROJECTS

The Departamento Autônomo de Carvão Mineral (Autonomous Coal Department) was created by the Governor of the State of Rio Grande do Sul on July 7, 1947, by decree law 1477. The principal motives given by the State for this action were:

1. To promote and stimulate industrial and commercial development of coal deposits within the State, supplementing the production of private producers.
2. To furnish the State-owned Viação Ferrea do Rio Grande do Sul (railroad) with coal, which private producers had recently failed to supply. Production of marketable coal in Rio Grande do Sul had dropped from 925,759 tons in 1943 to 676,000 tons in 1946. The State, as the largest consumer of coal, was therefore compelled to take steps to remedy the situation. During 1947 the State-owned railroads alone consumed 30.5 percent of Rio Grande do Sul coal production, in addition to that used by navigation and other public services.
3. To permit basic industries to function in the event of a shortage of foreign coal. During this period (1943−46) the importation of foreign coal became increasingly difficult. In 1946, when the coal shortage became most acute because of strikes at the CADEM mines, it was necessary to appeal to Santa Catarina for coal in order to keep basic industries functioning.
4. To reduce the cost of coal. The State considered that the price it had to pay for coal was too high. It was decided that a reduction in cost of production could be realized by developing an open-pit mine in the coal deposits at Leão, in the São Jerônimo area, and at Dario Lassance, along the railroad.

Table 3 shows the fuel consumption of the State-owned railroad from 1944 through 1948.

<table>
<thead>
<tr>
<th>Fuel</th>
<th>1944</th>
<th>1945</th>
<th>1946</th>
<th>1947</th>
<th>1948</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firewood</td>
<td>749.987</td>
<td>761.653</td>
<td>778.965</td>
<td>766.806</td>
<td>714.306</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>306.288</td>
<td>415.993</td>
<td>376.520</td>
<td>363.122</td>
<td>456.645</td>
</tr>
<tr>
<td>Pellets</td>
<td>1.401</td>
<td>75</td>
<td>1.948</td>
<td>674</td>
<td></td>
</tr>
<tr>
<td>Briquettes</td>
<td>8.657</td>
<td>8.543</td>
<td>7.778</td>
<td>7.850</td>
<td>2.755</td>
</tr>
<tr>
<td>Santa Catarina coal</td>
<td>6.121</td>
<td>1.979</td>
<td>1.234</td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States coal</td>
<td>21.955</td>
<td>57.789</td>
<td>17.218</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Last 4 months estimated.

If the different fuels are converted into equivalent tonnages of domestic coal it is apparent that private producers are supplying less than 60 percent of the railroad's total fuel requirements. One of the principal aims of the D. A. C. M. is to supplement this supply from private producers.

D. A. C. M. also considered another major factor. The frontier region between Cacequi and Rio Grande is some 625 km. by railroad from the CADEM mines. Transportation of coal to this area increases its cost by about 50 percent. The Candiota Valley in this region contains some of the thickest coal deposits in the State, at least some of which can be mined by open-pit methods, and the State proposes to develop these deposits.

Included in the State electrification plans is a thermoelectric plant to be built in this frontier region to supply power to the cities of Bagé, Pelotas, and Rio Grande and to permit the electrification of the railroad between Bagé and Rio Grande. The coal deposits and probable market will determine the exact location of this plant. Studies on the development of an open-pit mine to supply the power plant with coal have been carried on since 1946 and have reached the final stages.

In the region near São Jeronimo the D. A. C. M. is exploring a coal deposit by open-pit methods. Reserves are estimated at about 1,000,000 tons, and it is planned to produce 150,000 tons a year. There is also under development in the same area a drift mine, with reserves of about 500,000 tons, which is expected to produce 60,000 tons a year. These two mines will probably be worked out within 5 to 8 years. Additional reserves lie somewhat deeper in the form of a synclinal deposit; the State plans to mine this coal eventually but not at present.

The area around São Jeronimo will supplement the coal supplies for the railroad trunk lines in this region, while the Candiota area will supply the frontier region.

SANTA CATARINA

The coal-mining industry in Santa Catarina made considerable progress during the period 1942-46. Impetus was supplied by the necessity of increasing domestic production to replace the shortage of imported coal during the war period and by the fact that the new Volta Redonda steel plant of the National Steel Company planned to obtain at least 50 percent of its metallurgical coal from Santa Catarina.

The producers—the National Department of Mineral Production, the National Steel Company, and the individuals concerned—did a splendid job of increasing production during these critical years. Improvements were made in mining practice, but few basic changes could be made because of a shortage of personnel, material, equipment, and time for planning and execution.

Although some of the larger and better organized companies have competent engineers, mine foremen, and shift bosses ("capatazes"), many of the producers have no technical mining men on their active staff, and supervision is often exercised by men with no mining background or experience.

Coal deposits usually lend themselves to rather exact evaluation methods, but economic mining requires meticulous attention to detail.
and the ability to adapt specialized methods and machinery to varying conditions. Cost control of various operations is important, and basic elements of safety, ventilation, and handling of material are problems peculiar to a coal mine. With competent technical and underground supervisory personnel, a mining company will enjoy distinct operating advantages and can utilize natural resources more efficiently. Many of the smaller producers neither observe nor take advantage of these factors.

"EMPREITEIRO" SYSTEM

The "empreiteiro" system, common in Santa Catarina, was a deterrent to the sound development of the coal industry, although it was a distinct advantage—almost a necessity—when shortages of imported coal made it imperative to increase domestic production quickly. Under this system a company owning coal concessions would allow individuals or small groups to mine coal from the company property, buying the production from the empreiteiro at a stipulated price for resale as company coal. This system has been common practice for many years; even the larger companies often actually operated only a few mines and derived an appreciable part of the "company" production from empreiteiro mines. Under the necessity of quickly increasing production these empreiteiro mines flourished and, in fact, accounted for a substantial production when it was badly needed.

Most of the empreiteiros, however, were persons or groups with limited capital, who invested little in permanent installations or long-range mine-development programs. They usually were not subject to either technical or administrative supervision by the company on whose property they mined. Empreiteiros sometimes produced coal comparatively cheap for several reasons. The mines were small, with no development work; little capital was invested in surface installations or equipment, and overhead charges were low or nonexistent. Empreiteiros could afford to ignore proper mine maintenance and a high percentage of recovery; the life of the mine was short, and they operated only when conditions were advantageous, abandoning mining when adverse conditions were encountered, with little or no loss of capital investment. Proper utilization of mineral resources was of no particular importance, as the coal did not belong to them.

When the National Steel Company central cleaning plant was constructed near Tubarão the large number of producing mines and their scattered pattern presented another difficulty. By Federal law all coal produced in Santa Catarina was delivered to the National Steel Company for preparation in the central washer. Coal produced from about 56 separate mines was delivered to the washer by 23 companies. The natural variation in the quality of the coal from so many different operations offered an annoying problem in controlling the quality of washer feed within practical limits. As a basis of payment, coal shipments from each producing company are sampled and analyzed separately, a task which complicates the physical operation of the cleaning plant considerably.

The empreiteiro system conflicted with certain provisions of the Brazilian Mining Code. In 1944 the National Department of Mineral
Production advised all coal concessionaires to abandon the system, and on January 11, 1945, by act of the National Council of Mines and Metallurgy, all companies concerned were allowed 6 months in which to "legalize the irregular situation." An extension of time was granted in some cases. This action was necessary but unfortunately does not solve many of the ills inherent in the practice. Actually, the companies reimbursed the empireiro for the physical inventory at the mine and assumed responsibility for the operations by transferring accounting and personnel to their own books. In many instances these small mines continued to operate as before, under the same conditions and with the same personnel.

With a scarcity of capable mine supervision in even the larger operations, it is patently impossible to provide efficient supervision to the numerous smaller mines. The basic ills of this system as it affects mining practice and the growth of the industry from "garimpeiro" to the industrial stage will not be remedied until concessionaires are convinced of the advantages of concentrating their mining operations.

The following table shows the size of the producing coal mines in Santa Catarina during 1944, the last year before the empireiro system was abandoned and the year before the National Steel Company appeared in the field as a producer.

<table>
<thead>
<tr>
<th>Yearly production of run-of-mine coal, metric tons</th>
<th>Mines</th>
<th>Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent of total production (group)</td>
</tr>
<tr>
<td>150,000 to 200,000</td>
<td>1</td>
<td>22.0</td>
</tr>
<tr>
<td>100,000 to 150,000</td>
<td>1</td>
<td>9.1</td>
</tr>
<tr>
<td>75,000 to 100,000</td>
<td>2</td>
<td>33.3</td>
</tr>
<tr>
<td>50,000 to 75,000</td>
<td>4</td>
<td>9.3</td>
</tr>
<tr>
<td>25,000 to 50,000</td>
<td>9</td>
<td>11.1</td>
</tr>
<tr>
<td>Less than 10,000</td>
<td>65</td>
<td>18.6</td>
</tr>
<tr>
<td>Total</td>
<td>86</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Run-of-mine coal production increased from 696,727 metric tons in 1944 to 980,000 tons in 1946, a gain of almost 41 percent. An important factor in this increase was the new National Steel Company mines, which only started to produce in 1945 and completed their first full year of production in 1946.

**Paraná**

Although coal had been mined in small quantities for some years in Paraná, exploitation on a commercial scale did not begin until 1941-42 in the Rio do Peixe region of that State.

In 1942 eight companies were actively interested in the coal field of northeastern Paraná, and several others were inactive. Individual concessions were comparatively small, and total proved reserves (of minable thickness) in the entire area were only slightly more than
7,000,000 metric tons. Since then, however, drilling and further exploration have indicated reserves of at least 20,000,000 tons.

Individual companies hold concessions containing only a few hundred thousand tons to more than 5,000,000 tons of minable coal each, but none of the present active mines are large. Production from each of the two largest mines in the field is only about 100 tons a day.

During 1946 seven mines in the northeastern Paraná field produced a total of 95,580 metric tons of run-of-mine coal. The largest producer mined 29,560 tons and the smallest 480 tons.

On a smaller scale the Paraná coal-mining industry is similar in many ways to that in Santa Catarina. Mining methods are much the same, and production is derived from a number of small mines rather than from a few larger mines as in Rio Grande do Sul.

**NATURAL CONDITIONS AFFECTING MINING**

**RIO GRANDE DO SUL**

The coal in Rio Grande do Sul, as in Santa Catarina and Paraná, occurs in the “Permo-Carboniferous” deposits overlying the ancient crystalline complex of granites and gneisses. The base of the sediments is composed of tillites, which reach a thickness of about 492 feet (150 meters) in places and taper out toward the southern border of the sedimentary basin. Immediately above the tillites is a bed of soft, reddish-gray shale, ranging in thickness from about 164 feet (50 meters) at Butiá to about 492 feet (150 meters) at Leão. This shale bed contains some beds of black, carbonaceous shale and occasional lenses of sandstone and dolomitic limestone, which is the predominant rock in the region.

Extensive alluvial deposits are found in the valleys of the Conde and Porteirinha Creeks as well as in the valley of the Arrói dos Ratos. At Butiá the thickness of these alluvial deposits rarely exceeds 3 feet, but on the right bank of the Arrói dos Ratos they are about 98 feet (30 meters) thick, completely masking the topography of the predominant shale.

On some hills near Butiá diabase sills have been exposed by erosion. At Arrói dos Ratos, where no sills of importance have been observed, some diabase dikes cut the sediments at an angle of more than 45°.

Some faulting occurs; a fault with a vertical displacement of slightly more than 39 feet (12 meters) has been observed at Butiá and another with a vertical displacement of about 72 feet (22 meters) at Arrói dos Ratos.

At Butiá minor folding also occurs, easily discernible in the coal bed but not strong enough to affect the general structure of the deposit. At the Arrói dos Ratos mine a north-south anticline axis, some 1,000 meters east of the stream of the same name, elevates the coal bed approximately 164 feet (50 meters). Possibly between the mines of Recreio and Leão disturbance of the coal bed through faulting and folding has been even more pronounced, resulting in a displacement of the order of 650 feet (200 meters).

The commercially exploitable coal beds in the region occur at the contact zone between the tillites and the shales (fig. 1). At Butiá sometimes one and sometimes two dirty beds of coal 8 inches (20 cm.)
thick are found about 52 feet (16 meters) above the bed now mined. Similar beds occur about 20 feet (6 meters) above the bed explored at Arrôio dos Ratos. These minor beds disappear toward the margins of the coal basin.

In the São Jeronimo area the coal basins have definite limits and are not continuous over large areas as in the Santa Catarina coal field.

![Figure 1](image)

**Figure 1.**—Profiles showing relation of beds at Butiá and Arrôio dos Ratos mines, Rio Grande do Sul.

The Butiá deposit is long and narrow (fig. 2); possibly, the northern and eastern extremes, as indicated, connect along the valley of the Taquara Creek.

The known part of the Arrôio dos Ratos Basin in general is formed like a spoon, with the coal bed rising in all directions from the center. The northern limit of the basin is known, but the eastern boundary may follow the valley of the Arrôio dos Ratos (creek).
Figure 2.—Carboniferous region of São Jeronimo, Rio Grande do Sul.
The quality of the roof varies with the quality of the rider seams of coal, which are usually left up to form the immediate mine roof. In general, this coal is softer and more friable toward the center of the carboniferous basin, and the quality of the roof deteriorates somewhat.

At Butiá lenticular masses of tillites are occasionally found above the top coal or rider seam, particularly near the southern borders of the basin. In these zones the characteristics of the coal bed vary greatly, making mining difficult and costly. The shale cover at Butiá is impermeable, and the mine is dry.

At Arrão dos Ratos the thickness of the roof shale diminishes toward the edges of the deposit, while that of the alluvials increases. Toward the center of the deposit diabase dikes extend to the surface. Because of these conditions, there is an appreciable infiltration of water at No. 1 shaft, although No. 5 shaft is dry and working conditions are similar to those at Butiá.

**Figure 3.**—Typical bed sections from the Arrão dos Ratos (São Jeronimo), Butiá, and Rio Negro mines, Rio Grande do Sul.

**Characteristics of the Coal Beds**

Most of the coal now mined in Rio Grande do Sul can be classified as subbituminous and noncoking. Figure 3 shows typical bed sections from the principal mines at Arrão dos Ratos (São Jeronimo), Butiá, and Rio Negro; Rio Negro is a small State-operated mine near Bagé in the southern part of the State.

At Butiá the coal bed averages about 48 inches (120 cm.) and attains a maximum thickness of about 79 inches (200 cm.). The minimum limit for economic extraction is 32 inches (80 cm.). Small faults in the bed are common, but they are generally of small lateral extent, with displacements of less than 10 feet (3 meters), and lie parallel to the east-west axis of the coal basin.

Compressed lenses of pyrite (several millimeters thick and several centimeters long) occur near the bottom of the bed. In some places these lenses are so abundant as to form a continuous band, which
complicates mining, because the coal when shot tends to break at the horizon of the pyrite band instead of at the contact with the bottom rock. The average pyrite content of the coal is only about 3 percent, however, and is rather easily separated because it is concentrated rather than finely disseminated.

As the faces are advanced part of the rock immediately over the principal seam is taken with the coal. The remaining rock normally falls, leaving the thin top coal or rider seam to serve as the roof.

At the Arrôio dos Ratos (São Jeronimo) mines the coal seam averages about 71 inches (180 cm.) and does not exceed 79 inches (200 cm.) in the present workings. This does not include the top coal, or rider seam. Coal less than 36 inches (90 cm.) is not considered economically minable. On the right bank of the Arrôio dos Ratos (creek) an area has been prospected that contains an exceptionally thick bed of coal averaging 138 inches (350 cm.) in thickness and reaching 177 inches (450 cm.) in spots. This coal has not as yet been explored.

In the area now being worked at Arrôio dos Ratos many diabase dikes and small sills cut the coal bed or intrude into it. Near the contact zones of these intrusions metamorphic action has transformed the coal into a sort of semianthracite. This material has a low volatile content and is dense, hard, and difficult to mine.

Samples of run-of-mine coal from the São Jeronimo mines contained 42 percent ash and 3 percent sulfur and had a heating value of 9,400 B. t. u. (5,200 Cal.). The best washed 1½-inch by 0 size contains about 29 percent ash and as high as 1.5 percent sulfur and has a heating value of about 10,000 B. t. u. (5,600 Cal.).

Coal from the Rio Negro mine in the southern part of the State near Bagé is of poorer quality. An acceptable fuel for locomotives can be prepared from the bottom bench of the bed, but the coal from the top bench can be utilized only in nearby industries, as its quality does not justify transportation for any distance from the mine. The run-of-mine product from the top bench contains more than 50 percent ash. Washing tests conducted on run-of-mine coal passing a 3/8-inch screen indicated less than 30 percent of float material at a density of 1.60, with an ash content of about 36 percent.

SANTA CATARINA

STRATA OVERLYING THE COAL BEDS

Although there are five coal horizons in the Bonito group of the Permo-Carboniferous deposits of Santa Catarina, only two—the Barro Branco and the Bonito—are of commercial value. In Santa Catarina the Barro Branco is virtually the only one explored, while the Bonito, about 164 feet (50 meters) below the Barro Branco, has not yet been explored except in a few isolated places where it outcrops. Cia. Metropolitana has opened two mines near Criciuma in a bed referred to as the Bonito, but this coal is probably a local basin formed about the same time as the Barro Branco and is not related to the Bonito.

The cover or depth of the strata overlying the Barro Branco coal ranges from a few feet to about 130 feet in the eastern part of the carboniferous belt; in the valleys and arroyos the coal is exposed in
many places. In the western part of the belt the cover attains a maximum thickness of 650 feet but generally is 300 to 350 feet thick.

The rocks of the Bonito group are principally sandstone and shale, and the immediate roof in the coal mines is either dark shale or sandstone. In some places the shale roof ranges in thickness from a few inches to 3 or 4 feet and is followed by sandstone. In many places, however, the shale is missing, and the immediate roof is sandstone, which in the eastern part of the field continues to the surface, with occasional beds of shale.

The roof is generally strong, and timbering has never been a serious problem with the light ground pressure of the comparatively shallow mining.

The floor of the mines is usually composed of a few inches to a few feet of dark-gray shale followed by sandstone. In places the shale is missing, and the sandstone forms the immediate bottom; in either case the bottom can be classified as “good.”

CHARACTERISTICS OF THE COAL BEDS

Although the Barro Branco coal bed in general dips south and west, over local areas it can be classified as level or only slightly dipping. Occasional igneous intrusions or dikes are found, but there are few faults of any importance and only rarely are the displacements greater than a few feet.

A marked difference between the Barro Branco coal bed and most of the commercially mined bituminous beds of the United States is noted in the structure of the bed and the thickness and quality of the recoverable coal. Figure 4 shows three sections of the Barro Branco bed taken in three different areas of the Santa Catarina coal field.

Of the 10 separate benches or stringers of coal from the top down in figure 4, a, only the first, sixth, seventh, ninth, and tenth probably would be mined. The fifth, known as the “coringas,” depending on the mining method, might or might not be recovered. In a total seam thickness of 81 inches (2.06 meters), therefore, only 32 to 34 inches (81 to 86 cm.) of coal is recoverable.

Of the 10 coal benches from the top down in section b, only the first, fifth, sixth, seventh, eighth, and tenth probably would be recovered, a total of 33 inches (84 cm.) in a total seam thickness of 75 inches (1.90 meters).

In section c, perhaps the most typical of the Barro Branco bed and representing the average total thickness of recoverable coal, the first, fifth, sixth, and seventh benches would be recovered, making a total of about 28 inches (70 cm.) of coal in a total bed thickness of 62 inches (1.58 meters).

Heavy pyrite inclusions are general throughout the Barro Branco coal, in some places accounting for as much as 25 percent of the total weight of material mined. The pyrite, besides causing a high sulfur content in the run-of-mine coal, makes mining more difficult and is hard on mining equipment.

In some places the coal is fairly soft and friable, particularly near outcrops or under light cover, but in general it is strong and hard to cut by the hand methods commonly used.
None of the Santa Catarina mines are gassy. Although it is generally conceded that all coals give off hydrocarbon gases during the coalification process, the numerous outcrops and thin cover in the area of active mining have permitted the gases to escape. As a general rule, in the United States the mines become increasingly gassy as the depth of mining increases. Some of the deep anthracite mines in Pennsylvania and certain mines in the Pocahontas field are among the most gassy in the world.

Because the Barro Branco bed outcrops in many places the mines, almost without exception, have been opened by drifting from the outcrops. In the entire district only four very short slopes and only one shallow shaft about 35 feet deep are used as a means of access to the coal.

PARANÁ

STRATA OVERLYING THE COAL BEDS

The sediments that include the coal beds of Paraná belong to the Tubarão series of the Bonito group in the Santa Catarina series.
in Santa Catarina, the rocks of this group are principally sandstones and shales. In some areas of the Paraná field beds of limestone occur between the coal horizon and the surface.

The immediate roof in the coal mines is shale or sandstone. In most of the mines visited the roof was strong, and in some timbering was not necessary in headings or entries. In a few the shale roof was weak and required lagging over the timber sets to keep it up, but this condition was the exception and not the rule.

