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Report of Investigations 5019



OIL-SHALE OPERATIONS IN THE UNION
OF SOUTH AFRICA, OCTOBER 1947

BY H. M. THORNE AND A. J. KRAEMER

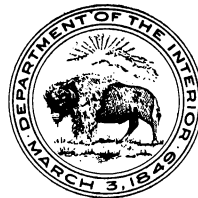
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UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary
BUREAU OF MINES
J. J. Forbes, Director

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H. M. Thorne^{1/} and A. J. Kraemer^{2/}

CONTENTS

	<u>Page</u>
Introduction	1
Units of measure	1
Summary	2
Acknowledgments	3
Early interest in oil shales of South Africa	3
South African Torbanite Mining and Refining Co.	4
Ermelo mining and retorting plant	4
General layout of plant	5
Living quarters for natives	6
The mine	6
Surface equipment	7
Mining	7
Productivity and costs	8
Crushing and retorting plant	9
Shale crushers and gas producers	9
Crushing and screening	9
Davidson retorts	9
Operation of Davidson retort	11
Salerno retorts	11
Operation of Salerno retorts	13
Condensing, filtering, and gas scrubbing	14
Disposal of spent shale and ash	15
Productivity and costs	15
Refining operations at Boksburg North	16
Crude oil distillation and cracking	17
Vacuum distillation	18
Chemical treating of pressure distillate	18
Lachman process	18
Products and markets	19

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CONTENTS (Cont.)

	<u>Page</u>
Raw materials and products	20
Oil shale	20
Characteristics of crude shale oil and its products .	24
Crude shale oil	24
Satmar cracked distillate and gasoline	26
Asphaltic products	26
Research and development	30
Conclusions	31

TABLES

<u>No.</u>		
1.	Assay analyses of South African oil shales	21
2.	Composition and properties of South African oil shales compared with Colorado oil shale	23
3.	Bureau of Mines crude shale-oil analysis	25
4.	Properties of fractions of South African crude shale oil	27
5.	Properties of South African shale oil cracked distillate and treated gasoline	28
6.	Properties of asphaltic residuums from South African shale oil	29

ILLUSTRATIONS

<u>Fig.</u>		<u>Follows</u> <u>page</u>
1.	Oil-shale occurrences in South Africa	2
2.	Torbanite deposits in eastern Transvaal, South Africa	4
3.	Ermelo plant layout	4
4.	Claim map, showing workings of South African Torbanite Mining and Refining Co., Ltd.	4
5.	Houses in native compound, Ermelo, Transvaal	6
6.	Sectional view of Davidson retort	8
7.	Davidson retort--arrangement of gas main from retort to condensers	10
8.	Elevation and sectional elevation of a Salerno retort	12
9.	General arrangement of mechanism on discharge end, Salerno retorts	12
10.	Arrangement of gas oftakes, collector mains, and oil piping for Salerno retorts	12
11.	Houses for Salerno retorts 5 to 10, Ermelo, Transvaal, Union of South Africa	16
12.	South African Torbanite Mining and Refining Company, shale-oil refinery at Boksburg North, Transvaal ...	16
13.	Flow diagram of shale-oil refinery	16
14.	Flow diagram of combination crude-oil distillation and cracking plant	16
15.	Flow diagram of absorption plant	16
16.	Flow diagram of pressure-distillate treating plant ..	18
17.	Lachman zinc chloride treating and reclaiming unit ..	18
18.	Flow diagram of tar-acid plant	20

INTRODUCTION

The Union of South Africa has been interested in oil shale for a long time, and deposits of oil shales, torbanites, and similar rocks have been found in many parts of the country. (Fig. 1.) Samples differ markedly in oil yield and in the characteristics of the oil. The strata vary in thickness, and most of the deposits that have been found are in unfavorable locations because of remoteness from markets or absence of transportation facilities.

This report deals mainly with the torbanite deposit near Ermelo, Transvaal, in the Union of South Africa, and the operations of the South African Torbanite Mining and Refining Co., Ltd. (hereafter referred to as Satmar), in mining the torbanite, retorting it, and refining the crude oil.

Facilities and operations of Satmar were surveyed by the authors in October 1947 to obtain information to aid the synthetic liquid fuels program of the Bureau of Mines, pursuant to the Synthetic Liquid Fuels Act of April 5, 1944 (30 USC 321-325 as amended). The survey was a part of the Bureau's plan to study at first hand the activities being conducted throughout the world on a plant scale to manufacture gasoline, other liquid fuels, paraffin wax, and other products from oil shale and torbanite. Representatives of the oil-shale section of the Synthetic Liquid Fuels Branch of the Bureau of Mines visited plants in Scotland, Sweden, Germany, France, Spain, Brazil, Australia, Union of South Africa, and Manchuria. This report is one of a series,^{3/} which have described oil-shale operations in other countries.

Units of Measure

Quantities and costs are stated in equivalent terms used in the United States, unless specifically indicated otherwise, rather than in imperial gallons and South African currency. An imperial gallon is 1.20 United States gallons. In the petroleum industry of the United States a barrel is 42 U. S. gallons, equivalent to 35 imperial gallons. In South Africa weights are expressed in short tons of 2,000 pounds as in the United States. Oil-shale assay values, reported in imperial gallons a short ton in South Africa, have been converted to U. S. gallons a short ton by multiplying by 1.2. Monetary

^{3/} Kraemer, A. J., Oil Shale in Brazil: Bureau of Mines Rept. of Investigations 4655, 1950, 36 pp.

Thorne, H. M., and Kraemer, A. J., Oil Shale in Spain: Bureau of Mines Rept. of Investigations 4736, 1950, 21 pp.

Guthrie, Boyd, and Klosky, Simon, The Oil-Shale Industries of Europe: Bureau of Mines Rept. of Investigations 4776, 1951, 73 pp.

Kraemer, A. J., and Thorne, H. M., Oil-Shale Operations in New South Wales, Australia: Bureau of Mines Rept. of Investigations 4796, 1951, 48 pp.

values have been converted on the basis of the exchange rate in October 1947, which was 4.00 U. S. dollars a South African pound.

SUMMARY

In this report the reader's attention is directed briefly to the deposits of oil shales, torbanites, and similar rocks that have been found in many parts of the Union of South Africa and efforts that have been made to exploit the deposits. The formation and capital structure of South African Torbanite Mining and Refining Co., Ltd. (Satmar), is outlined. This organization is operating the only oil-shale project in South Africa.

The Satmar mine near Ermelo, Transvaal, is a combination coal-and-torbanite mine in which coal overlies the torbanite and is removed before the torbanite is blasted. The production is approximately 1,400 tons of coal and 800 tons of torbanite a working day.

The retorting plant at Ermelo comprises a Davidson rotary unit of 4 tubes and 10 Salerno retorts with the auxiliary facilities needed to operate them, including housing for the staff and the native workmen and their families. In 1947 the average charging rate to the retorts was 720 tons of torbanite a calendar day, 90 tons of coal a day was used as boiler fuel, and 70 tons was used in producer-gas generators to supply fuel for the retorts. Production of crude shale oil was about 810 barrels a calendar day.

In the refinery at Boksburg North, near Johannesburg, crude shale oil received in tank cars from the retorting plant at Ermelo is charged to a combination crude-oil distillation and thermal cracking unit. The main products of the refinery are 70-octane (A.S.T.M. Motor Method) gasoline (made without use of tetraethyl lead by blending with purchased benzene and ethyl alcohol), asphaltic products, and cresylic acids. The refinery is on stream approximately 180 days a year and processes about 1,640 barrels of crude oil an operating day.

The Ermelo mine and retorting plant has a large number of employees in proportion to the production of the plant. In the mining operations 675 negroes (called natives or boys) and 26 white men are employed underground and 230 natives and 8 white men above ground. In the retorting and auxiliary plants 200 natives and 27 white men are employed. These figures do not include employees in the boiler house, power plant, shops, warehouse, office, laboratory, or those engaged in other incidental activities. The technical staff consists of a superintendent, a chief engineer, a mining engineer, a chief chemist, a retorting superintendent, and their assistants.

The refinery at Boksburg North employs 180 natives and 107 white men, including supervisory and technical staff made up of a superintendent, a chief chemist, a chief engineer, and assistants.

The company does not have a direct subsidy or remission of taxes as is true of oil-shale organizations in most other countries, but is aided substantially by high freight rates on petroleum and petroleum products from