The floor of the mines is usually sandstone, although shale or clay often is found immediately below the coal, between it and the characteristic sandstone. The bottom appeared to be good in almost every mine and is therefore suitable for the use of mechanized mining machinery; no trouble was encountered from "heaving" in any of the mines.

Thickness of the cover overlying the coal in the various basins or zones in northeastern Paraná ranges from a few feet near the outcrop lines to more than 350 feet in some areas. All of the mines have been developed by horizontal drifts from convenient outcroppings, as in Santa Catarina.

The coal in some areas and concessions lies under more than 300 feet of cover and can be reached only through slopes or shafts. No attempt had been made to develop mines in these areas by the end of 1947, although the authors know that at least one company has drilled an area where the coal bed is about 340 feet from the surface and has drawn up tentative plans for development of a shaft mine.

**Characteristics of the Coal Beds**

The coal beds in Paraná vary considerably both physically and chemically between the different zones and within a particular zone or basin. The two mines operating in the small coal basin near Barbosa, on the north-south link of the Rêde Viação Paraná-Santa Catarina, are good examples of this variation. Apparently, both mines are operating in the same bed, but the coal characteristics are decidedly different. The coal from one mine is hard and brilliant, has a heating value of about 6,800 calories per kilo (hand-picked), and contains only 6 to 8 percent volatile matter. The bed is very undulating and shows great irregularities in thickness, sometimes varying from 20 to 36 inches within a distance of 50 feet.

The coal in the second mine, which is about 1 km. west of the first, looks like shale and contains about 23 percent volatile matter. The calorific power of this coal seems to be appreciably lower than that of the low-volatile coal. The thickness of the bed in the area ranges from about 12 to 36 inches.

In other basins variations are common but not quite so marked as in the instance described.

The largest and most promising area in the Paraná field lies west of the Rio do Peixe (river) and extends almost to the town of Caeté. In general, the coal beds in this area dip 2° to 3° NW., but local variations, rolls, and faults frequently change the direction and degree of dip. Inclinations of 5° or 6° were observed in some places, although the bed can be considered to be flat.

Figure 5 shows four bed sections, all taken in active mines in the Rio do Peixe region of Paraná.
Figure 5.—Sections of coal beds in the Rio do Peixe region of Paraná.
The maximum thickness of the beds in this area is about 52 inches (not all recoverable coal). Figure 5, c, shows a bed section totaling 218 cm., but the condition seems to be peculiar to a small area and may be regarded as two beds separated by 93 cm. of compact clay. A 16-inch bed is generally accepted as a minable minimum. The coal in operating mines ranges between those limits, seldom attaining the maximum cited and probably averaging 25 to 32 inches.

The coal ranges from hard and strong to weak and friable. Pyrite inclusions in the form of finely divided particles as well as large nodules are common but not as prominent as in the Barro Branco bed in Santa Catarina. All of the coal thus far developed in the Rio do Peixe area is bituminous. The coking qualities of the coals from the various mines have yet to be definitely established, but there seems to be an organic sulfur content of 3 to 4 percent that cannot be eliminated by normal cleaning processes.

Although the percentage of recoverable coal in the Paraná beds is greater than in the Barro Branco bed of Santa Catarina, the thinness of the bed usually demands that top or bottom be taken for clearance, at least in the haulage roads. In the past some operators took enough top or bottom, even in the rooms, to allow the miners to stand upright while working. This expensive practice has been stopped in most of the mines.

**PHYSICAL SUMMARY OF PLANTS**

**RIO GRANDE DO SUL**

Coal-mining operations in Rio Grande do Sul are much more concentrated than those in the other coal-producing States of Santa Catarina and Paraná. About 98 percent of Rio Grande do Sul production comes from the two CADEM mines at Arróio dos Ratos and Butiá; this concentration has naturally justified more elaborate installations than those normally found at most of the mines in Santa Catarina.

**SURFACE**

Modern coal-preparation plants are located at both the Butiá and Arróio dos Ratos mines. All the coal produced is not treated in these plants, however (at times much of the coal is sold after being hand-picked), nor do the plants operate all of the time. The cleaning facilities are used only when market demands make it necessary or desirable to prepare a product of better quality. (See Preparation Practice.)

Power is supplied by thermoelectric plants at each of the mines.

At São Jeronimo the power plant is at No. 1 shaft (now worked out). The unit includes six boilers connected in parallel, three of which are hand-fired, one stoker-fed, and two equipped to burn pulverized coal. Three turbogenerator groups, also connected in parallel, have a total capacity of about 2,200 kw. The current is 3-phase, 60-cycle. Power is transmitted at 2,300 volts and reduced to 220 volts at points of utilization. One 11,000-volt transmission line supplies power to the municipality of São Jeronimo and the port of Charqueadas.

The plant at Butiá includes five boilers and two turbogenerator groups, with a total capacity of about 2,000 kw. Current is 3-phase,
50-cycle. Power is transmitted at 6,600 volts and utilized at 220 volts. In addition to the usual administration buildings, surface plants at the CADEM mines include a general machine shop, blacksmith shop, foundry, carpenter shop, electrical repair shop, and a repair shop for rolling stock of the mine transportation system. At Butiá repair work is also done on railway rolling stock.

As both Butiá and São Jeronimo are shaft mines, hoisting equipment is necessary. Each mine also has an inclined slope equipped with a belt conveyor for bringing coal to the surface.

Coal from the Butiá mine crosses the Jacuí River at the port of Conde on a 3,600-meter aerial tramway, which has a capacity of 60 metric tons per hour.

Black powder, the explosive normally used in mining operations, is manufactured in company-owned factories at each of the two mines. Normal consumption is about 2,640 pounds (1,200 kilos) of powder per day at each mine, and each factory can produce about 6,600 pounds (3 metric tons) in 8 hours. The formula used in manufacturing the black powder is: 75 percent sodium nitrate (from Chile), 15 percent charcoal (made locally), and 10 percent sulfur (from the United States).

**UNDERGROUND**

At Butiá the room-and-pillar mining system is used, with occasional modifications. (See Mining Systems.) The use of mechanical mining equipment is limited to pneumatic puncher-type cutting machines and pneumatic jackhammers. The cutting machines generally are used only in driving narrow work, while the jackhammers are employed in driving rooms and development headings. More-modern coal-mining equipment, such as chain cutting machines, loading machines, and face conveyors, are not used in either of the two CADEM mines. In this respect actual mining and loading operations at the face are no more mechanized than those in the larger mines in Santa Catarina. Some years ago electric chain cutting machines of the longwall type were reportedly used for a short time in the old Leão mine, apparently with poor success. Possibly the failure of the machines was due to inexperience of the operators, a general reluctance on the part of the miners to accept innovations, and the fact that other operations in the mines, such as loading and transportation, were not geared to their use.

At the Arróio dos Ratos (São Jeronimo) mine a modified longwall panel system is used. Mining equipment, as at Butiá, is limited to pneumatic puncher-type coal cutters and jackhammers.

Several methods of underground transportation are employed in the CADEM mines. At Butiá endless-rope haulage systems are used exclusively on the main haulage roads, while at Arróio dos Ratos electric trolley locomotives are used in combination with tail-rope systems and auxiliary winches on the secondary roads. In both mines mechanized haulage is usually confined to the principal and secondary haulage roads, and loaded and empty cars are hand-trammed between collecting points and the face.

Both of the CADEM mines are ventilated by exhaust fans of the centrifugal type. The mines are free of methane, according to mine
officials, and the systematically controlled ventilating system is far above the average found in the coal mines in other Brazilian fields.

MINE SHAFTS AND SLOPES

At present three vertical shafts and one slope serve the São Jeronimo mine and two vertical shafts and one slope, the Butiá mine.

Originally the shafts used for hoisting coal were also used to lower men and materials. As production increased it was necessary to open auxiliary "service shafts" devoted exclusively to the circulation of material and personnel, as well as air, and providing access for power conduits. These service shafts are rectangular, lined with timber, and usually divided into two sections—a large one for the cage and a smaller one for a counterweight. The smaller section also carries the conduits. A few service shafts have two cages, with a third section for air and conduits.

When the coal-hoisting shafts are shallow or short-lived they are also rectangular and lined with timber. The deeper and longer-lived shafts are circular and lined with brick. Both have two cages or two skips.

The slopes at each mine are brick-lined and inclined 20° to 21° from the horizontal. The Butiá slope is about 492 feet (150 meters) long and is equipped with one 32-inch (80-cm.) belt conveyor. The Arrôio dos Ratôs slope is about 984 feet (300 meters) long and has two 36-inch (90-cm.) belt conveyors in series.

The CADEM administration has offered the following comments on the comparative advantages of shafts and slopes under local conditions:

1. The cost of sinking a shaft is less than the cost of driving a slope. The slope has a smaller section than either the rectangular or circular shaft, but this advantage is more than offset by the fact that when driven about 20° off the horizontal the slope is about three times as long as the vertical shaft.

2. More mine cars are necessary with the vertical shaft, as they must travel from the face to the surface (this would not be true if skip hoisting were used), while with a slope equipped with belt conveyor the mine cars circulate only from the face to the foot of the slope.

3. The equipment and installation costs are greater for the slope with belt conveyor. Maintenance costs are also greater, principally because of the high cost of the belt, which under local conditions must be replaced every 2 to 3½ years.

4. If the belt conveyor presents economic disadvantages, they are compensated by more satisfactory operation. The belt works continuously, delivers a constant flow of coal, and rarely imposes interruptions on work at the face. The vertical shaft has a more intermittent cycle, and work at the face must occasionally be stopped because of breakdowns of the hoisting machinery.

5. The conclusion reached by the CADEM operators was that if the reserves of the area in question are small, it is advisable to use a vertical shaft but that if the area is large and the mine is expected to have a long life a slope equipped with belt conveyor is to be preferred.

SANTA CATARINA

In the discussion of coal mining in Santa Catarina the field is treated in a general manner, but methods, equipment, and practice vary somewhat in detail among the more than 80 producing mines in the field. As space in this report is limited, it is impossible to describe each operation in detail. Some operators have introduced refinements
of the practices discussed, which have proved efficient and have produced results above the average. Unless a marked difference exists, however, these exceptions are not discussed separately.

SURFACE

With few exceptions, the buildings or surface installations at the Santa Catarina mines are not as modern or elaborate as those usually found in mining properties in the United States, principally because the individual mines are comparatively small. Until recently there was no central or commercial power-generating station from which the mines could purchase power, and only the largest operations had their own source of power. Because of an almost complete absence of mining machinery, machine shops are confined to a few large central units, and repair or maintenance shops at the mines proper are nonexistent or limited to small blacksmith shops for the repair of hand tools.

The only structure common to almost all of the mines is an open shed of timber construction for screening and hand-picking the coal. In a few instances this structure combines picking facilities with bin capacity for gravity loading of trucks. A small frame foreman's shanty and sometimes a blacksmith shop and storage shed complete the typical surface installations.

The larger companies have somewhat more elaborate plants, usually situated so that they can serve several or all of the company mines.

Preparation facilities consist of the hand-picking sheds, mentioned previously, and in some instances small hand-operated jigs for cleaning the fine coal. Two companies, Cia. Brasileira Carbonifera de Araranguá and Soc. Carbonifera Prospera, S. A., each operate one Deister table on which they clean fine coal collected from several mines.

Until 1945, when the new central coal-cleaning plant at Capivari was completed by Cia. Siderurgica Nacional (National Steel Company), the only two mechanical coal-preparation plants in the field were operated by Cia. Carbonifera de Urussanga, near Urussanga, and Cia. Nacional de Mineracão de Carvão do Barro Branco at Lauro Müller. The washery feed at each plant was supplied by several mines.

The surface installations of these larger producers also include a central mine office, warehouse, garage, blacksmith and machine shop, carpenter shop, and small power plant.

The new McNally-Pittsburg cleaning plant built by Cia. Siderurgica Nacional at Capivari, near Tubarão, is by far the most-modern and best-equipped installation in Santa Catarina. (See Preparation Practice.) Located at a railroad junction of the three coal-producing zones, it was designed to clean the entire coal production of the Santa Catarina field. This cleaning plant was completed in 1945; a well-equipped machine shop, carpenter shop, laboratory, and the usual accessory buildings complement it. A thermoelectric generating plant designed to burn a low-grade product of the coal washery supplies power to the washery itself as well as to mines in the coal-producing areas.
Cia. Siderúrgica Nacional has also built a well-equipped surface plant at its newly developed coal properties near Siderópolis. A timber tipple is fed by conveyor belt and combines hand-picking facilities with bin capacity for direct loading of railroad cars. Most of the coal handling on the surface is done mechanically. All maintenance shops, warehouse, housing, etc., are well-built and well-equipped.

Figures 6 and 7 show the only two mechanical cleaning plants in the field with the exception of the new control washery built by Cia. Siderúrgica Nacional (National Steel Company) near Tubarão.
Figures 8 and 9 show typical surface structures found at most of the mines.
Figure 10 shows one of the hand-operated jigs in common use.

UNDERGROUND

Almost all of the mines use some modification of the room-and-pillar method of mining. Recently some experimental work has been done under the modified advancing, longwall system, but the method has not yet been adopted as common practice in any one entire mine.
Underground operations are characterized by an almost complete absence of mining machinery. A few of the mines with power available use locomotive haulage, but most of the coal is hand-trammed; even in the three operations using locomotives their use is confined principally to the main haulage roads.

Compressed-air-driven, puncher-type coal-cutting machines are used in a few mines in driving narrow work, but chain cutting machines, loading machines, conveyors, or other types of such equipment are not found in any of the mines. Recently pneumatic picks and jackhammers for drilling the coal face have been introduced in a few mines; pneumatic picks have proved to be very successful and are readily adapted to local mining methods. An electric chain cutting machine of the longwall type was tried at one time in the mines of Cia. Nacional de Mineração de Carvão do Barro Branco, but the experiment was reported to be a complete failure, very probably due to the inexperience of the operators in the use of chain cutting machines and to frequent machine and bit failure caused by excessive pyrite in the coal. Cia. Siderurgica Nacional has recently ordered equipment for experimental work with chain cutters, but delivery of the machines has been delayed and results are yet to be determined.

As hand tramming is the common practice, mine cars are limited in size, ranging from 1,300 to 1,900 pounds carrying capacity. A common size is slightly more than 1,500 pounds (700 kilos). Most cars are of wood construction, with an end or side gate to facilitate loading and discharging.

Although a few mines use light steel rails (15 to 30 pounds), most of them, particularly the smaller ones, use wooden rails exclusively.

Mine ventilation, except in a few mines, is natural. Some mines have driven small shafts or drilled holes at intervals to aid circulation, but in general ventilation is very poor and often nonexistent. Unfortunately, the small size of most of the mines and the fact that
methane has never been encountered have caused many operators to ignore ventilation in laying out their mines or at best to consider it of minor importance.

Multiple-entry mining systems are almost unknown in Santa Catarina. Single and double entries are most common, and in some instances rooms are turned directly off the main heading. Where butt entries or room headings are turned off the main headings they are usually single entries except in some of the larger and better planned mines, where the double-entry system is more common. Rooms almost always are mined on the advance, and rarely are they driven off both sides of a double-entry heading.

Because haulage is seldom mechanized, the direction of headings and rooms is controlled largely by the coal contours. Local rolls or changes in grade in the coal bed are matters of great concern, and frequently entire sections of a mine are abandoned because grades are contrary to natural drainage or against the flow of hand-trammed loaded cars.

A common working unit underground consists of three men to a room face or two men for advancing headings or narrow faces. Each unit or group is usually responsible for all the operations in that particular working place, including cutting (by hand), drilling, loading, shooting (or breaking down the coal by hand), loading the coal into cars, stowing the waste, tramming the coal to the surface, and timbering. In mines where pneumatic coal cutters, jackhammers, and picks are used the work cycle is somewhat different, and the duties of the miners are more specialized. A few mines have special timbering and track crews.

In most instances the miners are paid on the basis of tonnage or number of cars produced. The rate varies with local bed conditions. An accurate check on the quantity of coal produced by an individual or from a face is possible only where weigh scales have been installed outside the mine. The usual practice is to pay so much for each loaded car, the actual volume and quality assumed to be standard and subjected only to a visual check. Where scales are used the miners, of course, are paid on an actual weight basis, subject to penalties for excess rock.

**Paraná**

**Surface**

Surface installations at most of the Paraná mines are very simple. Near the mouth of the mine is usually an open shedlike structure for hand-picking the coal and screening out the fines. Sometimes a bin is provided for loading the coal into trucks. A foreman's shanty and small warehouse normally complete the installation at the mine proper.

The company village usually is situated on favorable terrain within easy walking distance of the mine. It generally consists of housing units for the mine employees and supervisory personnel, office, warehouse, company store, etc. One or two of the companies operate their own sawmills, and most of them have small blacksmith shops. Several of the larger producers operate small machine shops and garages.

There is no central source of electricity in the field, although several producers have small thermoelectric generating plants that pro-
duce a limited amount of power for illumination and power-driven equipment on their own properties.

Until 1946 there were no mechanical coal-cleaning installations in the Paraná field. During that year Cia. Carbonifera Brasileira, S. A., built a simple plant at its mine, which eliminated much manual handling of the coal, and provided facilities for mechanically crushing and screening the run-of-mine coal and cleaning the smaller sizes. (See Preparation Practice.) The installation includes a thermoelectric plant using modern stoker-fired equipment for steam generation.

Some thought has been given to the idea of building a central cleaning plant to serve all the mines in the area, as was done in Santa Catarina, but much investigation will be necessary before the project can be presented in concrete form.

UNDERGROUND

The Paraná mines are so new that mining systems and methods have hardly had a chance to crystallize. Most of the mines use a variation of the room-and-pillar method of mining.

One or two mines use some compressed-air equipment such as pneumatic picks, jackhammers, and puncher-type cutting machines, but with these exceptions no mechanical mining machinery or equipment is used any place in the field.

Underground conditions and practice in Paraná are very similar to those in the average mine in Santa Catarina. To save repetition the reader is referred to the preceding section summarizing conditions in that field. The few differences are noted in the following more detailed description.

MINING SYSTEMS

RIO GRANDE DO SUL

In Rio Grande do Sul the coal now mined in the São Jeronimo area occurs in disconnected basins rather than as a continuous bed over a large area as in Santa Catarina. It is also deeper and is seldom accessible from outcrops, as in Santa Catarina or certain areas in Paraná. The necessity of larger capital investments to develop shaft mines and the fact that production is concentrated into fewer and larger units have resulted in better mine planning.

The CADEM organization, which includes the Butiá and Arrôio dos Ratos mines, has four core drills working exclusively on its own drilling and prospecting program. Drilling operations are kept well ahead of active working areas, as natural conditions make it advisable to always have a proved mine reserve.

In pioneering, prospect holes are put down at the corners of 1,000- to 1,200-meter squares; as drilling progresses the pattern is reduced to 300- to 400-meter squares. Toward the border of the coal basins the interval is sometimes reduced to 100 meters.

At Butiá the coal bed is more regular, and exceptionally close drilling is not necessary because the use of endless-rope haulage is not so sensitive to moderate changes in grade. The minimum drill-hole interval at this mine is normally fixed at 400 meters.

At Arrôio dos Ratos the occurrence of intrusive dikes and faults and
the peculiarities of the mining system require closer drilling; at the
mine the minimum interval is usually 250 meters.

Mine projections are laid out well in advance of active workings,
and mine maps are accurate and up to date.

BUTIÁ

The room-and-pillar system of mining is normally used in the Butiá
mine. Occasionally, where conditions permit, one or two room pillars
are eliminated and two or three rooms are advanced together as one
face.

Figure 11 is a schematic diagram of the mine lay-out at Butiá.
Development headings are represented by a single line, but it should
be noted that they are all double-entry headings as indicated by the
identification letters and figures and as illustrated by the enlarged
section.

In figure 11 entries LN and LS to the east and W5 and W6 to the
west are referred to locally as “penetration mains.” They serve as
permanent main haulageways and air courses during the development
and mining of that particular area. Panels are developed by driving
entries to the north off the principal mains. As shafts 1, 2, and 3
at Butiá are in the southern part of the deposit, only rarely are panel
entries driven to the south.

Room headings or butt entries are turned off the panel entries, and
the rooms are developed off both sides of the butts. All entries are
driven in pairs about 6¼ feet (2 meters) wide and on about 33-foot
(10-meter) centers. Crosscuts are driven every 65½ feet (20 meters).

Formerly panel entries were turned off the mains every 1,968 feet
(600 meters). After the mine had been mechanized to some extent
this distance was reduced to 1,312 feet (400 meters), and consequently
the length of the room headings was reduced from 984 to 656 feet.
The room headings are normally turned off the panel entries on 295-
foot (90-meter) centers.

As rooms are driven off both sides of a room heading, the normal
length of a room is about 131 feet (40 meters).

Main and panel entries are advanced at the rate of about 984 feet
(300 meters) a year. Room headings are advanced about 787 feet (240
meters) a year.

Rooms are necked as the room headings advance, and a 16-foot
(5-meter) chain pillar is left before the rooms are widened to full
width. Normally, panels are mined full advance, that is, the outby
rooms are advanced first; but under ideal conditions the room head-
ing is first advanced to its limit, and the panel is then mined full
retreat.

The rooms vary in width, depending on local conditions. Pillars
between rooms also vary somewhat but average only about 1 meter
in thickness. Crosscuts are driven through these small room pillars
at 33-foot (10-meter) intervals to provide better circulation of air at
the face. Where the roof is exceptionally good one or two room
pillars may be eliminated, and two or three rooms are advanced as
one face. A room is usually mined out in 3 months. Center and
chain pillars along the room headings are recovered as soon as the
Figure 11.—Schematic mine lay-out at Butiá, showing detailed section.
panel of rooms is completed. Chain-pillar recovery accompanies the retreat where the rooms are mined full retreat.

When a room is cut by a fault parallel to the face a narrow entry is driven through the fault and again widened to full room width on the other side. Another solution is to drive an auxiliary room off of and at right angles to one of the adjacent rooms after the fault has been passed. Both of these solutions are illustrated in figure 12.

When heavy grades are encountered in the panel entries the room headings are turned at some angle less than 90° to help diminish the grade in the rooms. In some instances the interval between room headings is reduced to 164 feet (50 meters), and rooms are turned off on only one side of the heading.

The long, straight entries and the regularity of the mine plan at Butiá are possible because of the mining system used and the employment of endless-rope haulage. With this type of transportation, grades are not as important as straightness, and mine projections are followed in the main entries without much variation to adjust to coal contours.

**ARRÔIO DOS RATOS**

The mining system used at the Arrôio dos Ratos mine has some of the features of a modified panel longwall, but the actual advance of the working faces more closely resembles a form of the room-and-pillar system. Figure 13 shows the general lay-out of the mine.
Figure 13.—General lay-out of mine workings at Arróio dos Ratos.
workings at Arróio dos Ratos. Shafts 1, 2, 3, and 4 have been worked out and abandoned; shafts 5A, 5Δ, and 5B are active. Shaft 5Δ is an auxiliary to 5; it was sunk to recover the coal that would normally be within a radius of 5 but that lies north of an intervening diabase dike.

From shaft 5 "penetration galleries"—principal mains A, B, C, D, E, and F—about 8 feet (2.5 meters) wide were driven in pairs on 41-foot (12.5-meter) centers. Crosscuts were driven through the 33-foot pillar every 66 feet. From these mains a pair of panel entries, each about 6.5 feet (2 meters) wide, was driven every 295 to 361 feet (90 to 110 meters) on 33-foot (10-meter) centers. Adjacent pairs of panel entries are connected by single cross entries 6.5 feet wide, driven every 131 to 164 feet (40 to 50 meters) off the panel entries. These cross entries are called "longwall traverses" (detailed section, fig. 13); they usually are driven simultaneously from both ends to facilitate ventilation and develop the block of coal more rapidly. The longwall traverses are also connected by narrow openings about every 50 feet for ventilation.

The block of coal between two sets of panel entries is mined by advancing the inby rib of the first longwall traverse as a face. A 46-foot (14-meter) pillar is left between the first longwall traverse and the main entry, and 26-foot (8-meter) pillars are left at each end of the longwall traverse to protect the panel entries as the face advances. Square pillars of coal are also left in the mined-out area as the so-called longwall face advances. Figure 14 illustrates the details of this mining system at Arróio dos Ratos.

Track is laid in the longwall traverse, and as the face advances stubs are turned off the track normal to the face. Four of these stubs usually are advanced with the face until the next longwall traverse
is reached. They are then continued from track laid in the new traverse, and the previous set of tracks can be taken up.

During the first mining a thin bench of top coal is left in place to improve the quality of the roof. As soon as a new longwall traverse is reached, as much as possible of this top coal is recovered. After the block of coal between two panel entries has been mined out the pillars are recovered.

When a fault or dike is encountered it is passed by methods similar to those used at Butiá.

Usually 2½ months is required to advance a face from one longwall traverse to the next. With this system of mining, the operators claim about 70-percent mine recovery; the balance is lost in pillars or unrecoverable coal.

At Arrói dos Ratos the main entries are driven on grades suitable for locomotive haulage, and the panel entries and longwall traverses are laid out so that the grades favor the loaded cars. For these reasons the plan of the mine does not appear as regular as the one at Butiá. A closer knowledge of the contours of the coal bed is essential for laying out the system on proper grades, and the topographic work is done in much more detail than at Butiá.

SANTA CATARINA

Only one or two mines in Santa Catarina can produce as much as 400 tons of coal a day. Not more than 20 percent of the individual mines produce more than 1,000 tons a month, and only three or four produce as much as 5,000 tons a month. The average production of run-of-mine coal during 1946 was about 1,000 tons per month per mine, or 40 to 50 tons per day.

Except in the largest mines, few of the workings are developed according to plans laid out in advance. Few of the mines have accurate maps of any sort, and some have merely rough sketches of workings made at infrequent intervals from compass surveys. In general, coal properties are poorly drilled or not drilled at all, and accurate information on coal contours, thickness and quality of the bed, reserves, etc., is almost nonexistent except for such data as can be gleaned from nearby workings or convenient outcrops.

Of 23 producing companies in Santa Catarina, only 5 have reasonably good sets of mine maps and develop their mines according to projections based on adequate engineering information. These companies, however, account for about 90 percent of the total production.

The best example of a mine that was planned only after the property was thoroughly drilled is that of the Cia. Siderurgica Nacional operations at Siderópolis.

ROOM-AND-PILLAR SYSTEMS

The room-and-pillar system of mining is generally adopted in Santa Catarina; the rooms are almost invariably driven full advance. The direction of the main entries is controlled by the dip of the bed. A slight grade in favor of the loaded cars is imperative because hand tramming is the usual means of transportation. Thus, the location of most of the mines is limited to places where the coal is level or rises
away from the outcrop. In the few mines employing locomotive haulage slight changes of grade, while important, are not necessarily of vital concern in developing the mine. Only in rare instances have hoists been employed to permit mining a local basin or an area dipping inby.

In the better-planned mines one or more pairs of entries are driven on suitable grade from drift mouths; cross entries or butt headings are turned off the main entries at intervals, and rooms are driven off the inby side (usually) of the butt headings.

In many of the mines one entry or several single entries are driven from an outcrop line. These single entries are connected by a series of cross entries, with rooms turned off the cross entries or occasionally off the main entries.

Figures 15 and 16 are examples of common practice in mines following the latter (single-entry) system.

Where hand methods of mining are used the rate of advance in the headings is so slow that development work is seldom much in advance of actual working faces. With bad roof, the slow rate of advance in the rooms would result in the loss of a higher percentage of pillars and excessive timbering to keep the rooms open. Fortunately, the generally light cover and good roof of the Barro Branco bed have caused little trouble in this respect.

Main and cross entries are driven 2 to 3 meters (6½ to 9¾ feet) wide; entries 2½ meters (about 8 feet) wide are the most common. This width provides enough room for a 60-cm. (about a 23½-inch) gage track, drainage ditch, and timber sets where necessary. Seldom is any effort made to provide separate manway room even in the main haulage roads.

Rooms are driven 5 to 9 meters (roughly 16 to 30 feet) wide on 10- to 18-meter centers. The most-common practice is 8-meter rooms on 16-meter centers (26-foot rooms on 52-foot centers). Length or depth of rooms ranges from 40 to 90 meters (131 to 295 feet), but 50- to 60-meter (164- to 197-foot) rooms are most common.

From the room neck the room is widened out on one side to a total width of 8 meters. Track is laid close to the straight rib, and the room is advanced to its full length. As much of the waste as possible is stowed on the wide side of the room, leaving the trackway clear. Upon reaching the limit of advance a crosscut is driven from the track side of the room to the gob in the adjoining (usually outby) room, and the room pillar is mined retreating. Waste is gobbed behind the retreating face, and posts are seldom recovered. Because of the large quantity of waste in the bed the worked-out areas usually are completely filled by the gob, and rooms are seldom caved entirely. In narrow work, such as main entries or headings, it is usually necessary to remove from the mine a quantity of waste at least equal to the quantity of coal recovered. Some entries are driven wider than the customary 2½ meters, and waste is gobbed in the extra space; but this practice slows the rate of advance considerably and makes it more difficult to pull the entry pillars if or when it becomes desirable to do so.

Only in rare instances are crosscuts driven between rooms. In single-entry systems (fig. 16) it is not uncommon to drive a dead-end butt or room heading for several hundred meters and turn 10 to 20
Figure 15.—Single-entry room-and-pillar system common to many small mines.
Figure 16.—Double main entry; rooms driven off connecting crosscuts on the advance. Single-entry butt headings; all rooms driven on the advance.
rooms off of it. Actually crossect between such rooms are of little value for ventilation purposes, as there is little if any circulation of air in the heading itself.

Many mines are developed according to no particular plan, without taking into consideration efficient systems of transportation and ventilation or most-economical development plans and maximum recovery. In the smaller mines the usual procedure is to drive a drift from some convenient outcrop and develop working faces as the mine advances in whichever manner and direction seems to be convenient. As the Barro Branco bed exhibits many local rolls, mines or sections of mines are sometimes abandoned because of adverse grades, when a change of direction or proper initial mine lay-out would have permitted the recovery of much more coal. Modifications in development plans and methods are frequently necessary. Often a particular area is not completely mined out because the limits of natural ventilation and hand tramming will not permit further extension of the mine. Small local rolls or basins frequently have the same effect. As a result, perhaps only 20 percent of the reserves of many tracts or coal-bearing areas have been mined. The remaining coal may not justify reopening the abandoned mine or developing new entries, whereas if the mine had been properly planned in the beginning most of the coal could have been recovered from the original openings.

The larger companies realize the inherent disadvantages of these small, poorly planned operations and have planned more-efficient development of at least some of the larger mines.

The youngest producer in the Santa Catarina field is the National Steel Company. Before underground and strip mines were developed the properties were thoroughly drilled and mapped. Operations were planned to use at least partly mechanized methods, and no development work was started until enough information was collected to permit an intelligent mine lay-out. This planning eventually will be reflected in lower operating costs and a higher percentage of recovery.

Room-and-pillar mining is adaptable to most mining conditions, and the cost of production is less than longwall methods where backfilling is practiced and the stowing material must be brought in from the surface and other parts of the mine. When the coal bed itself contains a large quantity of waste material that must be handled under any circumstances, however, the advantage diminishes or reverses itself.

The average range of coal resources lost in abandoned pillars, barrier walls, etc., in room-and-pillar mining is probably 20 to 30 percent. The loss in longwall mining is less, and where conditions permit its use the system is generally considered safer. More damage to the surface usually results from room-and-pillar mining with extraction of pillars, although this factor has been of little or no concern to producers in Santa Catarina; there is not much valuable farming land in the active mining areas in Santa Catarina, and surface subsidence has been infrequent because of the small extent of the individual operations and the relatively large quantity of coal left in unrecovered pillars.
Longwall mining has been introduced in Santa Catarina only recently and to a very limited extent. Few mining men in the field are familiar with longwall methods, as it was generally assumed that natural conditions did not favor their use. Some experimental work was done with longwall methods by United States Bureau of Mines engineers in cooperation with the Brazilian National Department of Mineral Production, and the results were favorable. Several producers have since introduced longwall methods in one or two of their mines with varying degrees of success. Longwall methods, where conditions permit their use, offer marked advantages to mining in Santa Catarina, and the system may become more widely used as personnel becomes familiar with its operation and as mines become more highly mechanized.

Several points must be considered before adopting a longwall method. It is generally considered to be better adapted to working very deep beds than the room-and-pillar method, but it has been used very successfully under thin cover as well. An ideal roof for longwall work is tough and elastic material like shale rather than hard and brittle material like sandstone, particularly where the worked-out area is not completely backfilled; where the area is completely stowed, however, this characteristic of the roof becomes less important. In Santa Catarina there is plenty of waste material in the bed itself to provide complete stowing.

In room-and-pillar mining it is not always easy to avoid the expense and delay of removing quantities of waste and rock from the mine. In longwall mining there is usually ample space for stowing waste underground. This advantage is important in mining the Barro Branco bed because it contains as much waste rock as recoverable coal, and handling and disposing of the waste are major problems. The large quantity of rock in the bed makes complete stowing possible at a minimum cost, and the system provides a most-convenient method of waste disposal with a minimum amount of handling and transportation.

In a thin bed it is desirable to recover as much of the coal as possible and to keep the expenses for driving and maintaining roadways at a minimum. Longwall methods usually offer these advantages.

With respect to timbering costs, longwall is particularly advantageous. By withdrawing the props and resetting them as the face advances, much more of the timber can be used again than in room-and-pillar work. In Santa Catarina timber supplies are dwindling and becoming increasingly more expensive. Repeated use of props would be decidedly attractive and an important economic consideration.

Longwall is best adapted to a uniform, flat, or gently pitching bed. The Barro Branco bed is in general ideally suited to longwall work in this respect.

The bottom of the Barro Branco bed is generally hard and well-suited to longwall requirements. The roof is strong enough to permit keeping a space open between the face and the gob that will accommodate cutting machines and a conveyor or other means of mechanized transportation.
Some of the advantages claimed for longwall work are: A larger quantity of coal can be recovered at a minimum cost and smaller capital investment; fewer roadways are required than in room-and-pillar work; less timber is required in the roadways and at the face; better ventilation at the face is possible at less expense, and fewer stoppings, doors, and overcasts are necessary; few pillars must be drawn, and the system is generally safer than room-and-pillar mining; a mine can be developed for full-scale production quicker than with any other method.

To obtain good results with the longwall method the miners should be experienced. Extended periods of idleness or irregularity of output makes longwall work impracticable because of the danger of closing the longwall face if it is not advanced regularly. Although many workmen are required to build pack walls and stow rock or waste, comparatively cheap labor can be used for this work. At present it is not uncommon for the miners, the highest-paid workers in the mine in Santa Catarina, to spend a major part of their time disposing of the waste in the Barro Branco bed.

Concentration of the working faces would be a great advantage in Santa Catarina. Competent underground supervision is scarce, and as a result many inefficient and even dangerous practices exist which could be easily corrected with closer supervision. Ventilation, generally bad in Santa Catarina mines, could be provided more cheaply in longwall operations.

Some form of longwall panel system might be used to advantage in the Barro Branco bed. The face might be worked either advancing or retreating, but only experience will show the best methods and plan to be used. If the panel system is employed one section of the mine could be operated by longwall methods while training the personnel and determining the best methods under local conditions. In the remainder of the mine room-and-pillar methods could be used for comparison under similar conditions. The panels could be closed off if necessary without disturbing operations in other sections of the mine. A more-detailed discussion of mining practice follows.

Figure 17 shows a modified form of longwall tried in Santa Catarina. Several rooms are turned off of a single butt heading and holed into each other after leaving a suitable entry pillar. The face is then driven by longwall advancing. The rest of the mine in which this system was tried continued to use room-and-pillar methods.

The face had two fast ends, and in one instance the coal was shot from the solid without undercutting or shearing. As the face advanced, the worked-out area was almost completely stowed with waste from the bed itself. Little timbering was necessary, and posts were seldom recovered to be used again. Ventilation was bad; the coal was loaded by hand into mine cars and hand-trammed to the surface. The immediate roof and cover were sandstone, and the bottom was a hard shale.

The chief faults of this longwall operation were: (1) Poor ventilation. The longwall was advanced off of a single-entry butt heading, and the natural circulation in the heading itself was very poor. After shooting it was necessary to wait an appreciable length of time before the smoke and fumes were cleared enough to allow the men to work.
(2) Inadequate face transportation. (3) Excessive use of black powder and dynamite in shooting from the solid. As this longwall was in the experimental stage its operation was far from ideal but improved as the men gained experience. The three faults mentioned above, however, can be corrected only by introducing controlled ventilation and some mechanized equipment.

![Diagram of a longwall panel in Santa Catarina](image)

**Figure 17.**—Longwall panel in Santa Catarina.

**OPEN-PIT MINING**

Until 1945 there were no strip-mining operations of any size in the Brazilian coal fields. In Santa Catarina one or two small hand operations produced a few tons of coal a day, and two companies operated strip mines on a small scale with tractor and scraper equipment. In 1945 the National Steel Company developed a strip mine adjacent to the underground mines on its Sideropolis properties. The overburden, which has been thoroughly drilled, ranges from a few meters to about 12 meters in the original area delimited for this open-pit mine.

Planned to produce as much as 20,000 tons a month if desired, this mine during the first part of 1947 yielded 5,000 to 8,000 tons a month.

Equipment observed at the mine in March 1947 included a 6½-cubic yard steam shovel for stripping the overburden, several smaller electric shovels, an electric dragline, and several “skimmer” type shovels.
with horizontal booms. The use of modern stripping draglines and shovels is a departure in mining methods in the Brazilian coal fields; if strip-mining costs under local conditions prove to be appreciably lower than underground costs, possibly more of these operations will appear as other areas with stripping possibilities are located.

Detailed operational data on this project were not available. The ratio of thickness of overburden to thickness of recoverable coal in the area to be stripped will probably average about 12 to 1. Although removal of the overburden is simple enough with the proper equipment, the principal problem is handling the bed itself, which is the typical Santa Catarina Barro Branco.

As in the underground mines, mechanical handling of the bed is complicated by the necessity of removing it in benches (fig. 4, p. 20) and separating the shale and clay partings before the coal is loaded out. At present the bed is broken manually or with the aid of pneumatic picks, and the shale and clay partings are wasted as they are encountered. The recovered coal is loaded into trucks with mechanical shovels and transported to the picking and railroad loading plant near the underground mines 1 or 2 km. away.

This manual handling of the bed naturally defeats some of the advantages of an open-pit operation. Although it is feasible to load the top bench of coal mechanically with shovel, dragline, or scraper where the bed structure is similar to that shown in a or b, figure 4, manual separation of the shale stringers in the bottom bench is certainly necessary in a and probably necessary in b. If the coringa coal shown in a and b is to be recovered, the possibility of handling the quadração or center waste section mechanically as a unit is eliminated.

While manual handling of the bed might be eliminated where the bed structure is similar to that shown in c, figure 4, the coal must still be taken in three benches. If the shale stringers in the bottom bench are not removed as this bench is taken, this waste would be removed (1) by hand-picking in a central plant of the mine before being shipped to the central washing plant at Capivarí; (2) in a jig or other suitable device for precleaning or "scalping" the coal at the mine before shipping to the central washery; or (3) in the central cleaning plant itself. The best method would depend on economic considerations. The additional cost of subsequent removal of the shale partings in the bottom bench in this particular instance probably would be less than the amount saved through elimination of manual operations at the open-pit mine.

Even in this circumstance the bed must be mined in three separate benches—the top bench of coal taken and loaded; the quadração cast behind on the waste pile; and finally the bottom bench of coal taken and loaded.

Although the handling of the bed in this open-pit operation seems costly, one should remember that the same problems apply to underground mines in the Barro Branco bed to even greater degree. Where possible, open-pit mining of the Barro Branco bed probably will account for an increasing percentage of total production in the future.

In Rio Grande do Sul areas suitable for open-pit mining are being investigated, although no operations have been developed as yet.
PARANÁ

Although most of the Paraná mines have been developed since 1940, the leading producers consistently have tried to improve their mine projections as more drilling and map information becomes available. Most of the concessions actually being developed have been drilled, if not thoroughly, at least to an extent that permits some rational mine planning. Core-drilling operations are being continued with the cooperation of the National Department of Mineral Production (Departamento Nacional da Produção Mineral), and much valuable information on the coal beds is being collected.

Most of the producers have topographic and mine maps of their properties and have tried to collect as much pertinent information as possible and plot it on their maps. While this work may seem routine to some readers, it is by no means common practice among the smaller producers in the Brazilian coal fields, and its importance in intelligent mine planning should be emphasized.

ROOM-AND-PILLAR SYSTEMS

Some variation of the room-and-pillar system is employed in all of the Paraná mines. Because hand tramming requires that grades against the loads be avoided in the haulage roads, it is not always possible to take advantage of the most-efficient mine lay-out. Local variations of bed contours frequently necessitate a departure from advance mine projections.

Usually two or more entries are driven to the rise from an outcrop line, cross entries or butt headings are driven on the strike at right angles to the main entries, and rooms are turned at right angles to the butt headings on the inby or rise side. The shape of the area to be mined, of course, influences the lay-out.

In some mines the main entries are driven in pairs; in others two or more single entries are driven independently. These single entries may or may not be advanced in parallel and are connected by cross entries at varying intervals. In the latter instance the cross entries sometimes become room headings, with the rooms turned off the inby side and advanced parallel to the main headings. Sometimes cross entries are turned 90° off single or double main entries, butt headings are turned off the cross entries, and the rooms are driven from the butt headings at right angles to the direction of the main headings.

Although main and cross headings are sometimes driven in pairs, the single-entry system is commonly used for butt headings.

Headings are driven 2 to 2.5 meters (6½ to 8 feet) wide, and in narrow beds top or bottom is taken for clearance.