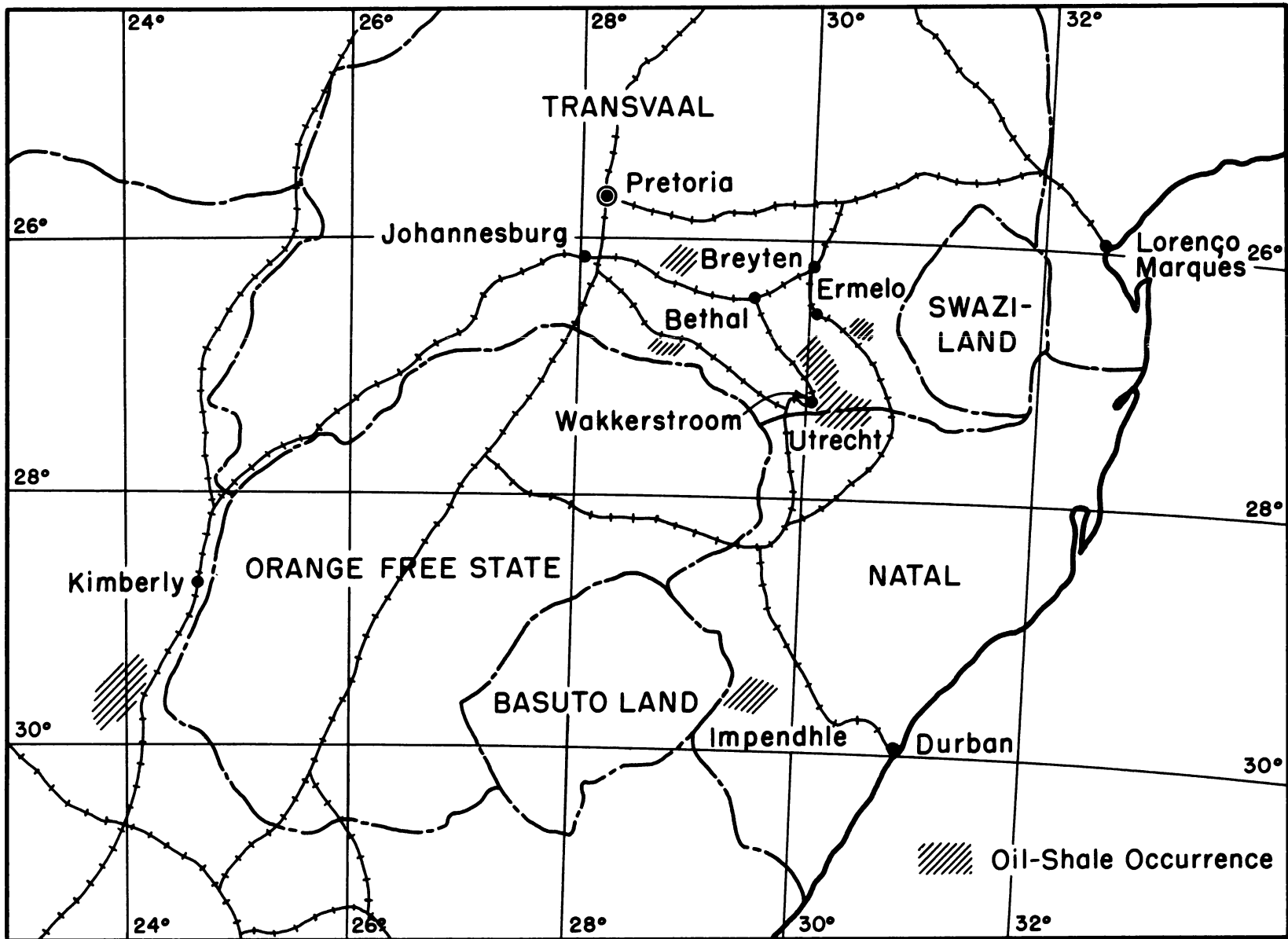


Figure 1. - Oil-shale occurrences in South Africa. (After Petrick, see footnote 4.)

seaports such as Durban and Capetown to the interior. The company bears an excise duty on production of gasoline. The production is only a minor fraction of the consumers demand within the Johannesburg marketing area. The company has operated at a profit, and has paid dividends regularly to stockholders.

ACKNOWLEDGMENTS

This report has been prepared under the general supervision of W. C. Schroeder, formerly chief, Synthetic Liquid Fuels Branch, and R. A. Cattell, chief, Petroleum and Natural Gas Branch, Bureau of Mines, Washington, D. C.

The authors are indebted to officials and members of the staff of South African Torbanite Mining and Refining Co., Ltd., for their hospitality and many courtesies. Special thanks are due to J. R. Case, O.B.E., general manager of the company at Johannesburg, for his kindness and cooperation. W. B. Somerville, superintendent of the mining and retorting plant at Ermelo, and J. A. Toubkin, formerly refinery manager at Boksburg North, gave much valuable information regarding the operation of the plants under their supervision.

The staff of the United States Consulate General at Johannesburg was very cooperative, and William Vanderburg, formerly minerals attaché, was especially helpful in making various arrangements.

Acknowledgment is due H. P. Rue, chief, Fuels Technology Division, Region IV, Bureau of Mines, and to the personnel of the Oil-Shale Research Branch at the Petroleum and Oil-Shale Experiment Station, Laramie, Wyo., for analyses of oil shale, shale oil, and products provided by Satmar.

Some illustrations were redrawn from prints supplied by Satmar under the supervision of L. F. Perry, formerly supervising engineer of the Graphic Services Section of the Bureau of Mines, Pittsburgh, Pa., and others were redrawn at the Petroleum and Oil-Shale Experiment Station, Laramie, Wyo.

EARLY INTEREST IN OIL SHALES OF SOUTH AFRICA

The story of oil shale in South Africa has been summarized admirably by Petrick,^{4/} and readers are referred to his bulletin and to references in his bulletin for detailed information to the year 1936.

Trevor^{5/} has written a comprehensive report on the geological and geographic distribution of the known deposits in 1923. The oil-shale deposits

^{4/} Petrick, A. J., A Contribution to the Study of South African Oil Shales: Fuel Research Institute of South Africa, Pretoria, Union of South Africa, Bull. 7, 80 pp. Reprinted from Jour. Chem. Metal. Min. Soc. South Africa, vol. 37, No. 6, December 1936.

^{5/} Trevor, T. G., The Oil-Yielding Rocks in the Union of South Africa: South African Jour. Ind., vol. 6, 1923, pp. 285-306; Petrol. World, vol. 20, 1923, pp. 358-360.

in the Transvaal were known as long ago as 1900, and in 1903 the Transvaal Oil Shale Syndicate, Ltd., investigated the oil-shale occurrence at Kikvorschfontein No. 4 (fig. 2). The shale gives high yields of oil, but the seam evidently is too thin to be workable on a commercial scale.

The shale deposits at Kromhoek, Virginia, and Goedgevonden in the Wakkerstroom area south of Kikvorschfontein were more promising, and the African Oil Corp. obtained options on these farms in 1919. A year or two later the Royal Dutch Shell Co. became interested and sent an engineer to conduct investigations. The prospects did not appear to be interesting enough and the Shell Co. surrendered its options.

The African Oil Corp. continued development work at Kromhoek and Goedgevonden and proved the amount of workable shale to be at least 7,000,000 tons. In 1931 this company abandoned the option, and it was taken up by a Volksrust syndicate, which still held the option in 1932 when the British Burmah Petroleum Co. is reported to have sent representatives to negotiate about them. However, Petrick was unable to find a definite reference in the available literature to any actual negotiations in South Africa. The British Burmah Petroleum Co. soon turned its attention entirely to the Ermelo deposit.

The oil-shale deposit at Ermelo is situated much more conveniently than those mentioned above. In 1910 the Transvaal Boghead Coal Co., Ltd., was organized to develop the oil-shale deposits at Mooifontein and Bloemfontein. Various other companies were organized from time to time to exploit these oil-shale deposits. In 1932 development was intensified, and numerous boreholes were sunk on Mooifontein, and the available quantity of torbanite became known fairly accurately.

South African Torbanite Mining and Refining Co.

The Anglo-Transvaal Consolidated Investment Co., Ltd., in collaboration with the British Burmah Petroleum Co. and J. Taylor & Sons, London, organized Satmar late in 1934 or early in 1935 with a capital of 750,000 South African pounds. The mine was developed promptly at Ermelo, and operation of the retorting plant was begun in November 1935. Satmar embarked upon a program to double the crude oil production and utilize lower grade deposits in 1944.

The authorized capital was increased to 1,000,000 pounds, in 4,000,000 shares at 5 shillings each, and in 1947 the issued capital was 693,437 pounds, 10 shillings in 2,773,750 shares at 5 shillings each. At that time the company had outstanding 5-1/2 percent first-mortgage debentures of 257,300 pounds. The Managers, Secretaries, and Registered Office are Anglo-Transvaal Consolidated Investment Co., Ltd., Anglovaal House, Johannesburg, Transvaal, Union of South Africa, and the Technical Managers are The British Burmah Petroleum Co. (S.A.) (Pty.), Ltd., Anglovaal House, Johannesburg.

ERMELO MINING AND RETORTING PLANT

This account relates to conditions of operation and other circumstances that existed at the time of the authors' visit to the Satmar plants and offices