Several methods of driving rooms have been employed in the Paraná field. Choice of method is influenced by the thickness of the bed, quality of the roof, and experience of the operator. Because local conditions vary considerably, comparison of the advantages of the different systems is difficult.

Figure 18 illustrates one system of mine development observed in Paraná. A peculiar feature of this particular mine was the fact that
Figure 18.—Single-entry mining system in Paraná.
the two main headings started from a common drift mouth, then separated until about 10 meters apart, and advanced in parallel. The mine was developed from the high side of the bed, and pumping was necessary. Mule haulage was used on the main haulage road. The fact that the main headings were driven to the dip and that mules were used for haulage was unique in the Paraná field.

Figure 19 shows one method of developing rooms in a thin bed in Paraná. Narrow entries were driven off one side of a room heading on about 20-meter centers to the desired distance (50 to 90 meters). Bottom was taken in this entry for clearance. Half or about 10 meters of the pillars on each side of this entry were then mined retreating back to the chain pillar, then left along the room heading.

In some places the room was widened to 10 meters after necking and advanced to the limit. Bottom was taken only along the straight rib where the track was laid, and the pillar on this side was recovered on the retreat. This latter system has one big advantage in thin beds where it is necessary to take top or bottom on the haulage roads—the waste material can be stowed in the extra space provided by the wide room.

Longwall methods are not used in the Paraná field, although in some areas conditions seem to favor this system. There are no open-pit mines in this field, and no areas of any extent have been located that could be profitably recovered by this method.
WORKING METHODS

MECHANIZATION

In the United States the term "mechanization" refers principally to mechanical loading. Cutting machines and mechanized haulage have been so generally used since early in the century that the more recent term "mechanization" as generally understood in the United States does not include them.

Mechanical loading has not been accepted so generally in European coal mines as in the United States, and the term "mechanization" is employed in a broader sense to include almost all mechanical equipment used to replace handwork.

In Brazil mechanization is used in the European sense, and the term as employed in this bulletin has the broader meaning.

MACHINE CUTTING

The coal-cutting machine was first developed in Great Britain. It consisted of a large horizontal disk with a toothed edge, driven by a compressed-air motor, used chiefly in longwall work. This machine was the basis for the more-efficient chain cutter first developed in the United States for use in rooms and heading. The latter cutter was supplanted by the modern motor-driven chain cutters known as shortwall, longwall, or arcwall machines. Recent designs include machines with adjustable cutter bars for cutting at different horizontal levels in the bed or for revolving the cutting bar so as to make a vertical or shearing cut.

Compressed-air-driven punching machines, so-called because of the punching action of the cutting head or bit, are no longer used in the United States except in a few isolated mines.

During 1945, 13,900 coal-cutting machines were in use in the bituminous-coal fields of the United States. The average output per machine was 31,720 net tons; 90.8 percent of all bituminous coal mined was cut by machines.

In Great Britain undercutting by machine is practiced extensively. Chain machines are most popularly employed, but some coal is still cut by disk, bar, or so-called punching machines.

In Germany, France, and Belgium cutting machines are not used to any great extent, principally because of adverse natural conditions. Poor roof, thin, steeply pitching beds, heavy pressure, and the fact that much of the coal is friable and easily brought down make the use of cutting machines difficult or unnecessary.

In Brazil chain cutting machines were tried some years ago in a Rio Grande do Sul mine and in one mine in Santa Catarina. The experiment in Rio Grande do Sul was reported to be unsuccessful, and use of the machine was abandoned. In Santa Catarina the failure was reportedly due to frequent machine breakdowns and constant bit failure due to the heavy pyrite inclusions in the bed. The disappointing results probably could be attributed to several causes: Machine operators were inexperienced and unfamiliar with both the machine
and its operation; mine lay-out and mining methods were not planned or organized to complement machine cutting; personnel was opposed to the introduction of mechanized methods; and the machines themselves were not adapted to operate under local conditions. Repair shops and personnel were not prepared for the proper maintenance of such machinery.

**RIO GRANDE DO SUL**

In the Rio Grande do Sul mines mechanical equipment used in mining coal or advancing the working faces is limited to pneumatic puncher-type cutting machines and jackhammers. In this respect mining methods are no more mechanized than in some of the Santa Catarina mines. In Rio Grande do Sul, however, the coal is seldom cut by hand as it frequently is in Santa Catarina.

Generally, puncher-type cutting machines are used only in advancing narrow work. A vertical kerf is cut in the face by the post-mounted cutting machine, and the coal is broken down with black powder made locally. Hydraulic-type commercial dynamite is used in wet places, in driving through faults and dikes, and occasionally for other work.

In the rooms at Butiá and the so-called longwall faces at Arróio dos Ratos the coal is drilled with jackhammers and shot from the solid.

A discussion of the advantages and disadvantages of the pneumatic puncher-type cutting machine is included in the following section on Santa Catarina. The machine is employed in similar ways in both fields. Its use is often justified in pioneering work, in pitching beds, and in small mines. In Butiá and Arróio dos Ratos, however, the use of modern electric chain cutting machines appears feasible. The mines are large, production is concentrated principally in two units, and underground transportation in both mines is already mechanized, at least on the main haulageways. The structure of the bed is favorable; it can be shot down and loaded without the manual separation of rock partings, which so complicates mining of the Barro Branco bed in Santa Catarina.

Personnel employed in breaking down the coal includes drillers, who drill the face with jackhammers; cutters, who handle the punchertype cutting machine; clean-up men or "bug dusters," who work with the cutters and clean up the cuttings; and shot firers, who help the drillers, prepare the black-powder cartridges, and load and shoot the holes.

The crew used in driving headings or any narrow work is made up of a driller, who commonly acts as crew foreman; a cutter; and a clean-up man. Such a crew will average about 13 feet (4 meters) of heading advance per shift. Each crew is responsible for more than one place, however, and the work cycle is such that any one entry is advanced only 65 to 82 feet (20 to 25 meters) a month.

At Butiá the work in the rooms is done on contract by a driller (the contractor) and his helper. In the so-called longwall faces at Arróio dos Ratos the coal is broken down by a driller (foreman) and a shot firer.

The working day in Rio Grande do Sul mines is divided into four 6-hour shifts. In any one section the coal is cut, drilled, and shot down
in one shift. The place then remains idle during the two succeeding shifts (12 hours). On the fourth shift it is timbered, and the coal is loaded out. The cycle is then repeated.

The following example shows how the work cycle is spread over the different sections: Section 1 is drilled and shot on the first shift; section 2 on the second shift; section 3 on the third shift; and section 4 on the fourth shift. Section 1 would then be loaded out on the fourth shift; section 2 on the first shift of the next day; section 3 on the second shift of the next day; and section 4 on the third shift of the next day.

The miners rotate by changing every week to the preceding shift. Thus, during a 4-week period a miner spends 1 week on each of the fourth, third, second, and first shifts.

Coal in the Rio Grande do Sul mines, as in the other fields, is 100 percent hand-loaded. Because of the thickness of the beds and the general absence of thick rock partings such as those found in the Barro Branco bed in Santa Catarina, it would appear that mechanical loading might be used to better advantage in the CADEM mines than in those in the Santa Catarina field. The present mining systems, however, were not designed for fully mechanized operation. Such factors, as well as uncertain market conditions and the limited life of the mines now operating, would no doubt make a large-scale mechanization program advisable at present.

HAULAGE

Various methods of underground transportation are used in the CADEM mines in Rio Grande do Sul, including trolley locomotives, endless ropes, tail ropes, and small winches.

The endless-rope system is used widely at Butiá on the main haulages. The system requires that parallel entries be driven on a straight line, regardless of the coal contours; one entry is used for outgoing loaded cars and the other for incoming empties. The maximum one-way distance served by a single endless rope in this mine is about 3,300 feet (1,000 meters). When the haulage distance exceeds this limit or if it becomes necessary to change the direction of the headings, two or more ropes are used in series. Subsidiary endless ropes are used in some of the secondary haulage roads. Occasionally the same rope is used in both principal and secondary roads by changing its direction 90° around a pulley at the intersection. In this instance the cars must be disengaged from the rope to pass the pulley.

The endless-rope units (with the exception of the cables) are constructed in the company shops. The average life of a new 5/8-inch cable is about 4 months under normal operating conditions. The rope is driven at a speed of 118 to 138 feet per minute (60 to 70 cm. per second), the approximate speed of a man walking. Figure 20 shows the distribution of the endless-rope units in the Butiá mine.

Electric trolley locomotives or a combination of these with tail ropes and small winches are used in the mines at Arrôio dos Ratos. The locomotives are used principally in the main haulage roads, and the tail ropes and winches are confined to the secondary roads. The mine has five locomotives in operation and one in reserve. Each is 11.5
Figure 20.—Distribution of endless-rope units in the Butlă mine.
feet (3.5 meters) long, 3 feet (0.95 meter) high, and 2.5 feet (0.75 meter) wide. Powered by two 15-hp. motors, they operate on 250-volt direct current.

Auxiliary winches are used wherever grades do not permit the use of locomotives—usually in the secondary roads at right angles to the main haulageway. When two locomotives are working at different elevations winches are used to coordinate the traffic between them.

The advantages and disadvantages of the two haulage systems might be interesting. The following comparison was made by the operating officials of the CADEM mines:

1. At Butiá, which uses the endless-rope system, the property is drilled principally to determine the existence, quality, and limits of the coal bed. At Arróio dos Ratos, where locomotive haulage is used, it is also necessary to determine the coal contours as completely as possible. This requires a closer drilling pattern and more frequent surveying.

2. The initial installation cost of the locomotive system is higher than that of the endless-rope system which is built in the company shops. Maintenance cost, however, is higher for the endless-rope system principally because the cable must be changed regularly, as are also labor costs because a larger operating personnel is required.

3. Double entries are driven at both mines. The endless-rope system requires that both entries be maintained, complete with track. Locomotive haulage requires that track be laid in only one road, and maintenance in the parallel entry can be virtually ignored.

4. With rope haulage, lighter-gage rails can be (and are) used successfully for both the empty and loaded track, even though heavier track on the loaded road increases transportation efficiency.

Heavier rails are used for locomotive haulage. At Arróio dos Ratos old 38-pound (19 kg. per meter) railroad rails are relaid on the locomotive-haulage roads.

5. Supervision is easier and more efficient with locomotive haulage; if a car is derailed, the motorman and helper are always present and aware of the fact immediately. They usually can put the car back on the track without assistance or with the help of the locomotive.

On the other hand, if rope-haulage traffic is interrupted by a derailment, a foreman must first locate the trouble. If more than one car is derailed, the situation cannot be remedied by the foreman alone, and he must call for help. The additional workmen must frequently come from some distant point.

6. With locomotive haulage, the cars are delivered at the bottom of the shaft in intermittent trips. The endless-rope system, on the other hand, delivers a constant flow of coal to the shaft and a steady stream of empty cars back to the working faces.

7. When the cars need not be shifted a number of times, that is, if the locomotive picks up the cars at a gathering point and takes them directly to the shaft bottom, then more cars can be handled with a given number of workmen than in the endless-rope system.

When, however, it is necessary to transfer the cars from one locomotive to another with winches, because of adverse grades, then the endless-rope system is more efficient and is given preference.
8. The use of locomotives in combination with winches demands perfect coordination of traffic. This difficulty does not exist where the endless-rope system is used.

9. Summarizing the comparison, the CADEM officials reached this conclusion: If the coal bed is regular and level enough to permit locomotives to proceed to the secondary entries, then locomotive haulage is preferable. If it is necessary to use auxiliary winches in combination with the locomotives because of bed irregularities or heavy grades, then the endless-rope system is to be preferred.

SANTA CATARINA

CHAIN CUTTING MACHINES

One argument against the use of chain cutting machines in the Barro Branco bed in Santa Catarina has been the high pyrite content of the bed. In the United States chain cutters are used successfully in material just as hard as that found in the Barro Branco. Recent improvement in the alloys used to tip cutting bits has made them far more resistant than they formerly were, and more rugged machine construction and powerful motors permit their use under surprisingly adverse operating conditions.

Cutting the coal by hand occupies the greater part of the miner's time in Santa Catarina. It is responsible in large part for the low output per man and for the comparatively high labor cost per ton of coal. If, as observation indicates, chain cutters can be used successfully in the Barro Branco bed, they also can be used in most of the large mines.

The National Steel Company has decided to experiment with undercutting chain machines and has placed orders for the equipment. According to reports, when the machines were tried some years ago the kerf was cut in the bottom of the lowest bench of coal. At that time Santa Catarina coal was not used to any extent for coking purposes, and lump coal demanded premium prices. Some of the coal was lost as fines or "bug dust" by machine cutting and, as previously stated, the pyrite inclusions caused frequent bit and machine failure.

Figure 21 shows a method suggested for the use of chain cutting machines in the Barro Branco bed. The chief difficulty in mining coal is the necessity for taking the center section of waste material known as the quadracão separately from the top and bottom benches of coal. If the entire bed was shot at one time, selective loading at the face would be complicated, and the large quantity of refuse would place an impossible load on any cleaning plant. By hand methods the quadracão is usually picked out, shot out, or wedged down, after cutting a kerf, and cleaned up. The top and bottom benches of coal are then taken by methods varying with conditions. As may be seen in figure 4, the physical composition of the Barro Branco bed varies appreciably, and the location of the kerf and method used for recovering the coal are modified to meet local conditions.

The method of chain cutting illustrated in figure 21 has the advantage of using regular shortwall machines with the cutter bar on the bottom, most easily used in longwalls or rooms. The kerf would
"Quadração" or center bench of shale and clay shot to top bench of coal and gobbed.
Top bench of coal is easily picked down

Figure 21.—Suggested method for using chain cutting machine in Barro Branco bed.
always be in the bottom; if a method of top cutting was used, variations of bed thickness or arrangement of the various benches of coal and shale would necessitate frequent adjustments in the height of the cutter bar. While the shale bottom is usually fairly hard, it would probably be easier to cut than the coal itself because of the high pyrite content of the coal.

There are disadvantages to the method illustrated in figure 21. The bottom bench would necessarily be shot first up to the clay bench locally known as the Barro Branco or white clay, from which the bed gets its name. Any shale stringers in this bottom bench would, of course, be shot down and mixed with the coal, making a separation at the face difficult. When the quadracão is removed first, as at present, the bottom bench is removed or "dismounted" by hand picks, pneumatic picks, or wedges, and the shale stringers are separated and gobbled at the face. It might be more economical, however, to shoot the entire bottom bench after undercutting, as illustrated, and remove the waste on the surface by hand-picking or in jigs designed to "scalp" the coal before it is sent to the central washery. Where the bottom bench is similar to that in figure 21 this practice would seem feasible and worth consideration, but when the bed section is similar to that in figure 22 it might not be advisable.

Washability tests (see Preparation Practice) indicate that the percentage recovery of "metallurgical" coal at the same specific gravities is greater from the top bench of coal than from the bottom bench. To load out the benches separately might therefore be an advantage with respect to washery operation, as the chief purpose is preparation of a metallurgical-grade fuel for coking purposes. If this is done, undercutting as indicated would be favorable, because separate loading of the two benches would be obligatory and not left to the discretion of the miners.

If separate loading of the top and bottom benches is not necessary, then undercutting would complicate the work cycle somewhat. The sequence of operations at the face would be: (1) Cut, (2) shoot and clean up the bottom bench, (3) shoot and clean up the quadracão or waste material, and (4) shoot or pick down the top bench and load it out. If the bed is cut so that the quadracão can be shot first, the sequence probably would be: (1) Cut, (2) shoot and clean up the quadracão, and (3) shoot top and bottom benches of coal or take both benches together by whatever means are used and load out. This procedure would be more desirable because it permits a more efficient use of labor and eliminates one clean-up operation. In practice, this latter sequence could be followed with undercutting if (fig. 21) at step c, instead of taking down the top bench of coal, the face is then again undercut first and shot. The top bench, which was kept up from the first cut, would be taken at the same time as the bottom bench from the second cut. The quadracão from the second cut would be shot and cleaned up and the operation repeated. This method would, of course, depend on the possibility of holding the top bench up while the second cut was made and the bottom bench shot down. Only experience will show the best method to be used, and the methods illustrated here are merely suggested possibilities.

Sometimes the coal stringer found immediately above the clay bench or Barro Branco attains a thickness of 3 to 4 inches. It is locally
known as the “coringa” and is recovered where hand methods are used and it is thick enough to warrant the extra work involved. If the bed was cut by machine, either the coringa would be lost when the quadracão was shot down, or the additional operations necessary for its recovery would defeat some of the advantages of machine cutting. In such instances the value of the recovered coal and increase in recovery must be balanced against the additional cost and time necessary to recover it.

If a chain cutting machine with a cutter bar adjustable to different heights is or could be used, the Barro Branco bed can be mined more effectively.

Figure 22 shows a bed section that is somewhat different from the section in figure 21. In this section the recoverable coal probably totals 81 cm. in a total bed thickness of 2.06 meters. The part below the Barro Branco clay parting, locally known as the “banco” and herein referred to as the bottom bench of coal, is actually composed of five coal bands totaling 44 cm. and four shale partings totaling 30 cm. If this coal was undercut, the bottom bench probably would be shot as a whole, and the job of separating the coal from the shale, either at the face or on the surface, would be difficult and costly. In this instance it would be preferable to mine the bed as indicated in figure 22. As shown, the kerf is cut in the shale parting immediately below the top bench of coal. The second best alternative would be to cut either in Barro Branco clay, which is often extremely compact and hard, or perhaps in the bottom of the top bench of coal, or in the top of the bottom bench immediately below the Barro Branco. The objection to cutting in the coal is its high pyrite content and resulting wear on bits and machine.

After cutting in b, figure 22, the entire center part of the bed or quadracão is shot out, leaving the top and bottom benches of coal. The top bench is easily picked down manually or with pneumatic picks. The bottom bench could then be taken, preferably with pneumatic picks, the coal and shale bands being taken separately and the shale discarded or gobbed as it is broken out.

This procedure usually is followed when the bed is mined and broken down manually; where the bottom bench has many shale partings it is almost the only way of avoiding a tremendous cleaning problem on the surface. This same method could be used where the bed section is similar to that in figure 21; after cutting and shooting out the quadracão, however, the bottom bench could be shot and loaded out as a whole, together with the top bench. The two shale partings in the bottom bench, totaling 10 cm., would then be removed on the surface either by hand-picking or preferably in jigs designed to remove this high-gravity waste material before final cleaning in the central washery.

PUNCHER-TYPE CUTTING MACHINES

The only type of cutting machine used in Santa Catarina at present is the post-mounted, compressed-air-driven, puncher type known as the “Radialaxe.” Only recently adopted on a limited scale by some of the companies, this machine has shown excellent results over hand-cutting methods. Although this type of cutting machine has been
**Figure 22.**—Suggested method for using chain cutting machine in Barro Branco bed.
almost entirely replaced by chain cutting machines in the United States, it has features that recommend its use in many Santa Catarina mines.

Because of the organization of the mining industry in many small producing units, general lack of electric power at the mines, absence of machine shops and machine maintenance crews, and scarcity of trained personnel, the introduction of mechanized units such as chain cutting machines and loaders is inadvisable in most mines at present. In the larger, better equipped mines or in planning new operations, however, the use of such units should be considered. The smaller mines would not justify the capital outlay necessary to equip and revamp them for mechanized methods.

Puncher-type coal-cutting machines, however, can often be used advantageously, particularly in the smaller mines. They can be powered by portable, mobile, Diesel or gasoline air compressors, are relatively simple to operate and service, and do not require highly trained personnel for efficient operation. Post-mounted, the machine will cut either a vertical or horizontal kerf, and the manually operated swing and feed mechanism is simple and easily controlled. Variations in the physical structure of the Barro Branco bed often necessitate altering the location of the kerf. For this the machine is well-suited; it is only necessary to change the position of the saddle on the post.

The machine with mounting is easily moved from one place to another. Over longer distances it can be transported in an empty mine car or on a light truck, and for short distances it can be carried by the two-man crew.

When cutting a room or longwall face the machine must be moved several times as its cutting range from any one setting of the column mount is limited. In advancing headings or narrow work, however, one setting is usually sufficient to cut the entire face.

Although the puncher type is by no means to be compared to the chain cutting type of machine where the latter can be used, the senior author has found from practical experience that excellent results can be obtained from these percussion machines under pioneering conditions that prohibit or discourage the use of more-modern mechanized units. If they are properly used in conjunction with pneumatic picks and jackhammers, the laborious task of mining and breaking down the Barro Branco bed can be considerably lightened, and the capital investment for such equipment is within the reach of even the smaller operators.

HAND MINING

By far the greater part of the coal in Santa Catarina is mined by hand. As yet, only a limited number of puncher-type cutting machines have been introduced, and in no one mine are they employed exclusively.

When cutting by hand, the miner starts the kerf in whichever part of the bed is softest or most easily attacked with a pick. This cut is usually in the center section of the bed, the quadracão. Figure 23 illustrates the three principal steps in mining and breaking down the bed by hand.

The miner cuts the initial kerf to a depth of about 80 cm. in that part of the bed most easily attacked with a pick (fig. 23, a). The location
Figure 23.—Mining the Barro Branco bed in Santa Catarina by hand.
of this kerf is not necessarily as shown in figure 23, although it is the most common. A narrow face of 2½ to 3 meters is cut in approximately one shift, but a room face of 8 or 9 meters requires 2 to 3 days. After this initial cut is made the remainder of the quadracao is picked down, shot down, or wedged down, and the rock is gobbed or loaded out of the mine (fig. 23, b). The top bench of coal is then picked or barred down, and the bottom bench is taken up with picks, wedges, or pneumatic picks (fig. 23, c). Sometimes this bottom bench is loosened with light shots of black powder, but it is rarely shot out completely. The alternate bands of coal and shale are taken in succession, but separately, and the shale gobbed as it is removed.

Pneumatic picks have proved to be very effective in breaking down the bed and are particularly useful in removing the bottom bench and separating the coal and shale during the process. The pneumatic picks are not very effective in making the first cut, as the narrow kerf limits their action to an almost horizontal position; the machine cannot be handled freely in such a confined space.

Attempts have been made to shoot the entire center section or quadracao from the solid in both narrow and long faces, but the results were discouraging. The numerous bedding planes and character of the strata make it difficult to shoot in this manner, and the cost of powder was high. By making a vertical cut first and then shooting the quadracao to this vertical free face some cutting is eliminated, especially in a long face, and results are improved over shooting from the solid.

The problem of mining or cutting the Barro Branco bed is a serious one and an important factor in increasing production and lowering costs. Where hand methods are used the miner does his work efficiently and produces as much work as can be expected under the conditions. The only way to increase production, then, is to increase the number of producing faces and the number of workmen. In many mines the lay-out makes this difficult or impossible, and the supply of mine labor is limited. The most logical solution for increasing production and lowering costs is, of course, to increase the output per man-shift, and the obvious way of accomplishing this is by improving methods and mechanizing at least some operations. Although mechanized transportation and perhaps loading are important considerations, they alone will not increase total production except in allowing the miner more free time in which to mine and bring down coal. In the ultimate analysis, however, an appreciable increase in output per man-day rests on the quantity of coal mined and brought down at a working face in a given time.

A 7- to 8-meter room face produces only about 2 tons of run-of-mine coal per shift by hand methods. At this rate the development work and total active area necessary to produce a relatively small daily tonnage is very great, and problems connected with supervision, transportation, maintenance, etc., are magnified enormously in comparison to tonnage produced.

Considering the structure of the Barro Branco bed, the quantity of waste material that must be handled, and the methods used, the low output per man is easily understood; because of these extraordinarily adverse conditions, more attention should be paid to improving methods and equipment to lighten the duty of manual labor.
In medium-hard to hard material in a given place the senior author has found from actual experience in several South American coal mines that with a puncher-type coal-cutting machine one man can cut three to five times as much coal in a given time as can be cut by hand. Although operational data are lacking on the use of these machines in Santa Catarina, their advantage over hand-cutting methods is obvious. If projected experiments with chain cutting machines are successful in the Barro Branco bed, a big step will have been taken in reducing costs and increasing production in Santa Catarina. The general use of chain cutting machines, however, is not likely until mining is concentrated into fewer and larger operations; until then the small mines will no doubt continue to use hand methods or puncher-type cutting machines in mining coal.

PNEUMATIC PICKS

The recent introduction of pneumatic picks in the Santa Catarina mines has already been mentioned. They, like the puncher-type cutting machine, can be used economically in the smaller mines as well as in the larger ones. Initial and operating costs are low, and the picks are adaptable to the mining methods prevailing in the Barro Branco bed.

Where hand methods are used entirely the pneumatic pick is employed in breaking down the quadracão as well as the top and bottom benches of coal. If the quadracão is shot out, pneumatic picks are used to square up the face before the coal benches are removed; they also are used to recover the top and bottom benches of coal after the quadracão is removed. Sometimes the bottom bench is shot lightly to merely loosen the coal and is then broken out with pneumatic picks; the alternating bands of coal and shale are removed in the order in which they occur and separated at the face.

Although pneumatic picks are used by only a few of the producing companies, their popularity is increasing. The use of pneumatic picks, jackhammers, and puncher-type cutting machines is locally referred to as "mechanization." As the three types of machines complement each other, they have almost invariably been installed as a working unit; that is, a mine has either all or none of these three types of equipment.

LOADING

Coal won by underground methods in Santa Catarina is 100 percent hand-loaded. With the adoption of cutting machines and modifications of the present mining system and methods, mechanical loading may find some application in the Barro Branco bed. At present, however, there are several arguments against it.

As explained previously, in mining this bed it is necessary to do a lot of hand-sorting at the face, particularly while loading the bottom bench or banco. The bed itself is approximately 50 percent rock or waste and 50 percent recoverable coal. Most of the waste is concentrated in the quadracão or center section of the bed (fig. 4, p. 20), which is removed separately from the top and bottom benches of coal. As much of this waste as possible is gobbed behind the face, but
usually some of it must be loaded out of the mine, particularly in driving headings or in narrow work. When it is gobbed, of course, there is no necessity for loading into cars, and the use of scrapers or the practice of loading it mechanically onto short conveyors to carry it to the gob is not practical under present conditions. The quantity of rock that must be removed to the surface is not large enough to justify mechanical loading at the present rate of production at the working faces.

Besides the fact that much of the coal is hand-sorted at the face, the actual quantity produced per shift is very small, whereas loading machines require large piles of coal in order to operate continuously and efficiently.

If large quantities of the waste in the bed must be loaded out, if the top and bottom benches of coal could be loaded without the necessity of removing the bands of impurities by hand at the face, and if cutting machines are used to speed up the rate of advance, then perhaps loading machines could be used efficiently in mining the Barro Branco bed. Under present conditions, however, loading machines would be idle most of the time or would spend the major part of a working shift moving from place to place.

HAULAGE

Except in a few mines in Santa Catarina, all coal is hand-trammed from the working face to the surface. Three mines use small (6-ton or smaller) trolley locomotives, and one of these also uses 1½- to 3½-ton battery locomotives. All locomotives are used principally on main haulage roads. Cars are hand-trammed to and from gathering points inside the mine, where the locomotives pick them up for transportation to the surface.

At several mines short slopes have been driven through shallow cover to reach the flat-lying coal bed; the coal is hand-trammed to the bottom of the slope and hoisted to the surface with small gasoline or electric winches.

The lack of central electric power plants and the small productive capacity of most of the mines have been largely responsible for the general use of hand tramming instead of mechanized haulage methods in Santa Catarina. The small production capacity and life expectancy of some mines do not warrant the capital investment necessary to mechanize haulage. In others, however, the distances, tonnages, and conditions involved are well beyond the range within which hand tramming is economical.

Track work in the Santa Catarina mines is generally bad. In the few mines using locomotive haulage 15- to 30-pound steel rails are used on the main haulage roads, and track maintenance is above the average. In the majority of the mines wooden rails are used; in some, light 10- to 15-pound steel rails in the main headings are supplemented by wooden rails in the cross entries and rooms. These light steel or wooden rails are poorly laid, and track maintenance is unsatisfactory. The wooden rails are hard to aline properly, and as they are often made of green wood they soon warp badly. The resulting track is wavy, crooked, and varying in gage. Derailments are frequent, and resistance to rolling stock is high.
The marked acidity of the mine water in Santa Catarina causes rapid deterioration of steel rails in wet places. Some mine operators justify the use of wooden rails by this fact, but in most instances proper drainage on the haulage roads would eliminate much of this trouble. The time lost and the human energy wasted because of derailments are considerable. Any money invested in building and maintaining better track in the mines would be more than repaid by the increase in haulage efficiency.

Switches and curved turn-outs are unusual in Santa Catarina mines. The usual practice is to drive cross entries, butt headings, rooms, etc., directly off a developed heading, usually at a 90° angle. Mine cars are transferred from track to track by means of turntables. In some mines a short section of track revolves with the turntable, and in others the car is revolved directly on the turntable, which consists of a metal disk sloped downward toward the edge and pivoted in the center. With hand tramming and little traffic, the system is satisfactory and eliminates the necessity of driving curved turn-outs and laying curved track. With locomotive haulage or intensive production, however, the system is impossible or inadequate.

The size of the mine cars is necessarily limited by the practice of hand tramming; 1,500 to 1,600 pounds is the usual capacity of a mine car. It is usually constructed of wood and has a high body to facilitate pushing by hand and side or end gate to make hand loading and unloading easier. Even where locomotive haulage is employed the cars are small, as they are usually hand-trammed to and from the gathering points on the main haulage roads.

Figure 24 illustrates the type of mine car commonly used in the Brazilian coal fields.
Although natural conditions and characteristics of the coal beds in many areas in the Paraná field favor the use of mechanized mining equipment, the small size of the individual mines and limited production have discouraged the use of such equipment.

As transportation and market conditions improve and permit expansion of production capacity, the larger mines can profitably mechanize many of their mining operations.

At present, mechanized mining equipment in the Paraná field is limited to a few pneumatic picks, jackhammers, and puncher-type cutting machines introduced by one company in 1946. In the one mine where they are employed the puncher-type cutting machines are used almost exclusively in advancing narrow work or entries. These machines offer many advantages to the small mine operator who desires to mechanize the operation of cutting the coal but cannot justify the greater capital investment necessary for the more-modern and efficient chain cutting machines.

Percussion coal-cutting machines are light, portable, and simple and easy to operate; personnel can be quickly trained to use them efficiently. They are powered by steam, Diesel, or gasoline-driven air compressors and do not require elaborate electric-power installations—a decided advantage to mines in remote areas or in pioneering stages of development. Although these machines cannot be compared to chain cutting machines in efficiency, they are a distinct improvement over manual cutting methods and are an acceptable compromise between hand-cutting and cutting by chain machine.

The pneumatic drills, picks, and cutting machines are of the same type and are used in the same manner as those in the Santa Catarina field. To avoid repetition the reader is referred to the discussion of their use in that field.

Hand-mining methods in Paraná are basically the same as those in the Santa Catarina field. Usually a kerf is cut by hand in the softest part of the bed, and the coal is then broken down with picks and wedges, shot down, or picked down with pneumatic picks. Thick binders or benches of waste material encountered are removed as completely as possible at the face and gobbed. In some instances the coal is shot from the solid, but this method is practical only when the bed is fairly clean and requires little or no hand separation at the face.

Mechanized cutting methods can probably be used to better advantage in the Paraná beds than in the Barro Branco bed in Santa Catarina. In many places the thick quadracão or middle bench of waste material so characteristic of the Barro Branco is missing in the Paraná beds, and it is not necessary to take the bed in benches to avoid mixing the coal with this waste material. There is usually at least one binder of varying thickness in the Paraná beds, but if the kerf is cut in this binder the remainder of the bed often can be shot down at one time. Whereas the Barro Branco bed in Santa Catarina cannot be mined and loaded out as a whole without putting an impossible load on a cleaning plant, with proper preparation facilities some of the Paraná beds can be loaded out with little or no hand separation at the face.
Containing less waste material and approximately the same thickness of recoverable coal, Paraná beds are generally thinner than the Barro Branco bed in Santa Catarina. Frequently the top or bottom must be taken for clearance in the haulage roads, and the authors observed that the top was brushed over a full room width in some mines to give the miners standing room.

LOADING

All coal mined in the Paraná field is hand-loaded. At present the small production capacity of the mines would not justify mechanical loading methods. If mining conditions were more intensive and mechanical cutting and haulage equipment was used, mechanical loading might pay dividends when the coal bed could be loaded without resorting to hand separation of refuse at the face.

Extensive mechanization of the Paraná mines, especially mechanization of loading operations, would require a much larger production than is apparently possible at present. Until transportation and market conditions offer a reasonable guarantee for such production the producers are probably wise to continue with hand-loading methods.

HAULAGE

Mule haulage has been used to some extent in one Paraná mine, but with this exception hand tramming is practiced exclusively.

Several of the mines are not extensive enough and do not produce enough coal to warrant mechanical haulage; on the other hand, some of the mines have passed the economical limit for hand tramming. In a few mines the limited capacity of the hand-tramming system is the controlling factor in mine production.

Trackwork, type of cars, and haulage conditions in the Paraná field are similar to those in the Santa Catarina mines, which use hand-tramming methods. Shaft hoisting equipment is not necessary, as all of the present mines are developed from horizontal drifts. Hand tramming demands that grades be kept to a minimum and that they favor the loads. This frequently precludes the use of the most efficient mine lay-out and results in the abandonment of some dip areas that would have been recovered with mechanized transportation methods.

The extent to which any of the underground mining operations are mechanized, including haulage, will depend largely on the possibility of increasing production from present operations and the development of new and larger mines in the future. Under present conditions it is doubtful if the existing mines will be mechanized to any great extent; the future development of the Paraná field depends largely on the capacity of railroad facilities to transport the coal to market.

VENTILATION

RIO GRANDE DO SUL

As both Butiá and Arróio dos Ratos are shaft mines, ventilation is an important factor in their operation and receives more attention than is usually given it in the Santa Catarina and Paraná coal fields.
Each mine is ventilated by centrifugal-type exhaust fans driven by 50- to 75-hp. motors. The mines are considered nongassy, and the precautions usually taken in a mine where methane is found are not necessary. The quantity of air normally circulated is about 2 to 3 m.\(^3\) per minute per underground worker.

Doors, stoppings, and brattices are used to control and properly distribute the ventilating current, and worked-out areas are sealed off promptly.

As previously noted, each shaft is divided into four sectors as regards ventilation and the cycle of mining operations. The working day is also divided into four shifts of 6 hours each. In any one sector the coal is cut, drilled, and shot down in one shift. The sector then remains idle for two shifts (12 hours), and the coal is loaded out on the fourth shift. This cycle is staggered in the different sectors so that the coal is shot down in only one sector during any one shift and is loaded out from only one (different) sector during the shift. This cycle was adopted apparently for several reasons. Brazilian labor laws permit the miners to work only a 6-hour day, portal to portal, and it was found convenient to allow a sector to remain idle for some time after shooting in order to clear the resultant smoke and gases from the faces.

In some instances a sector is ventilated by a separate split of air; in others two or more sectors are ventilated by one split. In the latter case the work cycle is arranged so that after the coal is shot down in one sector there is always an interval of at least one shift before the miners enter the sector on the return side of the one that has been shot. Thus, the miners are seldom if ever required to work in an atmosphere containing smoke or gases resulting from the explosion of black powder.

Dangerous concentrations of CO or CO\(_2\) have been found only occasionally near gob fires in abandoned or worked-out areas. Such places are promptly sealed off, however, and the fire normally burns out within a short time.

**SANTA CATARINA**

With one or two exceptions, all mines in Santa Catarina are ventilated by natural means. Most of them are opened by drifts driven from the outercrop, and the only ventilation obtained is the small amount of air circulating naturally through these openings. Usually two or more horizontal drifts are driven into the area to be mined and are connected through the system of headings and rooms subsequently developed within the mine. As the drift mouths are usually located close to each other and at approximately the same elevation, there is little if any pressure differential between them. In many instances the only air currents within the mine are those set up by movement of the mine cars.

In the larger mines drill holes or small shafts are sunk to connect with the developed mine workings and provide additional ventilation. In these mines a motive column of air is induced by the difference in elevation of the intake and return openings, but in the mines whose only openings are drift mouths at about the same elevation and at the same location no such motive column exists, and the actual "power upon the air" is virtually nil.
In the smaller mines, where the workings are not extensive and where enough openings connect with the surface, sufficient fresh air finds its way to the face to make the atmosphere tolerable though far from ideal. As the workings are extended, however, ventilation becomes rapidly worse. Small shafts or additional openings to the surface provide some relief and establish some movement of air, but in no mine examined was ventilation satisfactory or positively controlled.

One of the larger mines used a small exhaust fan placed at a vertical shaft, but the fan ventilated only part of the mine and operated more as a booster than as a positive ventilating control for the entire mine.

Except in one or two mines, no attempt is made to control ventilation within the mine. Doors, stoppings, curtains, brattices, etc., are extremely rare. Seldom are rooms connected by crosscuts, and rarely are worked-out areas closed off with tight stoppings, particularly in the smaller mines. Crosscuts or other abandoned connecting openings outby the working areas are often left open, thereby short-circuiting whatever air happens to be present. Dead-end, single-entry headings are not uncommon. No undercasts or overcasts were observed in any of the Santa Catarina mines.

In only one or two mines could a definite and constant air course be followed throughout the workings. During mine examinations made by engineers of the Brazilian Departamento Nacional da Produção Mineral and the Bureau of Mines an attempt was made to get specific data on ventilation on which to base recommendations and suggested improvements. It was often impossible to obtain anemometer readings because of the absence of air current.

Even in mines that have a definite current of air in the main and butt headings, ventilation at the working faces in the rooms is usually poor or nonexistent; as crosscuts are seldom driven between rooms there is no circuit for the air to follow.

Fortunately, the Santa Catarina mines are not gassy. Although methane has never been detected, there is no assurance that it will not be found as mines are extended and become deeper. In general, mine atmosphere in Santa Catarina is fairly free from coal dust. The slow rate of production, use of hand methods, and absence of mechanized mining, loading, and transportation units combine to keep down the dust hazard even though no special effort is made toward dust control.

The lack of ventilation is most noticeable where blasting is done. Almost all shooting is done with black powder, and after shooting it is necessary to wait for long periods before the atmosphere at the face has cleared enough to permit the miner to resume work. Where pneumatic equipment is used the compressed-air lines are usually left open at the face after blasting to clear the atmosphere more quickly. At faces where compressed-air equipment is used the air is much fresher, and the men can work more comfortably.

In most mines measurements of air circulation had never been made, and in no mine were they taken periodically or as part of a planned system of ventilation. No mine observed followed a definite plan of controlled ventilation; mine maps, when available, did not indicate the ventilating system, and mine officials were rarely able to supply information on the quantity and quality of the air circulated in the mine.
Apparently the only criterion for ventilation in most mines was the ability of the miner to work in a place without obvious acute physical discomfort.

**PARANÁ**

The same ventilation conditions found in the Santa Catarina mines were observed in Paraná. To avoid repetition, the reader is referred to the discussion of ventilation in Santa Catarina mines, as the conditions described are characteristic of the mines in both fields.

**ILLUMINATION**

Illumination within virtually all mines is furnished by acetylene lamps carried in the hand. The biggest disadvantage of these lamps is the fact that they must be transported in the hand as the miner moves from place to place in the mines. For work within a short radius the lamp is hung from a convenient post or placed on the ground near the working area, but the light is seldom concentrated on the actual spot where the miner is working. In Santa Catarina an attempt was made to introduce acetylene cap lamps of the type used extensively in the United States, but they were not favorably received by the miners. A common complaint against the cap lamp was the weight and annoyance of wearing them on the head. Some miners complained that the carbide reservoir had to be replenished too often.

In a few mines illumination both at the face and in the haulage roads was supplied by incandescent electric-light bulbs. One longwall face was illuminated by two large electric floodlights. These are isolated examples, however, as acetylene hand lamps were used in the majority of the mines.

**MINE SAFETY**

**SANTA CATARINA-PARANÁ**

Few if any of the mining companies in Santa Catarina or Paraná have specific safety regulations or enforce observance of precautionary measures and practice through systematic inspections and penalties for infractions. Although the Brazilian Mining Code refers to safety regulations that must be observed, the references are general, and enforcement of measures considered necessary for health and safety in the mines devolves upon the National Department of Mineral Production. The State itself does not maintain an inspection service, nor does it publish official safety regulations, and the burden falls on the federal agency.

In practice, this agency does not have the personnel necessary to make systematic mine examinations, and until such a group of inspectors is available it would be difficult if not impossible to enforce safety regulations.

Few companies require underground bosses to inspect working places at specified times or intervals, and rarely must a responsible supervisor keep a written record of inspections made or conditions found. No record of a supervisor’s visit is left at the face, and it is not customary for a section or a mine to be fully inspected before a shift enters the mine.
Only in a few instances is a systematic effort made to enforce safety regulations; generally, the only precautions taken are those that the miner himself considers necessary for his own safety.

Fortunately most of the mines are small, none of them are gassy, the roof in general is good, and most mines are overtimbered rather than inadequately timbered. Hand methods of mining, slow production rates, and lack of mechanized equipment tend to keep accident rates down.

Statistics on the rate and classification of accidents were not available.

The Brazilian National Department of Mineral Production is greatly interested in developing a program for the enforcement of better health and safety regulations in the mines, including the establishment of a specific health and safety code. Action has been hampered by the limited number of field personnel, and until it is possible to build up a competent corps of mine inspectors the approach to the problem must necessarily be rather academic. It is hoped that the program can be advanced more rapidly in the near future.