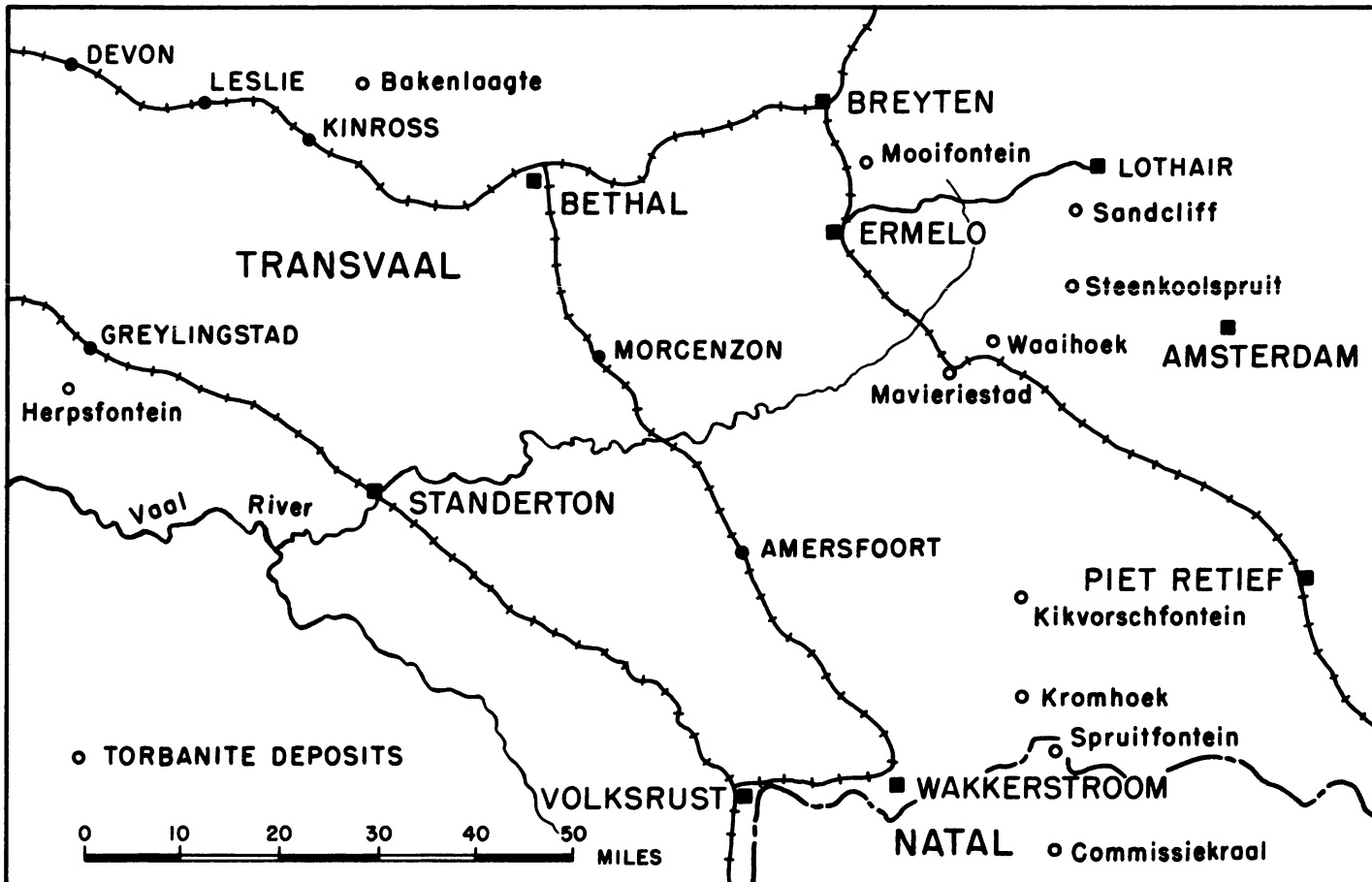


Figure 2. - Torbanite deposits in eastern Transvaal, South Africa. (After Petrick, see footnote 4.)

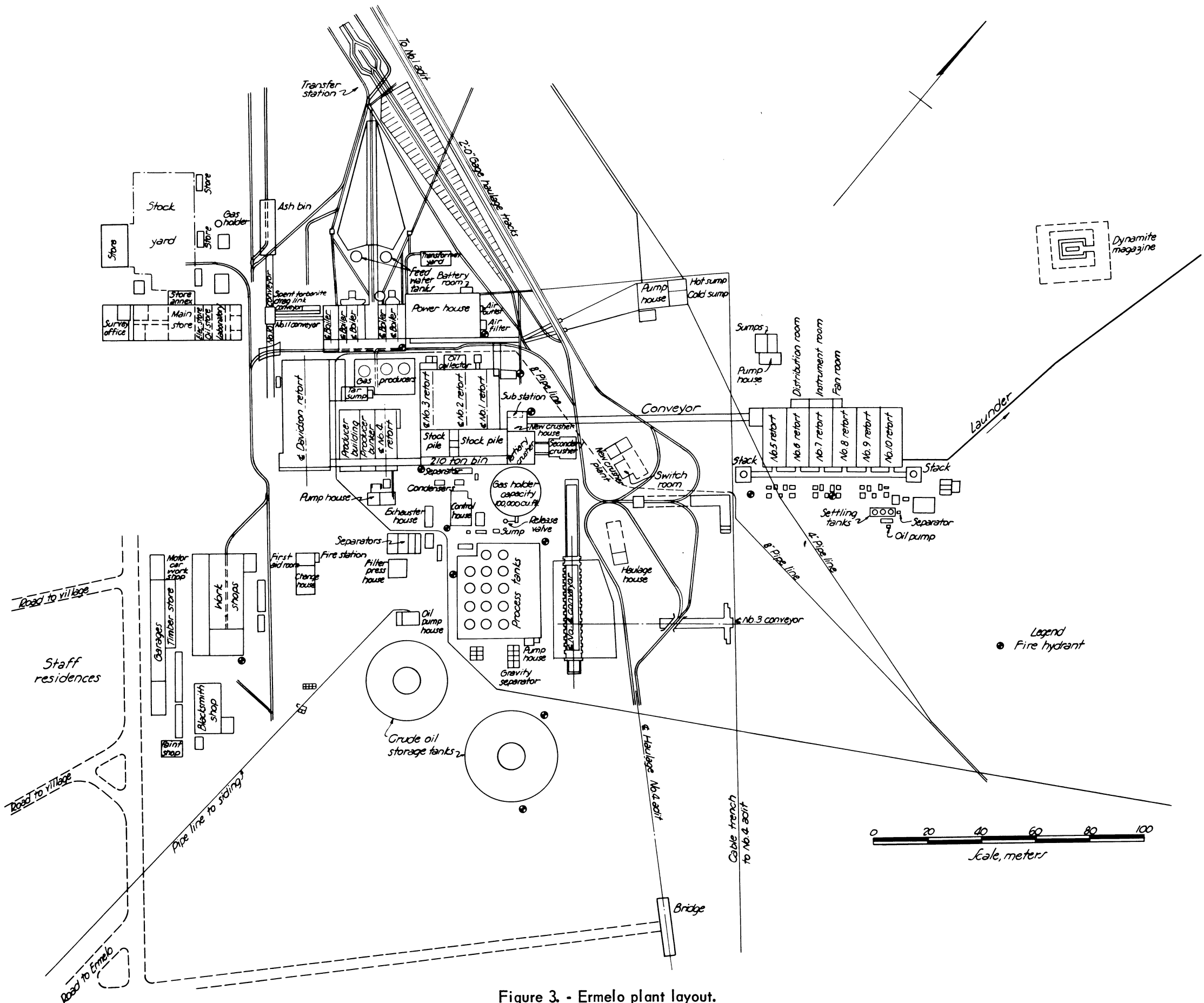


Figure 3. - Ermelo plant layout.

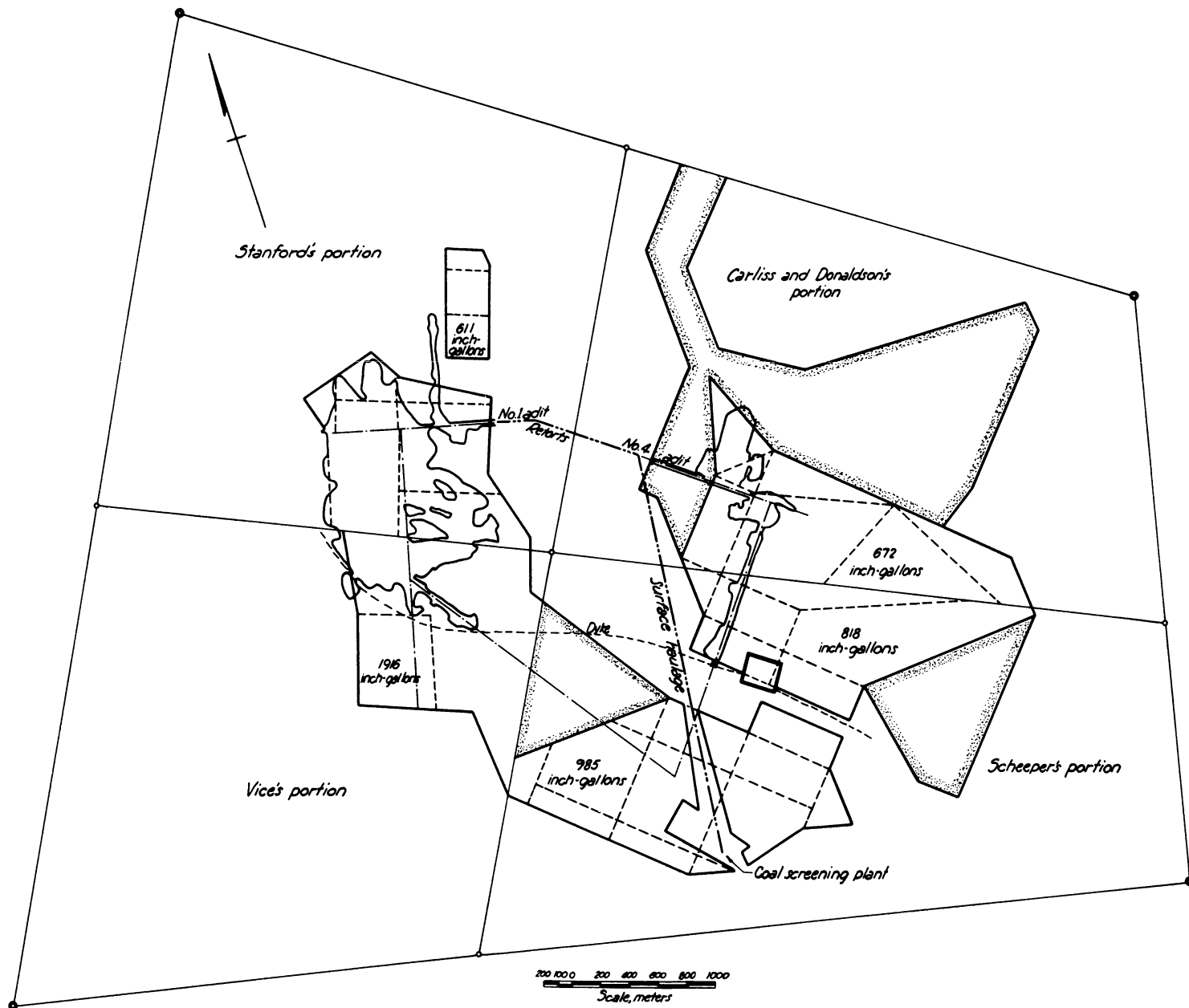


Figure 4. - Claim map, showing workings of South African Torbanite Mining and Refining Co., Ltd.

in October 1947. Occasional references to changes that have been brought about since that time have been abstracted mainly from recent reports by members of the Satmar staff. 6/7/8/9/

The Satmar plant begins about 8 miles from Ermelo at a railroad stop called Torbanite, where tank cars of crude oil are loaded for delivery to the refinery at Boksburg North, coal is shipped, and freight is received. The next step is the coal screening, cleaning, and loading plant, where coal is received from the mine over a 24-inch-gage railway powered by an endless wire rope 3 feet above the tracks. The coal is screened and handpicked for rock, lump coal is sold, some Pea size is returned to the plant for use as boiler fuel, and minus-4-inch plus-1-1/2-inch coal is used as gas-producer fuel.