PREPARATION PRACTICE

RIO GRANDE DO SUL

The established coal-mining operations of Butiá and Arróio dos Ratos in the northern part of the Rio Grande do Sul coal-mining region are equipped with modern coal-preparation plants of American design. The coals produced in this area, while very well suited for domestic use as railway and industrial fuel, contain a high proportion of ash in the raw run-of-mine state and are relatively difficult to prepare. Hence, it has been necessary to install efficient well-equipped preparation plants to process this coal for use. Typical bed sections (fig. 3, p. 17) indicate the difficult nature of these coals interbedded in place with many bands of slate and carbonaceous material that contaminate the fuel in the underground mining operations.

PREPARATION CHARACTERISTICS OF THE COAL

Investigation of the preparation characteristics of these coals by the Laboratorio da Produção Mineral in cooperation with the mission of the Bureau of Mines showed the washery feed to be of a very bony nature carrying a large proportion of near-gravity material at any washing gravity that might be attempted. Typical washability data of a sample of the raw coal processed in the washery at Arróio dos Ratos (São Jeronimo) are shown on pages 49 to 51, Brazilian D. N. P. M. Bulletin 13.7

PREPARATION AT BUTIÁ

Figure 25 shows the flow sheet of the coal-preparation plant at the Butiá mine. This plant was built in three different stages, the initial stage providing a screening plant only for separating the moinha or

slack size from the lump coal adapted to railway use. Later a picking-table plant was added, and in the third stage of construction a modern Baum-jig washyery designed and built by the McNally-Pittsburgh Manufacturing Corp. was installed.

In this modern plant the run-of-mine coal is discharged to a distributing feed hopper, from which it is fed uniformly to three shaking-screen picking-table units. The products from these units are: (1) The moinha, smaller than 20 mm.; (2) first-grade plus-20-mm. picked coal; and (3) the rock rejected by the pickers working at the picking-table sections of these combination units.
The moinha is conveyed to concrete storage bins, and from these bins it is loaded into railway cars. The coarse hand-picked plus-20-mm. coal was stored in loading bins in the original plant, and from these loading bins it was loaded into railway cars for shipment. The picking-table refuse is transported by a belt conveyor to a pit-car loading bin. It is then loaded into cars operated on an endless-rope haulage system for final disposal. The refuse is subjected to a secondary inspection and picking operation on the conveyor, and the coal thus recovered is added to the first-grade hand-picked coal for shipment.

When the washing-plant addition was erected in 1943 the following major facilities were provided: (1) A vertical pick breaker to reduce the hand-picked lump coal to smaller size for washing; (2) a conveyor and shaking picking table for hand-picking the broken lump coal; and (3) a McNally-Pittsburg Baum-jig washing unit. These additional facilities are shown in the flow sheet (fig. 25) and designated cruiser, picking table, conveyor table, wash box, and dewatering screen. From the pick breaker the broken coal passes to the secondary picking table, where it is separated into moinha (through 20 mm.), picked coal (200 by 20 mm.), and secondary refuse. The moinha and the picked coal may go to storage bins or to railway cars directly. The refuse is loaded into side-dump cars. The picked coal, 20 by 200 mm., from the secondary picking tables may be loaded into railway cars for shipment, or it may be transferred to the Baum-jig washing plant for further treatment, depending on the market requirements.

With the installation of the Baum washing plant shown in figure 26, the scraper conveyor T1, which takes the picked lump from the main shaking screen to the pick breaker, was arranged so that the return may be used to convey the crushed coal from this breaker to the washing plant. To do this it discharges the crushed coal to the top run of conveyor T2, which also receives the moinha from the main
shaking screen through the upper run of conveyor T4. These conveyors deliver the moinha and crushed coal from the pick breaker to concrete storage bins at the ground level. The bins are washer regulating bins having a total capacity of 60 tons. They also can be used to receive coal from other openings of the property besides the No. 5 slope, where the preparation plant is located. This foreign coal comes to the plant in dump-type railway cars.

The regulating bins discharge coal by means of two automatic reciprocating feeders with a wide range of speed settings. The feeders deliver to conveyor T3, which transports the coal to a double-roll crushe or the primary crushe of the washing plant. The crushe reduces the washery feed to 100-mm. top size and delivers the crushed product to the lower run of conveyor T2, which carries it to vibrating screens that separate the coal at 40 mm. The 40-mm. by 0 size is delivered to the McNally-Norton Baum-jig washing unit, and the oversize goes to a secondary double-roll crushe, where it is crushed to 40-mm. top size and joins the feed to the wash box.

This washing unit handles raw coal at the rate of 60 metric tons per hour. The wash box is adjusted to deliver three products: (1) Heavy pyritic refuse, (2) light shale and bony refuse, and (3) washed coal. The washed-coal product is sluiced with the wash water to a reciprocating dewatering screen jacketed with 1½-mm. wedge wire. The sludge and water through this screen is collected in a settling tank, and the overflow water of the settling tank is recirculated to the washery head tank to supply the wash box with wash water. The sludge recovered by the scraper line of the settling tank is discarded.

This washing plant takes the raw coal containing 40 to 50 percent ash and can deliver a washed product to meet the standard of 29 percent ash in railway and industrial fuel.

PREPARATION AT ARRÔIO DOS RATOS

At the Arrôio dos Ratos operations of CADEM the coal-washing plant is at No. 5 slope, but facilities are provided also to receive coal transferred on the surface from other openings. This is a modern Baum-jig washery of American design and manufacture. A photograph of this plant is shown in figure 27 and the flow sheet in figure 28. The run-of-mine coal from No. 5 slope is brought to the surface on a belt conveyor that delivers to the upper end of the main shaking screen in the preparation plant. This screen makes a three-product separation: (1) 1½-inch screenings, (2) 3- by 1½-inch nut, and (3) 3-inch lump. The screenings and the nut are discharged by shaking chutes, attached to the screen, upon a conveyor that delivers to two parallel shaking picking tables. The 3-inch lump coal divides into two streams; half of it is picked on the blank-plate picking section of the main shaker, which is a combination screen and picking-table unit, and the other half is delivered to a separate picking table. Hence, there are four picking tables in all, two for the small coal and two for the lump sizes. The picked lump coal goes by the upper run of conveyor T2 to the primary breaker, a double-roll toothed crushe similar to that in the washing plant at Butiá; the crushed coal from this breaker returns by the lower run of the conveyor to the washing plant. The picked coal from the nut and slack picking tables
joins this crushed coal on the lower run of the conveyor, and the combined product passes to a vibrating screen with 40-mm. openings. The 40-mm. undersize is ready for washing, but the oversize is transferred to the secondary single-roll crusher, which reduces it to approximately 40 mm. and delivers to the lower run of conveyor $T_3$, which transports the crushed product to the feed hoppers of the washing plant. The flow of coal from these feed hoppers is regulated by an adjustable gate.

These hoppers constitute the regulating mechanism that delivers the feed to the wash box at a uniform rate. The feed coal is carried from the bins to the wash box by a belt conveyor and flushed into the box by a jet of water in the feed sluice.

![Diagram of Arrôio dos Ratos washery](image)

**Figure 28.—Flow sheet of Arrôio dos Ratos washery.**

The wash box at Arrôio dos Ratos is similar to that at the Butiá plant but can handle raw coal at the rate of 80 tons per hour. It delivers three products—heavy refuse, intermediate refuse, and washed coal. The washed coal is sluiced with the overflow jig water to a shaking dewatering screen with a ⅛-mm. wedge-wire cloth. The washed coal after dewatering goes by conveyor $T_5$ to the storage bins and is loaded into railway cars.

The water and sludge from the washed-coal dewatering screen is collected in a settling tank from which the solids, recovered by a scraper conveyor, are wasted, and the water returns to the circulating system for re-use in the washing plant. Handling the raw coal (ash content, 40 to 50 percent) from the Arrôio dos Ratos mine, this plant can deliver the standard washed-coal product designated No. 290, which by specification carries an ash content of 29 percent. The
washed coal may be screened into several grades such as (1) 12-, 14-, or 15- by \( \frac{1}{2} \)-mm. screenings (the washery sludge is not remixed with the fine washed coal); (2) 40- by 15- or 12-mm. size; (3) mixed 40-mm. by 0 size; and (4) a grade called Energia, a mixture of 40- and 12-mm. screen sizes. Arrangements also are made by which raw coal may be loaded directly into railway cars for shipment.

**SANTA CATARINA**

In the early exploitation of the Barro Branco bed the object of preparation was to produce a fuel suitable for railway locomotives and for general industry by removing the several impurity bands in the bed. Typical bed sections are shown in figure 4 (p. 20). In mining operations it has been the universal practice to take out and discard the middle parting band of the bed, locally called the Barro Branco, and the quadracão before mining the coal benches, “foro” and “banco,” above and below, respectively. By careful hand mining the coal can be taken down virtually without contamination by roof or floor material; but, even by this method of working the raw coal is delivered to the surface with a large proportion of slate and bony material derived from the many narrower bands of impurities within these two benches of coal.

The separation of coal from impurity is difficult because of the bony interlaminated structure of the impurity bands. In sizes suitable for commercial use the material is not well broken apart; there is relatively little pure coal in dirt-free particles.

In the pioneer coal industry of the State, which was organized in relatively small producing units, it was the general practice to prepare the nut-size coal for the industrial market by carefully hand-sorting the raw coal, literally inspecting it piece by piece, and hand-spalling the larger lumps to separate the slate from the coal. A few of the more-pretentious plants were equipped to do this work with jigs; but more commonly mechanical treatment was applied to the fine coal screened out of the run-of-mine during the hand-sorting operation.

The Barro Branco coal thus yielded a small hand-picked egg-sized product suitable for hand-fired locomotives and a washed moinha from tables or hand jigs especially adapted to use in the gas plants at Rio de Janeiro and São Paulo. The coal as shipped commonly carried 25 to 30 percent ash in the egg size and 16 to 20 percent in the washed moinha.

The wartime development of a coke-fueled national iron and steel industry utilizing Santa Catarina coal brought about a complete re-orientation of the coal industry of the State, at least with respect to the preparation, marketing, and utilization of the product.

To provide coking coal for the new steel industry, it was necessary to enlist the entire producing industry of the State in a cooperative effort to supply metallurgical fuel. A central modern preparation plant has been erected at Tubarão, and virtually the entire production of the coal field has been harnessed to that plant by government decree. In this central plant the coal is cleaned and separated into two grades: (1) A metallurgical coal containing relatively little ash and sulfur, which goes to the steel plant at Volta Redonda; and (2)
a secondary coal containing more ash to be used for general industrial fuel. The multiple-product operation is dictated by the fundamental preparation characteristics of the coal. To produce a metallurgical coal as low even as 18 percent ash content, it is necessary to remove from the raw material large proportions of refuse material of substantial fuel value, and the only way to salvage this combustible and to establish an economically feasible operation is to market this intermediate material separately as a secondary fuel suitable for industry.

With this realignment of the industry, preparation at the mines has come to be a mere preliminary conditioning of the run-of-mine coal before shipment, and there is not as yet any universally accepted definite idea of the economy of such a preliminary conditioning treatment. Hence, the coal currently moving from the mines to the preparation plant varies widely in refuse content. This matter of precleaning at the point of origin is one of the important problems in the industry; it is primarily a question of relative economy, balancing of individual mine preparation costs against the costs of transporting and handling rock to and in the central plant. Only when the total production of the field overtakes the total demand of the steel industry for coking coal can the direct production and preparation of general-purpose industrial and railroad fuel again become a factor in the Santa Catarina coal field.

The long-term aim in the development of a coal-preparation program must embrace these three objectives: (1) Evolution of an effective process to obtain the optimum yield of low-ash coking coal; (2) development of a low-cost simple technique for rejecting the clear refuse at the point of origin; and (3) the mechanical preparation of industrial coal to become active after the total production passes 1½ million tons per year.

PREPARATION CHARACTERISTICS OF THE COAL

The Barro Branco coal, which to date has furnished the bulk of Santa Catarina production, is a very difficult coal to clean, judged by typical specific-gravity consist data. The specific-gravity consist constitutes the conventional means of appraising coal-washing problems. Figure 29 is a chart showing the washing characteristic of a typical example of the Barro Branco coal; it gives the composite specific-gravity consist of two samples taken in the Criciuma field in the course of early investigation of the washing problem. These were face samples representing the entire minable bed, excluding the quadração, which is always rejected in mining. Basic data for projecting such a chart of the washing characteristics of a coal sample are obtained by the float-and-sink test.

FLOAT-AND-SINK TEST

The float-and-sink test is a laboratory technique for breaking down a coal sample into specific-gravity increments to show what may theoretically be accomplished by washing the coal by a method that

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Figure 29.—Chart showing washing characteristics of a typical sample of Barro Branco coal.
separates the coal from the refuse by difference in specific gravity of the particles.

The float-and-sink test is very simple. It consists in just immersing the sample of broken coal in a bath of some heavy liquid, skimming off the light particles that float on the liquid and then recovering separately the heavy particles that have sunk to the bottom. This unit operation separates the sample into two fractions—the “float” consisting of all the particles lighter than the liquid and the “sink” fraction consisting of all the particles heavier than the liquid.

The float represents the washed coal that would be obtained if a perfect job of washing the coal could be done exactly at the test gravity. The sink represents the perfect refuse. But since at the beginning of a preparation study the gravity or gravities most suitable for washing any given coal are not known, it is necessary to use a series of bath liquids of different specific gravities to break down the samples into a series of specific-gravity fractions ranging from the very lightest low-ash particles through certain uniform-gravity steps to the category of heavy, pure-refuse particles.

Such a series of separations is made in one continuous operation by use of a series of vessels of test liquids arranged in descending order of specific gravities, 1.60, 1.50, 1.40, 1.37, 1.35, etc.

The sample is first introduced into the heaviest liquid (1.60). After settlement, the float particles are skimmed off, drained, and transferred to the next lighter liquid, and the sink particles remain in the bottom of the first vessel. The float particles of 1.60 specific gravity and lighter, being now in a liquid of 1.50 specific gravity, will again be divided into two fractions. The 1.50 float particles will be skimmed off, drained, and transferred to the next lighter liquid (1.40), and the sink particles, which will have a specific gravity of 1.50 to 1.60, will remain in vessel No. 2.

This process of transferring and refloating the float product is continued progressively to the light end of the series, where the 1.25 float skimmed off the last vessel becomes an end fraction. The other fractions, each having a closely limited specific-gravity range, are distributed in the vessels. When all these fractions are separately recovered from the liquids, weighed, and analyzed the result is the series of basic data shown in the first five columns of the table.

The cumulative data are then computed from these elementary observed data by a simple statistical operation.

Interpretation of float-and-sink data.—From the cumulative data, which are shown in graphs adapted to interpolation in the chart above the table, one may read the yield and ash content of the float product that might be obtained by complete separation at any desired specific gravity. The distribution of the coal in the specific-gravity fractions is significant in appraising the difficulty of effecting precise gravity separation. Obviously, the ideal easy washing condition would be furnished by a raw coal in which all the material is concentrated in two specific-gravity fractions, the lightest of which is pure coal and the heaviest pure rock, leaving nothing in between in the intermediate-gravity fractions.

The difficulty of cleaning the Barro Branco coal is measured by the wide distribution of the material with respect to specific gravity and the very small proportion in the lightest fractions that carry the
really pure coal. The intermediate fractions consist of combined coal and dirt particles. The dominant characteristic of the Barro Branco coal is a very large proportion of this mixed material. The relationship of this characteristic to the difficulty of washing is made much more apparent when the data are arranged in the form of a specific-gravity consist chart showing only the elementary breakdown of the sample.

Figure 30 is such a specific-gravity consist chart of the coal represented by the washability chart, figure 29. In this section horizontal sections across the chart represent specific-gravity fractions as designated along the left margin, and in each such specific-gravity layer the shaded area represents the percentage of the sample in that specific-gravity fraction. Compare this chart of the Barro Branco coal with the theoretically perfect coal chart of figure 31, and the fundamental difficulty of washing the Barro Branco coal is obvious.

One could not expect to find in nature a perfect coal such as shown in figure 31, but there are many easily washed coals such as illustrated by the consist charts of an English coal and a typical easily washed American coal shown in figure 32. Such a coal may be readily separated into a clean-coal product and a clean-rock product, whereas the Barro Branco coal obviously has no definite concentration of particles in either of these categories. This fundamental characteristic explains the basic necessity of the multiproduct separation being attempted at the central washing plant.
The washery can only separate the raw-coal mixture into groups of like particles with respect to specific gravity and ash content. Hence, the Barro Branco coal can be expected to yield at the very best only a small proportion of low-ash coal. Figure 29 shows 25.4 percent of float coal at 16.0 percent ash content (see the cumulative figures for percent weight and percent ash, third line); 51.5 percent is refuse heavier than 1.60 specific gravity carrying 60.1 percent ash. The remaining 23.1 percent of the in-between material ranging in specific gravity from 1.45 to 1.60 cannot possibly be salvaged in any other way than to separate it out as a secondary high-ash fuel product. In this particular sample the average ash of this product would be 28 percent if perfect gravity separation were obtained. The practical job of washing coal is simply a matter of obtaining an approximate duplication of this separation on an industrial scale.

With the central washery boiler-plant installation at Tubarão, it may be feasible to recover and use even a third fuel product consisting of the lowest ash part of the 1.60 specific-gravity sink material. The 1.60 to 1.80 specific-gravity fraction has some fuel value, which may be used with profit in the local power plant where virtually no transportation charge is entailed in getting it to the point of consumption.

In another more or less typical sample, on which the float-and-sink separations were carried to 1.80 specific gravity (fig. 38), 11.3 percent of the run-of-mine material is in the 1.60 to 1.80 specific-gravity range, and its average ash content is 38 percent. A fuel of this grade can sometimes be used economically to raise steam.
Figure 33.—Washability curve of Barro Branco coal from Alvaro Calão mine.
The efficiency of the washing operation on a coal of this character depends on precision of control in making the specific-gravity separation, and the operation is most sensitive to maladjustment in the low-gravity-separation range. Referring again to the float-and-sink chart, figure 29, one may observe that the 1.45 specific-gravity separation required to make a washed coal of 16.0 percent ash content must be made where there is a maximum of near-gravity material. Minor variations in the actual washing level will therefore make a big change in the yield and quality of the washed product.

The usual practice is to appraise the difficulty of a coal-washing project by the measure of the near-gravity material shown by the float-and-sink data. In studying these factors Bird has set up a tentative scale of relative washing difficulty based upon the amount of near-gravity material in the range of 0.10 point below the washing gravity to 0.10 point above the washing gravity or, with respect to the Barro Branco coal (fig. 29), between 1.35 and 1.55 specific gravity when considering the separation of 1.45 specific gravity to obtain a metallurgical washed coal of 16.0 percent ash content. The sample in question has 37.3 percent of the material in the near-gravity range. In Bird's table of relative difficulties, reproduced in table 5, observe that this figure puts the coal in the most-difficult category, actually beyond the range that would commonly be rated as responsive to washing treatment. Hence, the development of a plant to operate economically on this coal is a job of the utmost technological difficulty.

Supplementary separations at the higher gravities to recover the second- and third-grade fuel products from the refuse, while representing a somewhat smaller measure of near-gravity material, are nevertheless extremely difficult. Therefore, even the best coal-washing equipment currently available may not approach closely the theoretical performance indicated by the float-and-sink separations.

The ultimate solution of the problem is a major job of engineering research.

One expedient sometimes used to improve the specific-gravity consist of a coal for washing purposes is to crush the lumps to smaller size so that the mixed components may be more completely broken apart.

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FIGURE 34.—Washability curve of Barro Branco coal crushed to %-inch top size.
The advantage gained by finer crushing of the Barro Branco coal is indicated in figure 34, which gives the washing characteristics of an approximate duplicate of the sample shown in figure 29 but crushed to 3⁄4-inch top size. At this size the yield of float coal containing 16.0 percent ash is 32 percent, whereas at 11⁄2-inch top size (fig. 29) the yield is only 25 percent. However, this yield advantage is offset in some measure by the greater cost of handling and cleaning fine coal in the washing plant. There is also a definite loss in use value of the product due to the fine size of the fuel, particularly for general industrial purposes in hand-fired burning equipment. Hence, the economy of fine crushing to improve the washing characteristics is a matter of judgment based upon these several factors.

The Barro Branco coal is remarkable with respect to sulfur reduction by washing. Although the raw coal as mined may contain as much as 12.0 percent sulfur, this percentage is readily reduced to 1.5 or less by washing because the sulfur content of the coal in place is concentrated in relatively coarse pyrite particles. For this reason sulfur control is not the insurmountable problem that might have been anticipated, considering the raw-coal sulfur content. However, the float-coal sulfur runs near the generally accepted tolerance for sulfur in metallurgical fuel. The sulfur analyses must be watched carefully in the control of metallurgical coal preparation.

**RIO BONITO COAL**

Although the Rio Bonito coal has been generally known for many years, it has not been extensively developed or even explored. No specific information on the preparation characteristics of this coal is available. The interlaminated structure of the bed indicates that, however it may be mined, it will contain a large proportion of incombustible material. The difficulty of the operation required to separate the pure coal from this associated refuse can be appraised only by thorough examination of representative samples. Float-and-sink tests to obtain specific-gravity consist data would indicate probable washing performance. Such a field study of the Rio Bonito bed has been initiated by the Departamento Nacional da Produção Mineral at the Criciuma Experiment Station.