The plant proper consists of the following principal parts:

1. The combination torbanite and coal mine.
2. Conveyors and crushers.
3. Davidson rotary and Salerno retorts.
4. Seven gas producers and auxiliary equipment.
5. Boiler house and power plant.
6. Office and laboratory building.
7. Shop and warehouse building.

In addition there are the usual auxiliary plants and structures, such as a water-recovery plant and a garage.

General Layout of Plant

Figure 3 is a scale drawing of the surface plant at Ermelo, showing the relative position and size of the various units. The location of the mine with reference to the plant can be seen by comparison with figure 4, which shows the location of mine claims, plant, and mines. The area within the boundaries of the map is known as Mooifontein 287 (fig. 2) and is a "farm" in the sense in which this term is used in the Union of South Africa. Figures 3 and 4 are drawn to different scales, and the scale of figure 3 is approximately 20 times as large as that of figure 4. Both figures show the relative

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- 6/ Stelling, A. R., and Robertson, G. G., The Occurrence and Exploitation of Oil Shales in South Africa: 4th World Power Conf., London, 1950.
 - 7/ Blore, G. B., and Somerville, W. B., The Mining of South African Torbanite: 2d Oil Shale and Cannel Coal Conf., Glasgow, Scotland, July 1950, pp. 180-185.
 - 8/ Forbes, C. E., and Somerville, W. B., The Retorting of South African Torbanite: 2d Oil Shale and Cannel Coal Conf., Glasgow, Scotland, July 1950, pp. 428-439.
 - 9/ Robertson, G. G., The Refining of South African Torbanite Crude Oil: 2d Oil Shale and Cannel Coal Conf., Glasgow, Scotland, July 1950, pp. 571-582.

positions of adits 1 and 4 with reference to the original retorts, within the included angle between the haulageways from these adits. The coal-screening plant is beyond the limits of figure 3, but its location is indicated in figure 4 and by the pipeline to siding in the lower left of figure 3. Residences of the staff are in the area indicated by the caption Road to Village at the left of figure 3, and the housing for natives is to the right of the bridge over which the Road to Compound passes.

Living Quarters for Natives

Most of the natives employed at the Ermelo plant are single men, but a few married men are employed. Figure 5 is a view of the native compound showing, to the right, typical houses provided for men with families. Single men are housed in substantial circular concrete houses, some of which can be seen at the left of the picture. These houses have bunks for 6 to 8 men. The principal item of food is a cereal mush cooked in steam kettles in a central kitchen and supplemented with meat. Native-type beer is brewed in the compound. The area showed every evidence of efforts to maintain cleanliness and sanitary conditions.

The Mine

The following description of the Ermelo mine and its equipment and method of operation deals with conditions at the time of the authors' visit in October 1947. The paper by Blore and Somerville^{10/} describes more recent conditions and illustrates the changing nature of oil-shale mining when it is done by progressive organizations.

The mine is entered through adits 1 and 4 (figs. 3 and 4) at the plant level of 5,750 feet above sea level. In this mine coal overlies the torbanite, and both are in comparatively thin beds. The average thickness of the torbanite is 21 inches and the coal, 30 inches. The mine assay value of the torbanite is 56 gallons a ton, based on the entire workings. An area of about 20,000,000 square feet had been developed to the end of 1947, and the rate of depletion was about 4,000,000 square feet a year. The present torbanite deposit is estimated to have a life of 15 to 20 years at the rate of production during 1947.

The mine has been developed by the room-and-pillar method, with rooms 18 feet wide on 33 foot centers, leaving 15-foot square pillars, giving an 80-percent extraction of torbanite.

The roof usually is strong sandstone, and as a general rule roof supports are used only in areas where shale overlies the coal and in areas adjacent to igneous intrusions.

Figure 4 has several notations in inch-gallons, which are derived for each of the designated areas by multiplying the Fischer assay value of the torbanite in imperial gallons per ton by the thickness in inches of the torbanite bed.

^{10/} Work cited in footnote 7.



Figure 5. - Houses in native compound, Ermelo, Transvaal.

Surface Equipment

The haulage system (figs. 3 and 4) is the principal item of surface equipment that is related directly to mining. The mining section supervises transportation of torbanite from the mine face to the crushing plant, coal to the screening plant and back to the gas producers and the boiler plant, and waste coal to the dump. Ore cars are moved over a 24-inch-gage railroad with overhead haulage ropes of wire. Numerous interruptions, above ground and in the mine, are caused by cars jumping tracks and similar mishaps. Because of the interdependent arrangement of the haulage ropes, an accident on one part of the system stops all cars on the entire system.

The powder magazine is shown at the upper right of figure 3, at adit 4, and the battery room for recharging electric cap-lamp batteries is adjacent to the compound.

In 1947 air for pneumatic drills was compressed underground in portable 25-hp. compressors to keep up with the rapid advance of the mining operations, and one air compressor was installed above ground in the power station for surface requirements. Blore and Somerville¹¹ state that electric drills are used now.

Mining

In preparation for blasting the coal and torbanite beds, a kerf of 5 to 5-1/2 inches is cut in the overlying coal, as close as possible to the top of the torbanite, with arc-wall undercutting coal cutters having a radius of 7 feet 6 inches and shortwall machines. The cutter does not cut the torbanite, and because of the inequalities in its upper surface a few inches of coal may be left adhering to the torbanite.

The diameter of the kerf is 15 feet. Three holes 6 feet deep are drilled into the face of the coal body, "looking up" slightly, with hand-held pneumatic drills using 60 pounds per square inch of air pressure at the drill, with 7/8-inch, hollow, hexagonal drill rods fitted with chisel bits. The cuttings from the kerf and the shot holes are swept up carefully and shoveled into coal cars. Four holes of the same size are drilled into the face of the torbanite, "looking down" slightly.

Each of the 3 holes in the coal is loaded with 3 sticks of 1 by 8-inch 60-percent ammon-dynamite (a nonpermissible powder in the United States) and ignited with fuses, using mercury fulminate detonators. The coal is hand shoveled into ore cars, as much as possible of the coal adhering to the torbanite is removed with pinch bars, the place is trimmed where necessary, and the residue of coal is swept carefully and removed before the torbanite is shot.

Each of the four holes in the torbanite is loaded and shot in the same way as the coal, the broken rock is hand shoveled into ore cars, and the place is swept clean of torbanite.

¹¹/ Work cited in footnote 7.

Great care is taken to prevent mixing the coal and the torbanite to avoid contamination of the shale oil produced by retorting. Additionally, the care to exclude coal is necessitated by the increased load on retorting capacity and the uneconomically low yield of products therefrom.

The mine is ventilated by fans, and the air circuits are regulated by brattices.

The coal and torbanite are transported in 24-inch-gage railroad cars that hold about 1,500 pounds each. The coal is delivered to the cleaning and screening plant and the torbanite to the picking and crushing plant.

The torbanite from the two adits was mixed at the picking and crushing plant, and the coal from both adits was mixed at the cleaning and screening plant.

The mine is classed as nonfiery, and electric cap lamps are used for illumination.

Productivity and Costs

The Ermelo mine has a large number of employees in proportion to the production. In the mining operations 675 natives and 26 white men are employed underground and 230 natives and 8 white men above ground. Underground and surface mine labor is done almost entirely by the natives, and under the supervision of white men, and white men load the holes and fire the shots.

In 1947 the mine was operated in 2 shifts of 9.5 hours each, portal to portal, 6 days a week. The average gross production during the latter part of 1947 was 55,000 tons a month, divided approximately into 20,000 tons of torbanite, 30,000 tons of coal, and 5,000 tons of waste. This production was equivalent, approximately, to 30 tons of torbanite or 75 tons of torbanite plus coal, or 85 tons of gross production, including waste, per native underground per month. The 230 natives and 8 white men employed in the above-ground operations of the mining section were engaged mainly in transporting the torbanite to the crushers and the coal to the cleaning and screening plant and thence to the coal-loading station, the boiler house, producer-gas house, and waste dump.

The underground natives receive a minimum of 53 cents a day plus food, including beer brewed in the native compound, quarters, and hospitalization. White miners are paid 60 cents an hour (\$5.70 a day), the mine overseer \$320.60 a month, and shift bosses \$220.41 a month, excluding cost-of-living allowance.

Because of the dual nature of the mining operations and the fact that a large proportion of the mine output is coal of little market value, the proportion of the total cost of operating the mine that should be charged as cost of mining the torbanite is problematical, and figures for costs of mining are not given in this report.

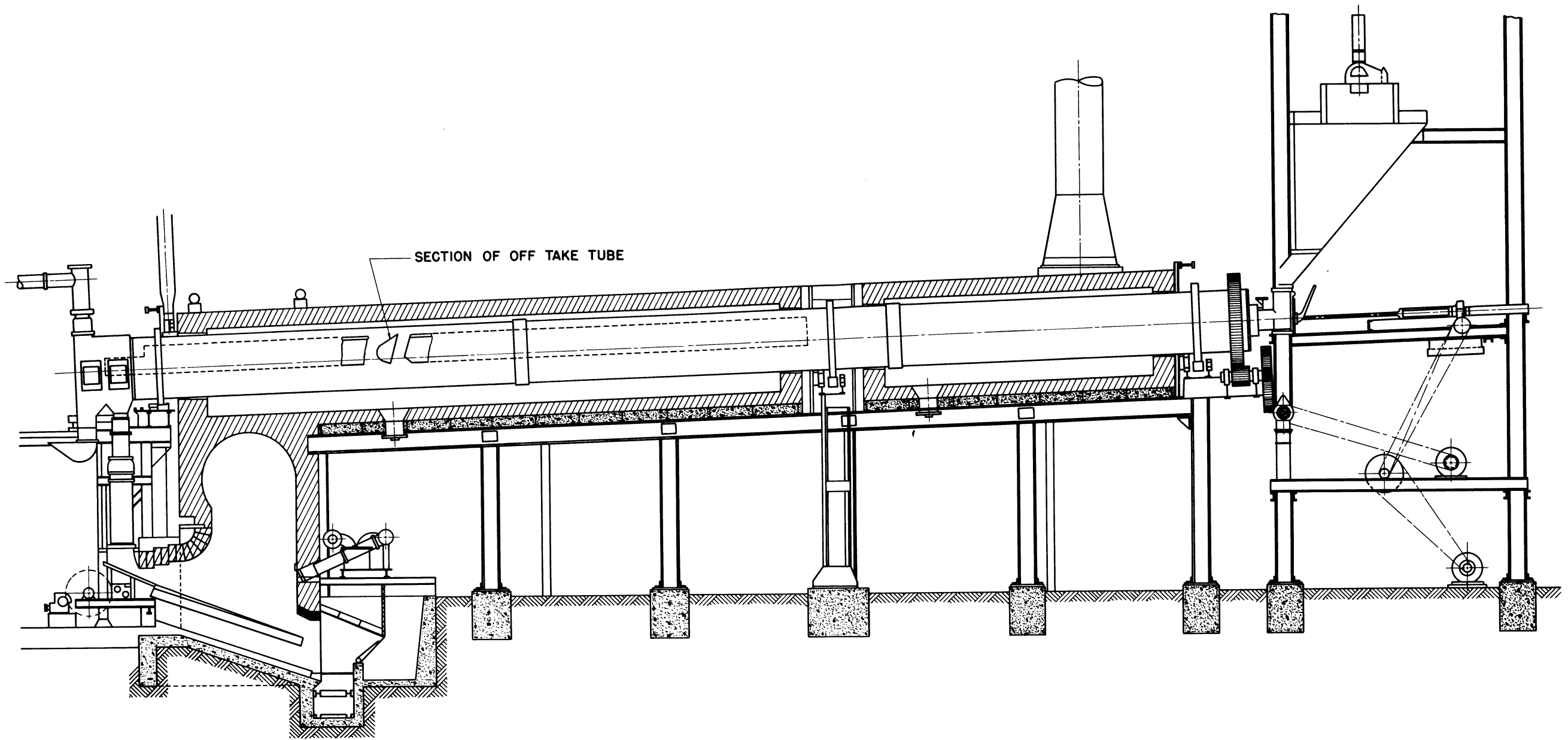


Figure 6. - Sectional view of Davidson retort.

Crushing and Retorting Plant

The retorting plant at Ermelo consists of the torbanite crushing and screening plant, a unit of 4 Davidson rotary retorts, and 10 Salerno retorts. There are also the auxiliary facilities needed to operate the retorts, such as seven gas producers to supply fuel gas. (See fig. 3.)

Shale Crushers and Gas Producers

The shale crushing and screening plant and the producer-gas generators are operated as a unit of the retorting section. The producer-gas plant comprises seven generators and their auxiliary facilities. The 7 gas producers consume an average of approximately 57 tons of coal a calendar day and generate 4,500,00 cubic feet of cold gas with a calorific value of 130 B.t.u. a cubic foot, at a conversion efficiency of 55 percent.

Crushing and screening. - The torbanite is received at the crushing plant (fig. 3) as run-of-mine shale and crushed in three stages. The primary single-roll crushers break the torbanite to 6 inches or slightly larger size. The secondary crushers, which also are of the single-roll type, reduce the run of the primary crusher to 3 to 4 inches, and the double-roll tertiary crushers are set to deliver 1-inch and smaller particles. The torbanite is not screened between the stages of crushing.

The shale from the tertiary crusher that passes over a 1-inch screen is charged to the Davidson retorts or cycled back to the crushers; shale that passes through the 1-inch screen is charged to the Salerno retorts. The crushed shale is transported by belt conveyors to elevated bunkers from which it is fed through an automatic weighing machine to each retorting unit, first passing over a magnetic pulley to remove "tramp iron," which might damage the retorts. No shale is discarded as fines. Figure 3 shows the position of the 2 torbanite stockpiles, 1 for the Davidson unit, and the other for the Salerno retorts.

Davidson Retorts

The Davidson rotary is an example of the indirectly heated rotary type of retort. It was used in Estonia as early as 1932 and has been described adequately in the literature.^{12/13/} The following description is quoted from the article by Stelling:

The Davidson retort tube consists of a slowly rotating cylinder, 4 ft. in diameter and 75 ft. long, sloping slightly towards the discharge end (fig. 6). This tube rotates in a fire-brick-lined heating chamber which is in two parts--the preheating and drying section at the feed end, about one-third of the total length, and a carbonizing

^{12/} Davidson, T. M., The Davidson Rotary Retort: Proceedings of a Conference on Oil Shale and Cannel Coal, Glasgow, Scotland, June 1938, pp. 157-173, The Institute of Petroleum, (London) 1938.

^{13/} Stelling, Robert, Oil Shales and Torbanite: Jour. Chem. Met. Min. Soc. South Africa, vol. 43, 1942, pp. 34-55.

section separated from the preheating section by a gap in which are located the intermediate supporting rollers. Heat is generated in a combustion chamber at the discharge end by burning the noncondensable retort gases, as in the Scottish retorts, and by providing additional fuel. The gases of combustion pass along a flue alongside the heating chambers, into which they are admitted through a row of ports, the closing of which, wholly or partially, regulates the heat distribution and temperature gradient throughout the chambers. In Estonia, the temperature falls from 610°C . at the discharge end to 565°C . at the upper end of the carbonization section, and the highest temperature in the preheating section is 275°C - 300°C . At Ermelo, the temperature is kept practically constant throughout the carbonizing section at 630°C ., and at 410°C . in the preheating section. Power consumption is 10.8 kw.-hr. per metric ton retorted in Estonia. This is reduced to 8 at Ermelo.

Coke Removal

One of the drawbacks of any indirect heating system applied to low temperature carbonization is the tendency to form coke on the shale side of the heating surface, and one of the Davidson patents applied to this rotary kiln consists of an ingenious device for scraping the coke off the cylinder walls. This train of scrapers, which overlap each other's working stroke, rides on the top of a D-shaped tube running through the center of the retort, acting as the gas offtake. The scrapers are moved by a long central shaft, which emerges at the feed end, and has a slow reversing movement (once in 15 minutes) imparted to it from a worm gear with reversing belts driven by a separate electric motor. This shaft also operates a train of push-plate scrapers inside the D-tube. This tube forms the gas offtake, and must be kept clear of dust, so the plates are pivoted to move the dust out of the tube towards the feed end of the retort. The D-tube is fixed to the discharge end, and rides inside the tube in roller bearings, the outer races of which are carried in spiders fixed to the tube shell. There is no lubrication of these races, and their temperature is probably around 400°C . The seals to atmosphere at both ends of the retort consist of rubbing rings held in position by springs.

The spent torbanite is discharged over a dam ring or circular sill (to maintain the thickness of the bed) into a discharge box, below which are two face-plate valves actuated by steam or air. These valves open and close in sequence so that spent material is dropped out of the discharge box without letting air get into the tube, or conversely, letting oil vapours escape and flash.

In Estonia the spent shale is discharged hot on to moving bar grates, where it is ignited to provide the heat for retorting. In Ermelo this is not feasible, due to the higher percentage of fixed carbon in the spent ore; hence, producer gas is mixed with torbanite gas to give the required heat.