Some small areas of coal are now being opened up and worked in the Rio Maina area north of Criciuma that are nominally referred to by the trade as the Rio Bonito coal, although the actual identity of the deposits and their relation to the major beds, Barro Branco and Rio Bonito, are questionable.

The coal is now being worked by Companhia Metropolitana at its Rio Bonito and Dom Pedro Segundo mines. It is shipped to the central washery at Capivarí and apparently washed successfully in the general plant feed mix; but, up to the present time, the proportion of this coal has been too small to greatly affect the average plant performance.

The general appearance and structural features of this coal are very similar to those of the upper part of the Barro Branco, and the average ash of the coal as mined is reported to be somewhat less than the Barro Branco average. Washability tests now being conducted will throw more light on the suitability of this coal for the preparation of metallurgical fuel.
PIONEER PREPARATION PRACTICE

In the early coal industry of Santa Catarina, where desultory operations are reported late in the nineteenth century, the coal, trammed from the mine workings by hand, was prepared for use by a sequence of small-scale cleaning and handling operations, all carried out manually on an individual piecework basis. The intricately interlaminated structure of the coal necessitated piece-by-piece examination and parting of the material; this laborious operation was facilitated by the small-scale operations and by low-cost labor, adept at manual work.

Although the total production of the State increased very rapidly during the war, the organization of the industry into small producing units persisted, and today much of the coal is handled at the mine in substantially the same pioneer manner. A few very simple facilities were developed to coordinate the whole operation into a routine sequence of some 8 to 12 individual and very simple manual operations that finally carried the coal from the pit mouth to the railway car. This routine became fairly well standardized in the Santa Catarina producing region. The facilities, which grouped together may be called the mine surface plant, consisted of a series of parallel tracks for hand-trammed cars flanked by rows of small stationary screens and picking tables; the whole articulated in such a manner as to facilitate the many manual handlings in substantially the following sequence: (1) Hand tram from pit to surface plant; (2) shovel run-of-mine coal from pit car to ground alongside; (3) cast run-of-mine coal to inclined stationary screen by hand; (4) shovel oversize coal to stationary picking table; (5) shovel undersize coal (moinha) to hand-trammed car spotted on track between mine-car track and picking tables; (6) hand-sort and break apart coal and refuse on table, throwing refuse on ground alongside; (7) carry hand-sorted coal (escolhida) to car or loading bin; (8) shovel refuse from ground to tram car; and (9) tram refuse to dump by hand. Usually each of these operations is performed by a separate group of workers, and each individual is paid on some piecework basis.

TYPICAL HAND-PREPARATION PLANT

A typical surface plant of this type is shown in figure 35. This plant is at the Mato mine of Companhia Brasileira Carbonifera de Araranguá near Criciuma. It is now being operated as a preliminary preparation operation, producing about 200 tons a day of the lavador-grade coal, which later moves to the Capivari washery for final preparation. During one of the field surveys conducted by the D. N. P. M. and the Bureau of Mines a study was made to ascertain the effectiveness of hand-picking operations at this plant.10

The run-of-mine coal mined and loaded by hand at the face is trammed by hand over the run-of-mine loaded track to the preparation plant. Wide, low, wooden cars of 600 to 1,000 kilos capacity are used, and tramping to the outside is done by the miners' helpers. They also shovel the coal onto the ground in the area between the

Figure 35.—Hand-preparation plant at Mato mine.
run-of-mine track and the screens and push the empty cars back to the working places.

In the preparation plant the run-of-mine coal is shoveled by hand upon the inclined wire-cloth screens, and the oversize that collects on the ground at the end of the screen is shoveled by hand onto the adjacent picking tables. This work of screening and transporting oversize to the tables is done by the same group of workmen.

Another group shovels the slack from under the screens to hand-pushed cars on the slack track and trams these cars to the slack storage pile or truck-loading station.

The pickers work at the picking tables on the opposite side from the screens. The picking tables are just stationary, long wooden tables of convenient height housed in open sheds. The pickers sort over the coal on the tables and collect the clean coal in wooden boxes of about 20 kilos capacity, which they carry to the inspection stations on the clean-coal loading track. The raw coal is not only sorted over piece by piece, but mixed pieces are broken apart by small hand picks during the table sorting. The final picked-coal product is the size of about 4-inch egg and nut.

At the inspection station the box of clean coal is emptied into a tram car spotted there; the quality of the contents is checked by the inspector, who then gives the picker a metal counter which she can cash at the pay office. When the car is filled it is pushed by hand to the railway car loading station.

During the picking operation at the tables the reject material is thrown onto the ground between the tables and the refuse track. At some installations this material is sorted over again by a small group of pickers before it is shoveled into cars on the refuse track for hand tramming to the refuse dump.

Women and girls have generally been more adaptable than boys to the work of sorting and inspecting the coal; virtually all the workers in these classifications are girls. This operation is done on a piecework basis. The scale in the Criciuma area is 3.5 cruzeiros (approximately 17.5 cents) per metric ton of clean coal delivered. The inspectors are paid 7.000 cruzeiros per day, which amounts to about the average earnings of good steady pickers.

The individual pickers generally work independently, but at a few plants they work in pairs and together carry the picked coal to inspection stations.

The output of individual pickers varies greatly. Typical labor breakdown at one of these plants is shown in table 6.

**Table 6.—Labor breakdown at hand-preparation plant during a period in which 1,388 tons of run-of-mine coal was handled**

<table>
<thead>
<tr>
<th>Operation</th>
<th>Total man-hours</th>
<th>Man-hours per metric ton of R. O. M. coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Coal discharged to ground by mine labor</td>
<td>1,948</td>
<td>1.29</td>
</tr>
<tr>
<td>2. Screening and shoveling</td>
<td>385</td>
<td>0.29</td>
</tr>
<tr>
<td>3. Transporting slack</td>
<td>7,150</td>
<td>4.74</td>
</tr>
<tr>
<td>4. Picking coal</td>
<td>571</td>
<td>0.37</td>
</tr>
<tr>
<td>5. Waste disposal</td>
<td>1,300</td>
<td>0.86</td>
</tr>
<tr>
<td>6. Tramming picked coal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>11,354</td>
<td>7.52</td>
</tr>
</tbody>
</table>

1 Charged to mining operation.
Sorting these coals by hand is very arduous work, requiring constant painstaking attention as the coal matter is so intermixed with schists that almost all the lumps must be broken up to free the coal from the refuse. This characteristic of the raw coals is indicated in figure 36, which shows the specific-gravity consists of some of these

![Specific Gravity Charts](image)

Figure 36.—Specific-gravity consist charts of several types of coal.

coals compared with typical American raw coals. The Brazilian coals contain much more refuse and mixed particles of intermediate specific gravity than even our most-difficult bony coals, such as those of Bellingham, Wash.\textsuperscript{31} Hand cleaning of such a coal requires much labor. In the early fixed-table plants the throughput per picking-table worker is only 1 to 2 metric tons per 10-hour day; even in the experimental, partly mechanized plant recently developed in the expansion program this has been increased only to 3 to 4 tons.

The importance of hand preparation as a labor user in this kind of production set-up is shown by the breakdown of total mine workers

for the Criciuma-Uruussanga district given in table 7. This tabulation shows all registered workers in the area; hence, it does not reflect exactly the operational breakdown of employees actually working at any given time. However, it is significant in that it shows roughly the relative importance of the various classes of operations in an all-manual organization of the industry.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miners</td>
<td>1,010</td>
<td>16.5</td>
</tr>
<tr>
<td>Miners' helpers</td>
<td>1,506</td>
<td>25.7</td>
</tr>
<tr>
<td>Car pushers</td>
<td>254</td>
<td>4.1</td>
</tr>
<tr>
<td>Day men</td>
<td>1,710</td>
<td>28.1</td>
</tr>
<tr>
<td>Coal pickers (women)</td>
<td>1,227</td>
<td>20.1</td>
</tr>
<tr>
<td>Foremen</td>
<td>75</td>
<td>1.3</td>
</tr>
<tr>
<td>Truck drivers</td>
<td>59</td>
<td>1.0</td>
</tr>
<tr>
<td>Picked-coal inspectors</td>
<td>56</td>
<td>.9</td>
</tr>
<tr>
<td>Carpenters</td>
<td>93</td>
<td>1.5</td>
</tr>
<tr>
<td>Bricklayers</td>
<td>24</td>
<td>.4</td>
</tr>
<tr>
<td>Blacksmiths</td>
<td>29</td>
<td>.5</td>
</tr>
<tr>
<td>Total</td>
<td>6,105</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Approximately 20 percent of all the listed mine workers are picking-plant operatives, and roughly half as many more are engaged in shoveling, screening, and transporting material on the surface (tramm ing of refuse, picked coal, and raw slack) and as inspectors and overseers; so that around 30 percent of all registered mine employees are engaged in preparing and handling coal on the surface.

The situation presents an excellent opportunity to determine the effectiveness and cost of intensive hand-sorting of materials, which is a very common operation where low-cost labor is available. Such studies have been made at three operating plants in the Criciuma region. This program was undertaken to appraise the value of continuing the hand-picking operation at the mines as a roughing operation before shipment of the coal to the central washery at Tubarão.

The three plants at which performance tests were made are: (1) Mina do Mato plant of Companhia Brasileira Carbonifera de Araranguá; (2) Alvaro Catão plant at Bainha mine of the same company; and (3) Pio Correio plant of Sociedade Carbonifera Prospera.

Mina do Mato and Pio Correio are typical manually operated plants of the prewar class, although the two are somewhat different in organization. Bainha is the experimental plant developed by the F.E.A.-D.N.P.M. program to speed up production.

All these plants are handling hand-mined coal from Barro Branco bed in the Criciuma area. The raw run-of-mine coal as it is delivered to the preparation plant characteristically carries around 1.5 to 2.0 percent moisture, 35 to 40 percent ash, 22 percent volatile matter, 40 percent fixed carbon, and 7 to 10 percent sulfur.

BAINHA PLANT

At the Bainha plant of Companhia Brasileira Carbonifera de Araranguá a combined preparation and loading plant has been
erected to improve hand-preparation practice and speed up production by eliminating some of the steps of manual handling in the older designs.

Figure 37 is a sketch of the Bainha plant arrangement. The raw run-of-mine coal from the nearby Alvaro Catão mine and from the foreign-coal bins is trammed by hand to the dump tracks over the raw-coal bins. Here the side-dump cars discharge the coal into the bins below.

On the picking-table floor the girls stand beside the inclined screen picking tables and draw the coal out over the tables by hand. The tables are set at such an angle that the coal will not quite run by gravity, but it is easily raked down by hand. There are also manually controlled bin gates at the feed ends of the tables.

As the coal travels over these tables, the slack passes through the wire cloth on the deck, and the coarse coal is broken by hand picks
Figure 38.—View of Bainha picking plant.
and sorted. The good coal is raked over the end of the screen to the measuring box (100 kilos capacity) below, and the refuse is pushed into the open chute at the center of the table. The slack and stone are thus delivered by gravity to the loading hoppers below.

The picked product is checked in the measuring box by the inspector, who goes from table to table in the plant. After inspection the contents of the boxes are dumped into the clean-coal bins below by an easily operated tilting device. The inspector issues the counters to the picking crews that work at the several tables.

The end products are delivered to the railway or to storage by trucks that are loaded by manually operated gates in the clean-coal, slack, and refuse bins.

In this plant the material moves entirely by gravity from the pit-car dumping point to the trucks, and obviously there is a very large saving in manual labor by omitting the intermediate handling operations. Supervision and inspection are also simplified as compared with such work in the older type of plant, and the work of picking the coal is much less arduous, mainly because no boxes are carried to the check stations. Figure 38 shows this plant.

**PERFORMANCE AND COST DATA**

There is some question of the effectiveness of the cleaning operation in this plant as compared with the older method, owing to faster handling of material over the tables and limiting inspection to the top surface of the coal deposited in the measuring boxes. However, careful study of operations at the three plants named showed almost identical cleaning results at the two types of plant. Performance data shown by a typical shift-long test of each type of plant are given in table 8.

<table>
<thead>
<tr>
<th>Product</th>
<th>Weight</th>
<th>Impurities, percent</th>
<th>Ash, percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tons</td>
<td>Percent</td>
<td></td>
</tr>
<tr>
<td>Bainha plant:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R. O. M. (raw)</td>
<td>751</td>
<td>100.0</td>
<td>44.6</td>
</tr>
<tr>
<td>Picked coal</td>
<td>408</td>
<td>54.3</td>
<td>35.9</td>
</tr>
<tr>
<td>Refuse</td>
<td>143</td>
<td>29.1</td>
<td>80.1</td>
</tr>
<tr>
<td>Slack (raw)</td>
<td>200</td>
<td>26.6</td>
<td>45.0</td>
</tr>
<tr>
<td>Mina do Mato:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R. O. M. (raw)</td>
<td>1,568</td>
<td>100.0</td>
<td>46.3</td>
</tr>
<tr>
<td>Picked coal</td>
<td>912</td>
<td>60.8</td>
<td>35.8</td>
</tr>
<tr>
<td>Refuse</td>
<td>325</td>
<td>21.6</td>
<td>72.3</td>
</tr>
<tr>
<td>Slack</td>
<td>270</td>
<td>17.9</td>
<td></td>
</tr>
</tbody>
</table>

Incomplete data on another plant where the breakdown between clean coal and refuse has not yet been obtained shows a similar reduction in ash by the picking operation. In this case the ash content of the coal was reduced from 42.5 to 38.6 percent, and the rejected material analyzed 63.6 percent ash. This also was a plant of the hand-sorting type.

Labor breakdown at the Bainha plant is shown in table 9.
TABLE 9.—Breakdown of labor at the Bainha plant during a period in which 751 metric tons of run-of-mine coal was handled

<table>
<thead>
<tr>
<th>Operation</th>
<th>Total man-hours</th>
<th>Man-hours per ton of R. O. M. coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tramming to pit-car dump charged to mine:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Picking</td>
<td>1,424</td>
<td>1.90</td>
</tr>
<tr>
<td>Inspection</td>
<td>120</td>
<td>.16</td>
</tr>
<tr>
<td>Supervision</td>
<td>120</td>
<td>.16</td>
</tr>
<tr>
<td>Total</td>
<td>1,664</td>
<td>2.22</td>
</tr>
</tbody>
</table>

Comparative labor costs with the two methods of operation are shown in table 10, covering operating records of the Bainha plant and a typical hand-sorting plant of the type shown in figure 35.

TABLE 10.—Comparative operating-cost data, unit costs in cruzeiros per metric ton of picked coal

<table>
<thead>
<tr>
<th>Operation step</th>
<th>Bainha</th>
<th>Mato</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picking operation only</td>
<td>3.50</td>
<td>3.50</td>
</tr>
<tr>
<td>Screening</td>
<td></td>
<td>2.00</td>
</tr>
<tr>
<td>Transporting coal, slack, and refuse to stock</td>
<td></td>
<td>2.00</td>
</tr>
<tr>
<td>Inspections</td>
<td>0.19</td>
<td>0.33</td>
</tr>
<tr>
<td>Supervision</td>
<td>0.38</td>
<td>0.20</td>
</tr>
<tr>
<td>Total cost</td>
<td>4.07</td>
<td>8.03</td>
</tr>
<tr>
<td>Metric tons picked coal per picker per hour</td>
<td>0.34</td>
<td>0.15</td>
</tr>
</tbody>
</table>

1 This operation is on a piecework basis at 3.50 cruzeiros per ton of picked coal by both methods—at present rate of exchange the cruziero is equivalent to approximately 5 cents.

Obviously, the principal saving is in the elimination of manual handling of material through the plant, but there is also a better than 100-percent speed-up in throughput per picking-table operator, which greatly facilitates expansion in the rate of production. There is also a saving in overhead costs, although no direct change has been made in the piecework scale for the picking operation itself.

The throughput per unit of labor in these plants appears very small as compared with American picking-table practice; but considering that virtually every piece of coal and refuse is actually handled by the picker in much the way that the picker handles refuse pieces only in common American practice, the quantity of material handled per man-hour is not greatly out of line with such fragmentary data as are available on picking-table performance here on nut and egg coals.

At the hand-handling plant, where the picker sorts the coal and carries it to the check station, the material handled by each operator averages 1.7 tons per 10-hour day, and at the Bainha plant the average is 4 tons.

EARLY WASHERY PLANTS

The earliest form of mechanical aid in coal cleaning used in the Santa Catarina field was the hand-operated jig. These jigs were used rather extensively in the prewar period to wash the moinha that passed through the screens in the sorting plants. It was common practice to tram this fine coal from the screens to a separate plant site, where
the coal was shoveled by hand to the jig and the washed product was
rehandled, again by hand, to loading bins or to trucks for delivery to
the railway car. Three men working 10 hours can handle and wash
about 2 tons of coal with one of these machines. When the workmen
become skilled operators so that they can sense the optimum condition
with respect to stroke and water supply, they can produce a washed
coal equal to that from washing tables or fine-coal jigs. Washed coal
containing 14 to 16 percent ash is often shipped from these small oper-
ations. Jigs were used to prepare coal for the gas plants of São Paulo.
However, domestic coal for this use now comes from the central wash-
ery at Capivari, and the product of local washeries goes into the
general feed to that plant.

The earliest mechanical cleaning plant that may be considered the
forerunner of modern coal-preparation practice in the field was the
Schuchterman and Kremerbaum jig washery of Companhia Carboni-
fera de Urussanga. This plant, built in the early twenties to prepare
the two distinct types of coal from the Río America and Río Deserto
mines, is still operated satisfactorily for pretreatment of the raw coal
before shipment to the central washery at Capivari.

This early Urussanga washery was of the conventional German de-
gign embodying preclassification and washing of closely sized feed in
piston-driven, jig-type wash boxes with feldspar on the fine-coal jig
screens, a method still widely used in the Ruhr. The Urussanga plant
is well-described by José Fiussa da Rocha and Evaristo Pena Scorza
in their discussion of the Santa Catarina coal. The flow sheet, figure
39, is taken from that report. The coal is crushed to pass a 30-mm.
(1½-inch) screen and sized into four grades for washing. The finest
size, 4 mm. by 0 (3/16 inch by 0), is washed on feldspar jigs. After
washing, the washed coal is stored in a 700-ton loading bin at the rail-
road level for shipment to seashore or to the central washery. The
rated capacity of the plant when originally constructed was 500 tons
per day.

The jigs are small, but the separation is reported to compare favor-
able with modern washery-performance standards. The fine-coal
wash box, for example, produces a premium grade of fuel said to
carry an ash content as low as 14.0 percent when the product of the
plant was used for gas coal before the Capivari washery was installed.

At Lauro Müller a small washing plant of American design, but
similarly based on the principle of close presizing of the feed coal and
separate treatment of each size, washes the coal produced at operations
of Cia. Nacional de Mineração de Carvão do Barro Branco in that area.
This plant uses two Elmore jigs for the coarse coal and three Deister
Overstrom diagonal deck tables for the fine sizes. The total rated
capacity of the plant is 60 tons per hour.

In 1942 there were two fine-coal washing plants, each having one
Deister table and handling 5 to 7 tons per hour of moinha screened out
of the run-of-mine coal at hand-preparation plants. One of these
table plants was operated in Criciuma by the Cia. Brasileira Carboni-
fera de Arra
rug
á and the other by Sociedade Carbonifera Prospera
in the same area.

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12 Fraser, Thomas, and Driessen, M. G., Coal Preparation Practice in Western Germany: Bureau of Mines Inf. Circ. 7389, 1946, 70 pp.
These four mechanical cleaning plants with hand-sorting and screening plants and a few manually operated jigs cleaning moinha made up the coal-preparation industry in the coal fields of Santa Catarina in the period before the National Steel Company took control of the output of the producing industry and erected the Capivarí central washery near Tubarão. After Capivarí began to operate the older

![Diagram of Urussanga washery](image)

**Figure 39.—Flow sheet of Urussanga washery.**

...racilities described above were converted substantially intact to the service of roughing the run-of-mine coal at the mines to produce the "lavadora" grade now being shipped to the Capivarí washery.

**CAPIVARÍ PREPARATION PLANT**

A new phase of coal-preparation practice in Santa Catarina began with the erection of the central preparation plant of the National Steel Company at the railway junction city of Tubarão on the Tubarão River. This plant, designed by the McNally-Pittsburg Manufactur-
ing Corp., of Pittsburg, Kans., and erected by the National Steel Company, of Brazil, as part of the national steel project, is centrally located to take the output of coal from the three principal mining fields of the State, namely, Lauro Müller, Urussanga, and Criciuma. The central plant was designed to blend these coals and treat the blended run-of-mine material to make a final four-product separation as follows: (1) Metallurgical coal containing approximately 18 percent ash; (2) general, industrial, and locomotive fuel; (3) steam coal for use in the local power plant; and (4) a refuse. The plant is designed to treat hand-picked run-of-mine coal, consisting of a blend of Lauro Müller, Urussanga, and Criciuma coals and containing not more than 35 percent rejects, at a uniform rate of 400 metric tons (440 short tons) per hour, with provision for changing the blend to suit future requirements. Two parallel circuits permit operation at half or full capacity.