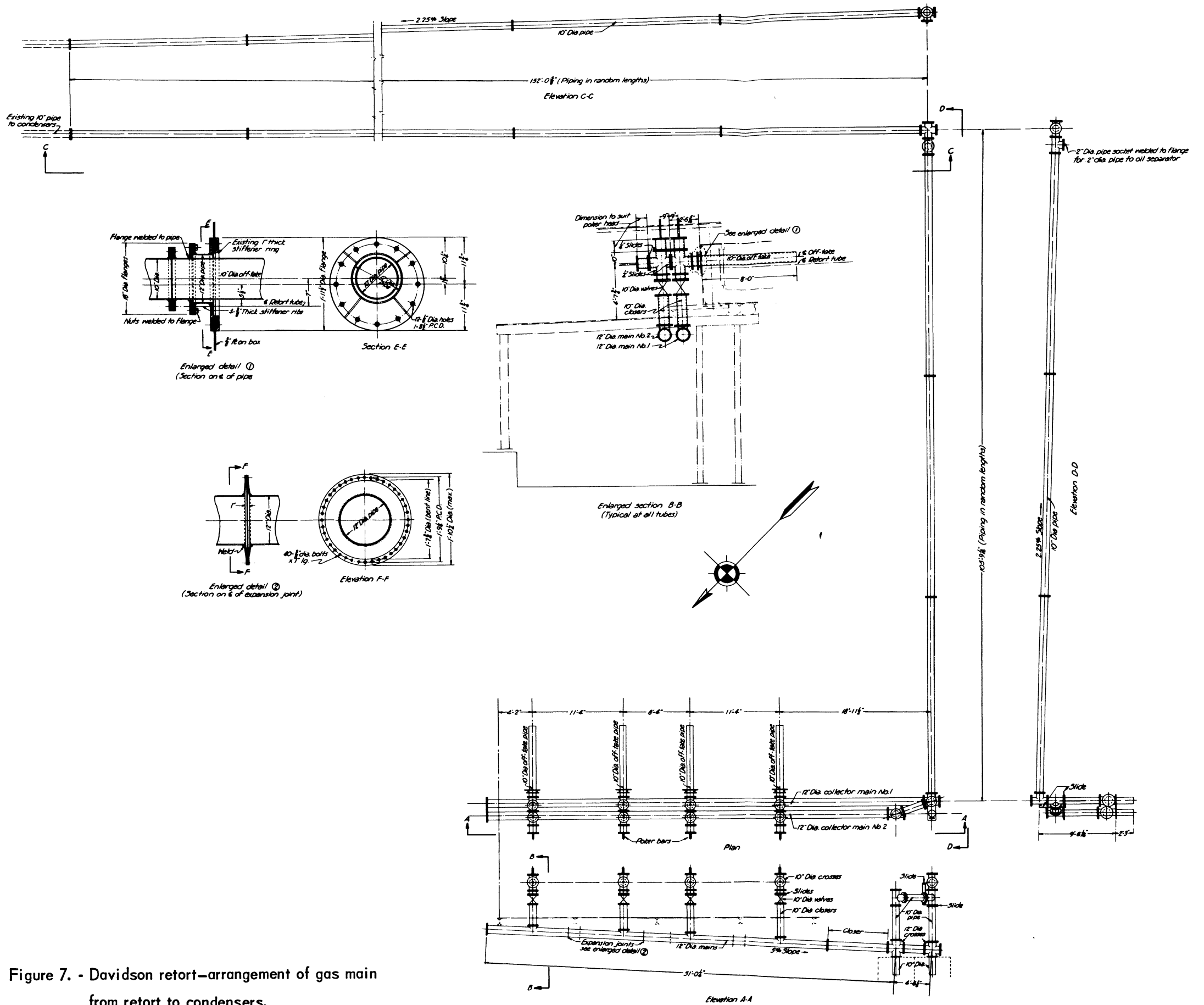


Figure 7. - Davidson retort-arrangement of gas main from retort to condensers.

The Davidson tubes are rated at 23 metric tons per day each in Estonia, and 30 short tons per day at Ermelo. The tonnage of the Davidson retort is limited by two factors: the depth of the charge or bed of shale in the retort, and the rate of heat transmission. The rate of feed can vary only between narrow limits, for it must be such that a rolling movement of the charge takes place. Too little causes the charge to slide only, with a tendency to cake, while too rapid movement prevents adequate heating.

The Davidson retorts were altered as a result of experience with their operation at Ermelo. The internal D-shaped tube and scrapers, mentioned by Stelling and by Davidson, were removed, and the retort tubes have no internal mechanism. In place of these dust catchers and coke scrapers, poker bars with piston heads were fitted into the 10-inch-diameter offtake pipes (fig. 7, plan and elevation A-A), with which dust and coke are pushed back periodically into the retort tubes.

Operation of Davidson Retort. - The Davidson unit of 4 tubes at Ermelo is charged at the rate of about 30 tons a tube a day, or 120 tons of torbanite ranging in size from 1 inch to 3 to 4 inches for the 4-tube unit. A weighmeter for each tube weighs the charges. The shale is heated to approximately 400°C. (750°F.) in the drying and preheating section, and the temperature in the retorting section ranges from 600°C. (1,100°F.) at the charging end to 650°C. (1,200°F.) at the discharge end of the tubes. The unit is heated by burning approximately 130,000 cubic feet of retort gas (1,000 B.t.u.) and 1,000,000 cubic feet of producer gas (130 B.t.u.) a day (2,167,000 B.t.u. a ton of shale). No attempt is made to burn the oil-spent shale.

The average Fischer assay value of the shale charged to the Davidson retorts in September 1947 was 56 U.S. gallons a ton, and the average recovery was 49 gallons a ton, or 88 percent of the assay value, excluding the filter cake. An additional 1,000 gallons of oil a day is obtained by charging to the Davidson and Salerno retorts the oil-soaked cake formed in filtering the shale oil produced by the retorts. Thus the production of the Davidson rotary retort unit at Ermelo is approximately 150 barrels of crude shale oil an operating day. This yield includes the proportional part of the scrubber naphtha extracted from Davidson and Salerno retort gases in the naphtha scrubber.

Salerno Retorts

Stelling^{14/} has given an excellent description of the Salerno retorts at Ermelo:

The Salerno principle is basically the external and progressive heating of small particles kept in continuous movement, so as to secure repeated brief contacts of the particles with a heated surface and constantly renewed contacts of particle with particle, thus

^{14/} Work cited in footnote 13.

largely increasing the efficiency of heat transfer. In practice, this is carried out by heating and agitating the material in a series of semicircular troughs (fig. 8), which are heated from the underside by products of combustion.

Salerno Retort

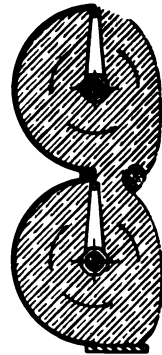
Each retort (fig. 8) consists essentially of a series of 36 semicircular mild steel troughs, 8 in. radius, 7 ft. 6 in. long, riveted together; these troughs form the bottom of the retort, the material is fed into these troughs and is heated through them. Side, end and top cover plates of mild steel form the closed vapour space. Below the troughs is built a gas-fired fire-brick furnace, consisting of a combustion chamber under the first nine troughs, and six flues leading away from this, along the underside of the troughs to the chimney at the discharge end of the retort. A shaft, having sixteen T-shaped paddles attached to it (fig. 8), revolves in each trough; the shaft is placed on the center-line of the trough, and there is about 1/4 in. clearance between the trough and the paddles. The shaft passes out through glands in the side plates, and is driven at 5 r.p.m. through bevel gears from a line shaft.

The action of the rotating paddles is such that the material is agitated, mixed, and transported from trough to trough coming into intimate contact with the discharge mechanism, which consists of two horizontal spiral conveyors and one vertical spiral. These are so constructed that the vertical spiral always remains full of material, ensuring that oil vapour will not escape from, nor will air gain access to, the inside of the retort.

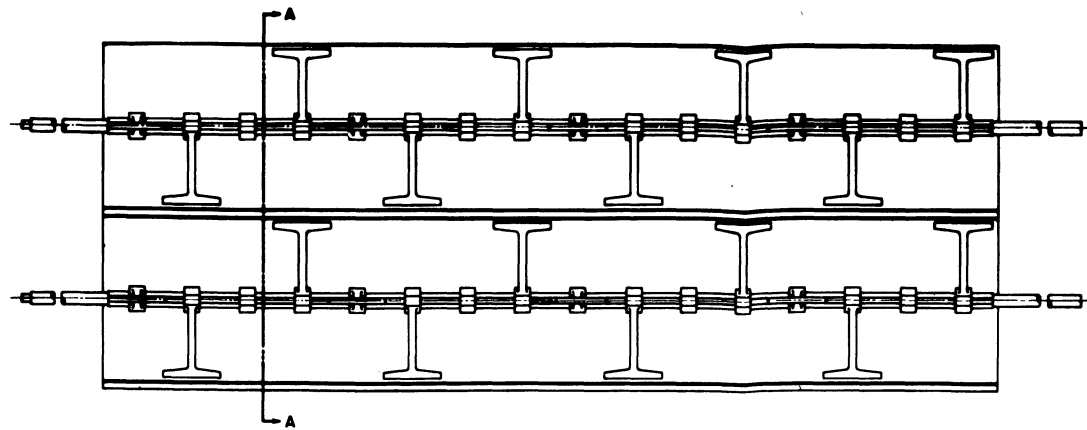
As the material moves along the retort it becomes heated. At No. 14 trough the temperature has reached 300° C. or over, at the end of the retort the temperature is between 450° and 500°, this temperature being carefully controlled, as the efficiency of the process depends mainly on this temperature.

Originally, delayed combustion was adopted to maintain the correct temperature gradient of the gas, but it was abandoned due to the deleterious effect of the reducing conditions on the troughs. The present method is outlined below.