Hand-picked run-of-mine coal is delivered to the plant from each of the three mining districts over a track of 1-meter gage in trips of thirty 20-metric ton railroad cars. The raw coal is stored in cars on six tracks in the raw-coal yard north of the plant, two storage tracks being available for a trip from each of the three mining districts. A general view of the plant is shown in figure 40 and the flow diagram in figure 41.

Cars move by gravity over the raw-coal-track scales, which automatically record the weight of each car, to a track hopper arranged for unloading two cars simultaneously. Unloading is done by gravity through a series of doors on each side of the car, as most of the cars are of wood construction. Future plans call for use of steel cars operating on 1.60-meter-gage tracks, at which time the present track hopper may be modified to accommodate a modern rotary car dumper. Present 1-meter-gage storage tracks, clearances, and track scales are so installed that they may be readily adapted to the future broad-gage cars.

The run-of-mine coal is drawn from the track hopper by two two-speed reciprocating plate feeders to a belt conveyor, which delivers to the run-of-mine shaking screen in the raw-coal screening and crushing plant for sizing into plus-4-inch, 4- by 11/2-inch, and 11/2-inch by 0. The plus-4-inch passes over an inspection table for removal of tramp iron and wood; it then is crushed to minus-4-inch top size and recirculated over the run-of-mine screen. The 4- by 11/2-inch size is crushed to minus-11/2-inch and combines with the 11/2-inch by 0 for delivery to blending bins.

The entire run-of-mine output, thus reduced to 11/2-inch by 0 size, is delivered by a belt conveyor to the blending bins and distributed by a scraper conveyor to six 100-metric ton blending bins, coal from each mining district being stored in the bin or bins designated for that district. The plant is so designed that additional blending bins may be added.

Coal is drawn from each bin at any desired rate by means of variable-speed belt feeders, ranging from 50 to 200 metric tons per hour, thus permitting control of the blending of coal from the different mining districts. Blended coal is withdrawn by the feeders and collected on a belt conveyor and delivered to the scraper-type-
Figure 40.—Capivaré central preparation plant.
Figure 41.—Flow sheet of central preparation plant.
washer feed conveyor at a uniform rate of 400 metric tons per hour for distribution to two Baum-type primary washers in parallel. Each can treat 200 metric tons per hour.

Washed coal from the two primary washers is sluiced with water to the washed-coal classifying screen for sizing into 1 1/2- by 1/16-inch round and minus-5/16-inch sizes. A plow-type gate on the washed-coal screen permits optional delivery of all or any desired amount of 1 1/2- by 1/16-inch as steam coal through a loading chute into railroad cars on the coarse-steam-coal track. Normally, about 50 percent of this 1 1/2- by 1/16-inch coal must be crushed to minus-1/16-inch size and rewashed to meet the metallurgical-coal requirements. After crushing, the coal is sluiced to a crushed-coal boot and elevated for rewashing in one or two four-launder, Rheolaveur washers (II, fig. 41). Provision is made in the crushing and rewashing equipment for handling the entire 1 1/2- by 1/16-inch product to meet increased metallurgical-coal requirements or decreased steam-coal demands. The minus-1/16-inch size with water is sluiced from the jig washed-coal screens to the settling tank and elevated for rewashing in two four-launder, fine-coal, Rheolaveur washers (I, fig. 41). To recover coal that adheres to the primary high-gravity and secondary intermediate-gravity refuse from the two primary washers, these products are collected together, crushed to minus 5/16 inch, sluiced to a crushed-refuse boot, and elevated for rewashing in a single-launder, crushed-refuse, Rheolaveur washer (III, fig. 41).

Refuse from washers II and optionally from washer I, together with the overproduct from washer III, are sluiced to the refuse wash boot and elevated for rewashing in a four-launder washer (IV, fig. 41).

Refuse from washers III and IV and optionally from washer I, as well as optional overflows from crushed-refuse and refuse wash boots are sluiced to the refuse sump for hydraulic disposal to a waste pond.

Regulating material of each washer is in closed circuit, being sluiced back to its own boot for recirculation.

The 5/16-inch by 0 metallurgical coal, prepared by washers I and II, is sluiced to the metallurgical-coal boot, elevated, and dewatered in five centrifugal dryers. The centrifuged coal is collected in a scraper-type conveyor and delivered through a loading chute into railroad cars on the metallurgical-coal track.

The 5/16-inch by 0 steam coal prepared by washers II and IV is dewatered over reciprocating screens and delivered by a two-compartment scraper conveyor through a loading chute into railroad cars on the fine-steam-coal track, with provision for mixing with the coarse steam coal.

The 5/16-inch by 0 power-plant fuel prepared by washers I and IV is dewatered over a reciprocating screen and delivered by a two-compartment scraper conveyor through a loading chute into railroad cars on the power-plant-fuel track. Since more power-plant fuel may be prepared than required for the local plant, provision is made for mixing any portion of the fine steam coal with the power-plant fuel to make an intermediate-grade steam coal for local industrial use.

The slurry that overflows the metallurgical-coal boot, crushed-coal-boot pump sump, and optionally from fine-coal recovery tank is sluiced to the thickener for recovery of the sludge solids. The sludge is
pumped to an 8-disk vacuum filter for dewatering, the filter cake being collected on the top strand of the metallurgical-coal collecting conveyor. The filter cake is broken in a disintegrator and loaded into railroad cars, optionally with the metallurgical coal, with the fine steam coal, or with the power-plant fuel.

Clarified water that overflows the thickener and filtrate pumped from filtrate receiver are recirculated as push water and hydraulic water for washers III and IV. Water that overflows from the crushed-coal boot into the pump sump is recirculated as push water for washers I and II and as flushing water for the washed-coal crusher. Water collected by settling-tank skimmer troughs is recirculated as wash water for the jigs and as flushing water for primary refuse crushers.

A pumping station, constructed along the east bank of the Capivarí River, delivers fresh water to a storage reservoir on Capivarí Hill, from which the water is piped downhill for use in the preparation plant. Fresh water is delivered through a float-operated valve into the fresh-water compartment of the head tank for use as vertical current for rheo boxes on washers I and II; any excess overflows into the recirculating-water compartment. The float is operated by water level in the latter compartment, thus permitting automatic regulation of fresh-water make-up. A booster pump provides high-pressure fresh water for sprays, dryer flush water, and water for clean-out, pump seals, wash-down, and fire protection.

Owing to the high sulfur content of the coal, an unusually large quantity of fresh make-up water is required, and this results in a large volume of waste water. All overflow slurry from the crushed-refuse and refuse rewash boots, as well as all or any part of the fine-coal recovery-tank operating overflow slurry, sluices directly to waste or to the refuse-pump sump. Provision is made for delivering the desired quantity of any one of these overflows to a pilot flotation plant.

Automatic samplers provide for continuous sampling of raw coal delivered to the blending bins, blended raw coal delivered to the washers, washed metallurgical coal, washed $\frac{5}{16}$-inch by 0 and 11½" by $\frac{5}{16}$-inch steam coal, power-plant fuel, and washer refuse sluiced to the refuse-pump sump. Samples are collected for analysis, thus providing a close check on all products that enter or leave the preparation plant.

A machine shop adjacent to the preparation plant provides facilities for repair and maintenance of all equipment as well as storage space for spare parts. Repair work within the plant is greatly facilitated by oxygen and acetylene outlets and welding-current outlets conveniently located throughout various sections of the plant.

The washed coal is loaded into railroad cars on four tracks, $\frac{5}{16}$-inch by 0 metallurgical coal, $\frac{5}{16}$-inch by 0 steam coal, 11½" by 0 steam coal, 1½" by 0 steam coal, and $\frac{5}{16}$-inch by 0 power-plant fuel, respectively. In addition to the above products, an intermediate grade of $\frac{5}{16}$-inch by 0 steam coal is loaded on the power-plant-fuel track.

Loading of cars is controlled by manually operated car retarders, and loaded cars are dropped by gravity over washed-coal-track scales, which automatically record the weight while the car is in motion. The cars continue by gravity to the washed-coal storage yard, which is provided with facilities for making up trains of 30 cars of metal-
lurgical coal and of each of the steam-coal sizes for delivery to their respective destinations.

A well-equipped pilot plant for research work on further improvements in the treatment of this coal is provided in the general plant arrangement. This pilot plant, equipped with experimental coal-washing tables, froth flotation machines, a heavy-medium separator of pilot-plant size, and other test equipment, provides for continual improvement of the preparation-plant practice. This coal, though of very good coking quality, is extremely difficult to wash to low ash content because of the intermixed condition of the coal and refuse materials; and the most intensive development work is necessary to obtain the utmost possible yield.

During some years of operation this plant has been delivering a metallurgical product suitable for use at the metallurgical works at Volta Redonda by blending with about 50 percent of lower-ash imported coals.

Owing to irregularity of the run-of-mine products and variations in inherent ash content of the raw feed as delivered to the plant, it has been found impracticable to attain uniformly a washed coal that will yield a metallurgical product containing as little as 18 percent ash. It was also found feasible to use this coal in a 50-percent blend with Appalachian coals of low ash content, even though the ash in the domestic coal might run as high as 22 percent. Considering these conditions and the need for stepping up the production of metallurgical-grade fuel to as high a rate as possible, the final washing plan of the Capivarí installation has been adjusted to deliver a metallurgical coal of about 22 percent ash content; with this change in adjustment, it is reported that the plant consistently delivers a product of at least 30 percent of this grade.

**PARANÁ**

Current practice in the preparation of coal in the Paraná field is very elementary and almost identical to that followed at the mine plants in the Criciúma area of Santa Catarina. (See the description of hand-picking operations in that field.)

The raw run-of-mine coal is trammed to the outside by hand and shoveled from the car to the ground by hand; it then is hand-screened over stationary, inclined, wire-mesh screens, and the fine coal that goes through the screen is generally discarded as refuse. The coarse coal that rolls down over the screen is shoveled by hand to stationary picking tables, where the rock particles and the coal particles are carefully hand-sorted one by one by working people, generally girls and women. The stone is discarded, and the coal is carried by the pickers to a mine car or bin for shipment to market.

**PREPARATION CHARACTERISTICS OF THE COAL**

The Paraná coals, occurring in separate small basins, vary greatly in preparation characteristics; since exploration work is by no means complete, it is impossible to give any detailed discussion of the preparation characteristics of the coal. However, all the coal being produced requires careful preparation before shipment, as the raw
material is relatively high in ash because of imbedded impurities. The character of the coal in the bed with the parting and bony layers is illustrated by typical bed sections shown in figure 5 (p. 22). Some of the Paraná beds are reported to be considerably cleaner than the coal being produced in larger volume in the Santa Catarina and Rio Grande do Sul coal fields, but the sulfur, on the other hand, is very much more difficult to remove; intensive testing and analyses of these coals would be expected to disclose that they are high in organic and finely disseminated pyritic sulfur forms.

Although study of the preparation characteristics of the coals is only beginning, it indicates that they readily may be prepared to meet the demands of the domestic market which is accustomed to use domestic coals from the older mining fields of the south.

![Flow sheet of the preparation plant of Cia. Carbonífera Brasileira.](image)

**MECHANICAL PREPARATION FACILITIES**

There is only one mechanical preparation plant in the Paraná field at the present time. It is a small plant for hand-picking the lump coal and washing the fines on Diester tables.

A flow diagram of this plant erected and operated by the Cia. Carbonífera Brasileira is shown in figure 42. The raw coal is first screened over a shaking screen, which delivers the coarse coal over $\frac{1}{2}$ inch in size to picking tables, where it is carefully sorted by hand. The minus-$\frac{1}{2}$-inch size that passes this screen is conveyed to a small feed hopper from which it is withdrawn to feed the Deister-Overstrom diagonal-deck, coal-washing table, which washes the slack. The washed coal from this table is discharged to the boot of an inclined
scraper-conveyor elevator; the overflow from this boot carrying a relatively high proportion of high-ash coal and clay is discarded. The dewatered product reclaimed by the scraper line is loaded into trucks for shipment at about 14 percent ash content.

LABOR

During the past few years conditions affecting the mine labor situation have changed considerably. Economic and social changes as well as government legislation have had a marked influence on the employment, wages, hours, and conditions of mine labor in the Brazilian coal fields.

The general trend has been toward higher wages, shorter working hours, and increased workers' benefits.

One of the most-discussed pieces of legislation affecting mine workers became effective in November 1943. Included in the Consolidation of Labor Laws, this act reduced the miner's working day from 8 to 6 hours, portal to portal, and resulted in an effective working day in many instances of about 43½ hours.

The conditions and laws governing the labor situation are complex, and the scope of this paper does not permit a lengthy discussion.

Although a few major producers have statistics applying to their own operations, detailed data on the entire coal industry, or indeed on any one field, were not available.

Of the three producing fields, the most-complete labor statistics probably are those covering Rio Grande do Sul. Production in that State has been confined almost entirely to the two CADEM mines, and the records of the producers, therefore, would furnish a picture of the entire field. Unfortunately, such data cannot be included here as the information was not available to the authors at the time this publication was being prepared.

In Santa Catarina the National Department of Mineral Production is now devoting some time to the collection of useful statistics covering that field. Some limited information is included here.

SANTA CATARINA

Although labor statistics over a number of years were not available in this field, table 11 shows the present distribution of labor in the Santa Catarina coal-mining industry and the output per man-shift during 1946. The information was collected from the individual companies by the National Department of Mineral Production. The figures given are weighted averages for the calendar year 1946, calculated on the basis of 292 working days. Average production per man-shift in many instances is necessarily an approximation, as production of run-of-mine coal is not weighed at the majority of the mines but is estimated from the number of mine cars of coal produced. The marked differences in production per man-shift is attributed to a variety of causes, but only in a few instances can it be considered the result of differences in operating efficiency. Variations in bed conditions and hardness of coal, size of the mine and distance the coal must be hand-trammed, difference in nomenclature of the underground worker, and other factors all have more influence on production per
TABLE 11.—Number of workers employed in coal mining and production per man per day, Santa Catarina, 1946

<table>
<thead>
<tr>
<th>Company</th>
<th>Miners</th>
<th>Miners' helpers</th>
<th>Special services</th>
<th>Day men</th>
<th>Coal pickers (female)</th>
<th>Administration</th>
<th>Total</th>
<th>Average production per day (shift), metric tons per —</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>1,293</td>
<td>2,223</td>
<td>1,789</td>
<td>2,393</td>
<td>420</td>
<td>423</td>
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man-shift than actual differences in the efficiency of mining methods, as methods in this field are pretty much the same. The few exceptions are those operations where some mechanical equipment has been introduced.

The following table shows the average production per man per day in bituminous-coal, lignite, and anthracite mines in the United States during 1945.

<table>
<thead>
<tr>
<th>Type of operation</th>
<th>Average tons per man per day</th>
</tr>
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<tbody>
<tr>
<td>Lignite, underground and strip mines</td>
<td>14.26</td>
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<tr>
<td>Bituminous-coal and lignite:</td>
<td></td>
</tr>
<tr>
<td>Strip mines</td>
<td>15.46</td>
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<tr>
<td>Underground</td>
<td>5.04</td>
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<tr>
<td>Total—all bituminous-coal and lignite mines</td>
<td>5.78</td>
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<tr>
<td>Anthracite (underground and strip mines)</td>
<td>2.79</td>
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1 Reprint from Bureau of Mines Minerals Yearbook, 1946.  
2 All employees, surface and underground.  
3 Legitimate operations only; "bootleg" mines excluded.

In comparing the production per man per day in Santa Catarina with that in the United States, the production figure for underground bituminous-coal and lignite mines in the United States is used. As probably about 10 percent of Santa Catarina coal is mined by stripping methods, a comparison on this basis is, if anything, favorable to Santa Catarina.

Production per man per day for all employees in Santa Catarina is only about 8 percent of that in underground bituminous-coal and lignite mines in the United States. Production per underground worker in Santa Catarina is about 15 percent of production per underground worker in bituminous-coal and lignite mines in the United States. This low productivity cannot be attributed to the working capacity of the employees; it is the result of adverse mining conditions, principally the small amount of recoverable coal and excessive amount of waste in the bed, as well as to the lack of mechanized equipment and the large number of small, scattered mines using inefficient methods.

PARANÁ

Labor statistics in the Paraná field were not available. However, conditions, including wage rates, are very similar to those in the Santa Catarina field. As the Paraná coal beds contain, in general, a greater percentage of recoverable coal per foot of thickness, production per underground worker per day is slightly higher than in Santa Catarina. This advantage is offset by the fact that, with the exception of one mine, all coal is prepared for market by hand-picking methods entirely. Because of the relatively greater number of coal pickers (similar to the situation existing in Santa Catarina before completion of the central washing plant), production per employee per day is comparable to present production per employee per day in Santa Catarina.
Figure 43.—Girl picking coal at a southern Brazil mine.

Figure 44.—Typical coal miner's home.
The hand-picking operations in Paraná and Santa Catarina are done almost exclusively by women and girls. Figure 43 shows a typical coal picker with the small hand pick used for breaking down the larger lumps of coal.

Figure 44 shows a typical miner's house in the Paraná field. Although design and construction details differ somewhat in different localities, housing for mine workers is essentially the same throughout the Santa Catarina and Paraná fields.

GOVERNMENT FIELD STATIONS

Almost every important coal-producing country has one or more experiment stations devoted at least in part to the testing of equipment, explosives, and machinery used in coal mines. Research is done on methods and equipment used in the detection of methane and on methods used for the prevention or limitation of gas and coal-dust explosions. Mine rescue apparatus is tested and developed. Several countries, such as the United States, Great Britain, and Germany, carry on fundamental research on methods of mining, roof support, and roof control aimed primarily at reducing the hazards of coal mining.

In Brazil the coal-mining industry is comparatively immature. Little mining machinery is used, the mines are for the most part shallow and nongaseous, and probably because of freedom from mine disasters in the past mine rescue apparatus and trained mine rescue crews are not found in any of the coal fields. There has been no research on mining methods, roof control, and cause, prevention, and control of gas and coal-dust explosions. No testing of mining equipment, safety lamps, methane detectors, etc., is done, principally because little of this type of equipment is used.

Mine inspections and the enforcement of legislation and safety regulations affecting the coal-mining industry are part of the responsibilities of the Departamento Nacional da Produção Mineral (National Department of Mineral Production), under the Ministry of Agriculture. Any basic mining research and experimental or testing work on the part of the Government is done by this agency.

In recent years the Departamento Nacional da Produção Mineral has broadened its activities in the coal fields. With the construction of the new Volta Redonda steel plant designed to use coke instead of charcoal as a metallurgical fuel, the growing importance of the domestic coal-mining industry, and the limited supply of foreign coal available during World War II, the Departamento Nacional da Produção Mineral is taking an active interest in field work and investigations contributing to the development of the domestic coal-mining industry.

During 1945 a well-equipped field station was completed at Criciúma, in the Santa Catarina coal field. This station, while not primarily an experiment station, was designed to act as a center for the activities of the Departamento Nacional da Produção Mineral in the Santa Catarina field. The main building of the physical plant houses a good-sized laboratory, a medical dispensary, a library, a drafting room, and a number of offices to accommodate resident administrators, geologists, engineers, chemists, a doctor, and clerical
personnel. Another building houses a supply department, facilities for the preparation of coal samples, a carpenter shop, and a large garage and machine repair shop. A group of comfortable individual houses for resident administrative and technical personnel completes the unit. A separate housing development for other employees at the station is planned.

Figure 45 shows the main building of the Criciuma field station (A) and the garage, etc. (B), at the rear.
Figure 46.—Facilities of Cricumã field station: A, Laboratory in main building; B, group of houses for administrative and technical personnel at field station.

Figure 46 shows part of the laboratory in the main building and one group of houses for administrative and technical personnel.

As planned, the field station directly represents the Departamento Nacional da Produção Mineral in normal administrative matters and executes such control as is exercised by that organ. It is also to serve as the working center for technical studies, investigations, inspections, drilling programs, etc., carried on by the Government in the Santa Catarina field. Unfortunately, it has been impossible to put
the full working plan of the station into effect because of a lack of personnel. Principally because the salaries paid to government employees are limited, it is hard to compete with private industry for the services of trained technical men. The station is understaffed at present. The D. N. P. M., however, plans to build it up to the point where the full potentialities of the station can be realized. Eventually the station should serve as an effective working unit for basic field studies of local geology and coal reserves, investigations of the physical characteristics and washability of the coals, regular mine inspections, and research and experimental work on mining methods, safety, and health.

The Departamento Nacional da Produção Mineral has a representative stationed in the Paraná coal field but has no physical plant there such as the one in Santa Catarina. As the newly developed Paraná field is much smaller, the duties of this representative, while similar to those of his counterpart in Santa Catarina, are on a smaller scale. A successful core-drilling program is being carried on in the Paraná field, but any work requiring laboratory or other plant facilities must necessarily be referred to the D. N. P. M. headquarters in Rio de Janeiro.