Torbanite gas, augmented by producer gas, is burnt in the combustion chamber under the first nine troughs, which are suitably protected, and provision is made for the addition of gas further along the flues under the troughs to raise the temperature toward the discharge end of the plant without excessively increasing that at the feed end. After leaving the underside of the troughs the flue gases pass directly to the stack at a temperature of 600° C. The heat input to the combustion chamber amounts to 17-19 therms per ton of torbanite carbonized, while 2-4 therms are applied from the smaller burners towards the discharge end. The oil vapours are



SECTION A-A



VIEW OF TROUGHS SHOWING FLOW OF MATERIAL THRU RETORT

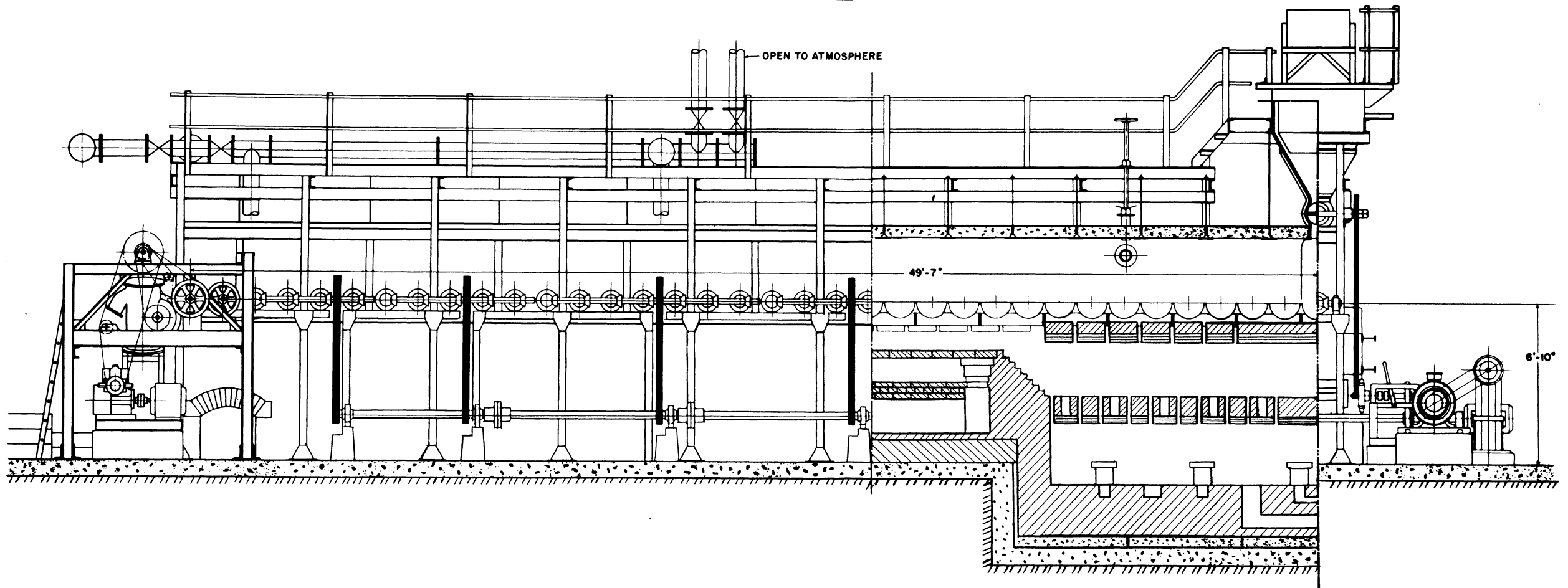


Figure 8. - Elevation and sectional elevation of a Salerno retort.

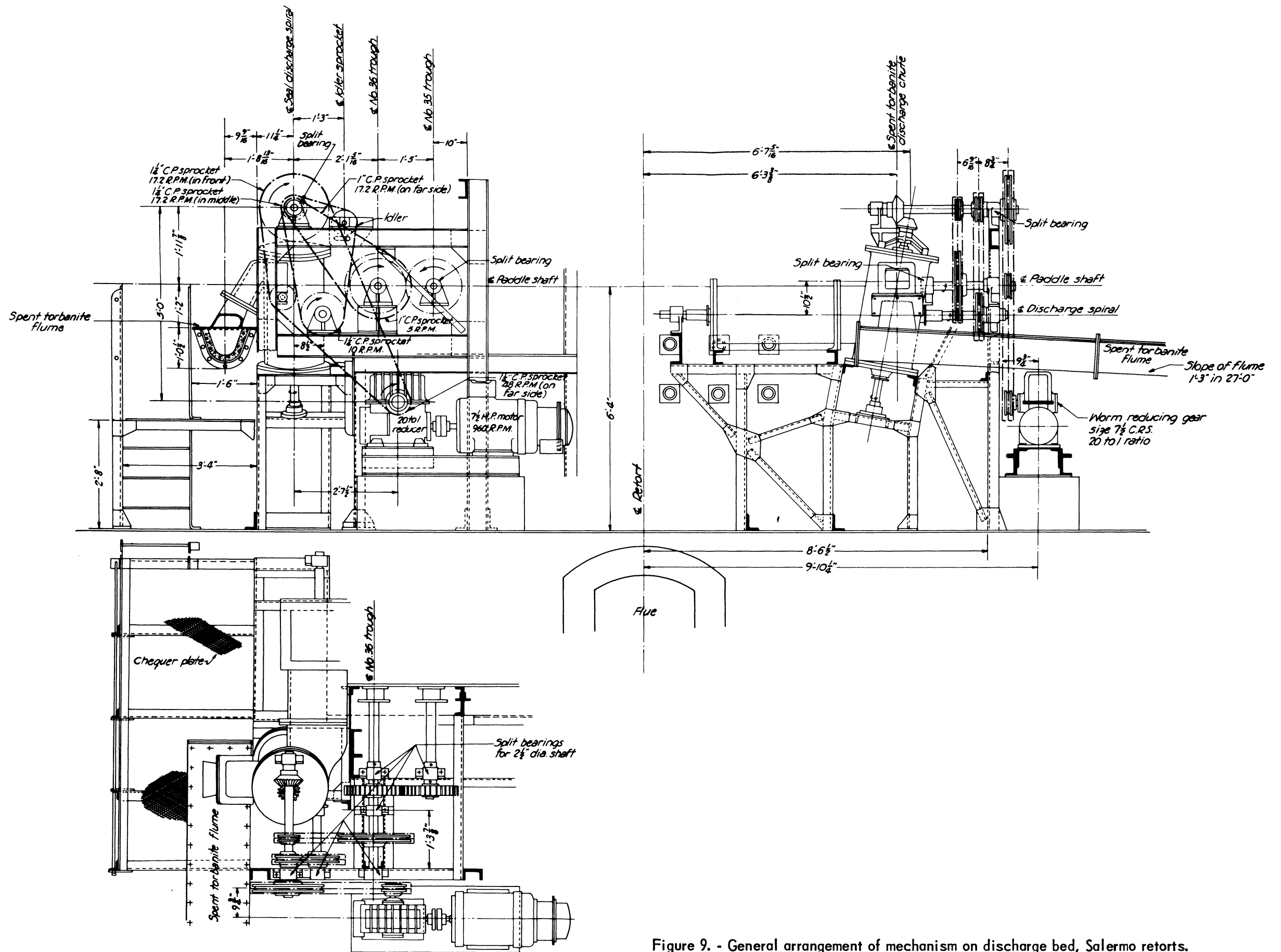


Figure 9. - General arrangement of mechanism on discharge bed, Salermo retorts.

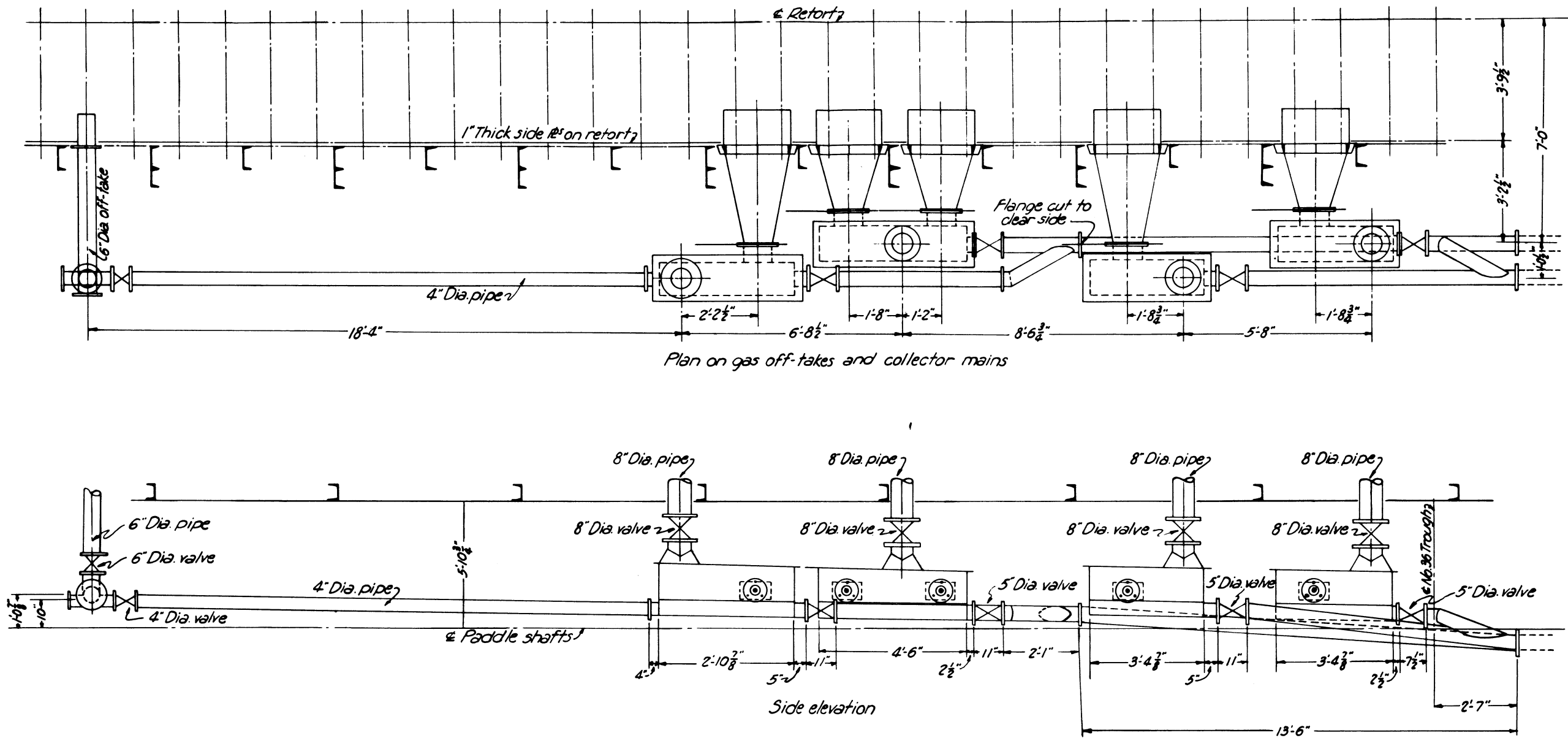


Figure 10. - Arrangement of gas off-takes, collector mains, and oil piping for Salerno retorts.

removed through offtake pipes and led to the condensers. The length of run averages above 110 days with 14-19 days for overhaul.

The rating of the Salerno retort is 75 long tons a day, and the power consumption does not exceed 3.5 kw.-hr. per long ton retorted. Troughs are of mild steel boiler plate, shafts are of 0.3 carbon mild steel, and paddles are cast steel with 0.3 percent carbon and 0.6 percent manganese.

Some of the operating temperatures, heat inputs, capacities, and yields mentioned in the foregoing quotation from Stelling's paper of 1942 differ materially from corresponding values for 1947 given in this report. The latter data, in turn, differ from those reported in 1950.^{15/} The progressive improvement in operating practices, yields, and other factors disclosed by these successive reports is due to the changes that have been brought about by trial and experiment to determine the most favorable conditions of operation.

At the time Stelling's account was written there were only 4 Salerno retorts at Ermelo (fig. 3) and retorts 5 to 10 were installed later. These retorts have an improved discharge mechanism, which is shown in figure 9, and an improved arrangement of gas offtakes, collector mains, and oil piping, shown in figure 10. The troughs, paddles, and paddle shafts of the latter retorts were constructed of special alloys for better heat and corrosion resistance.

Figure 11 shows the houses for Salerno retorts 5 to 10, with 2 smoke stacks in the middle ground and the overhead shale conveyor in the background.

Operation of Salerno Retorts. - The 10 Salerno retorts have an operating capacity of 67 tons of torbanite each a calendar day, or 670 tons a day for the 10 retorts. A retort is kept in operating status 140 days and then cooled, overhauled, and brought up to temperature again in about 3 weeks. Therefore, an operating cycle of a Salerno retort is approximately 160 calendar days and the "down-time" 13 percent. The throughput during an operating day averages 77.5 tons per retort.

The Salerno retorts are charged by feeding the torbanite that passes through the 1-inch screen at the crushing plant to the first trough of each retort through a star feeder. The shale charged to each retort is measured by a weightmeter. Oil vapors are withdrawn at various predetermined points along the retort, which facilitates the separation of clean and dirty oil.

The retorts are well instrumented, and operating conditions are stable. Combustion-chamber temperatures are approximately 1,100°C. (2,000°F.) and stack-gas temperatures 720°C. (1,330°F.). Temperatures of the torbanite in the troughs range from an average of 350°C. (660°F.) at the 13th and 14th troughs, to 460°C. (860°F.) at the 22d and 23d troughs, to 500°C. (930°F.) at the 26th to 36th troughs.

^{15/} Work cited in footnotes 6, 7, 8, and 9.

The oil yield is approximately 90 percent of the Fischer assay value excluding recovery from filter cake. For a charge that averages 56 gallons a ton in assay value this yield is 50 gallons a ton, including approximately 2 gallons of scrubber naphtha extracted from the retort gases in the naphtha scrubber. For the 10 Salerno retorts the production is 34,000 gallons (810 barrels), a calendar day.

The gas yield is approximately 1,400 cubic feet a ton of shale, or 940,000 cubic feet a calendar day, from the 10 Salerno retorts.

Fuel consumption per retort per day is approximately 70,000 cubic feet of retort gas (1,000 B.t.u.) and 500,000 to 650,000 cubic feet of producer gas, depending upon its heating value, at the rate of 1,800,000 B.t.u. a ton of torbanite retorted.

The spent shale ranges between 40 and 42 percent in fixed-carbon content and has a calorific value of 6,000 B.t.u. a pound. It is not considered a desirable fuel in view of the availability of coal of low market value, and no attempt is made to use it.

At the time of the authors' visit to the Ermelo plant in October 1947 experiments in the use of steam in the vapor space of the Salerno retorts had just begun, and conclusive results had not been obtained. It was thought that injection of steam not only would improve yields of oil by reducing decomposition of oil vapors into fixed gases, but would improve the quality of the oil by promoting removal of oil vapors at lower temperatures.

The Salerno retorts at Ermelo are said to give definite evidence of "fractional eduction" of oil from the torbanite. Although the gas and vapors from the offtake pipes are mixed in a gathering main between the retorts and the condensers, samples taken from each offtake are different in gravity and boiling range.

Condensing, Filtering, and Gas Scrubbing

The mixture of gases and vapors from the Davidson and Salerno retorts is conducted through collector mains to the condensers, which are a combination of direct water contact and water cooled condensers. The water contact tubular condensers are necessary because of the fouling of the tubes, which would be experienced on conventional tubular condensers. The collector mains have water sprays. The heavier condensate, which contains about 5 percent of dust and a substantial proportion of emulsified water, is filtered hot (150°F.) at pressures of 40 to 55 pounds per square inch through conventional plate filter press using canvas filter cloth. The filtered oil contains approximately 0.2 percent ash and 0.5 percent "bottom settlings and water". An analysis, made at the Bureau of Mines Oil-Shale Laboratory at Laramie, Wyo., on a sample of the filtered oil as received at the Boksburg refinery is given in table 3. The filter cake is scraped off the cloth and recharged to the retorts, yielding 1,000 to 1,500 gallons of oil per calendar day.

The uncondensed vapors and fixed gases from the water-cooled condensers are scrubbed in an absorption plant operating at substantially atmospheric pressure. The absorption oil is a distillate of approximately 26° API gravity (specific gravity 0.900 at 60°/60°F.). The production is approximately 1.5 gallons per 1,000 cubic feet of gas, or 1,000 gallons a day, of scrubber naphtha of 70° API gravity (specific gravity 0.702 at 60°/60°F.) and 11 pounds Reid (absolute) vapor pressure. The condensing and scrubbing plant is not efficient by present standards, as is indicated by the low vapor pressure of the naphtha and the high heating value of the gas. Improvements are contemplated.

Disposal of Spent Shale and Ash

The production of spent shale is approximately 65 percent of the shale charged, or 500 tons a calendar day. The spent shale from the Davidson unit is carried on a drag link conveyor to an ash bin (fig. 3) and then by the rope railway to a dump. Coal ashes from the producer-gas generators and the boiler houses are removed in the same manner. The spent shale from the Salerno retorts is disposed of by using flumes (fig. 9) with water flushing, and part of the water is recovered and cycled back to the plant from the spent-shale settling basin (not shown).

Productivity and Costs

The crushing and retorting plant at Ermelo in October 1947 had the following operating personnel:

<u>Unit</u>	<u>Native</u>	<u>White</u>
Davidson retort	6	1
4 old Salerno retorts	10	1
6 new Salerno retorts	11	2
Crushers and gas producers ...	23	1
Oil handling	4	1
Operator	<u>1</u>	<u>1</u>
Total, per shift	54	7
Three shifts	162	21
Over shift	-	4
Relief	27	2
Spare gang	<u>12</u>	<u>1</u>
Overall total	201	27

The retorting superintendent and the supervisory and technical staff also devote part of their attention to the crushing and retorting.

In 1 month these 201 natives and 27 white men crush and clean 20,500 tons of torbanite, retort it, and produce 23,000 barrels of shale oil. Incidentally, they also handle 2,100 tons of coal, that is consumed in generating producer gas used as fuel for the retorts.

The Ermelo plant has several unusual characteristics, which differentiate it from other oil-shale mining and retorting operations. Nearly twice as much coal as torbanite is mined. The coal has low market value, therefore the cost of mining the thin seam of torbanite is comparatively high, and expenditure to conserve heat or fuel at the expense of oil yield or to save coal is not justified. The concurrent mining of coal and shale creates a safety hazard that is seldom present in shale mines. Wage rates for native workers are low, which reduces the need for mechanical equipment to replace manual labor.

REFINING OPERATIONS AT BOKSBURG NORTH

The refinery of the South African Torbanite Mining and Refining Co. is at Boksburg North, Transvaal, about 20 miles east of Johannesburg. Crude shale oil is shipped by rail from the retorting plant near Ermelo, about 120 miles.

The refinery at the time of the authors' visit in October 1947 consisted essentially of (1) a combination crude distillation and cracking unit; (2) a vacuum-distillation unit to reduce the residuum from the combination unit to penetration asphalt, a gas-oil overhead, and a heavy-oil side cut; (3) a caustic soda and dilute sulfuric acid washing plant for pressure distillate; (4) a Lachman zinc chloride treating plant; and (5) a tar-acid plant for recovering crude or refined cresylic acids. Figure 12 shows a general view of the refinery, and figure 13 gives a flow diagram of the refining operations. Changes that have been made in the refining operations since the authors' visit were reported by G. G. Robertson^{16/} at the Second Oil-Shale and Cannel Coal Conference in Glasgow in July 1950.

Various units in the refinery were not designed either for the capacity or the conditions for which they were being used; consequently the units were not in good balance or best suited to the desired type of operations. During the early part of World War II imported crude petroleum was refined in addition to shale oil because a special low freight rate was allowed by the Government-operated railroads to transport crude petroleum from Durban to the plant. Since the end of the war, these low rates are no longer allowed, and no crude petroleum has been refined.

The crude shale oil was produced at the average rate of 810 barrels (34,000 U. S. gallons--28,350 imperial gallons) a day at the Ermelo retorting plant. The normal throughput of the refinery was 1,640 barrels (68,900 U. S. gallons--57,400 imperial gallons) a day, so the refinery was on stream less than half the time.

The crude shale oil consisted of a mixture of the oils obtained at the retorting plant from the two types of retorts and the scrubber naphtha from the absorption plant. Analyses of the crude oil and products are given later in this report (see tables 3, 4, 5, and 6).

^{16/} See footnote 9.

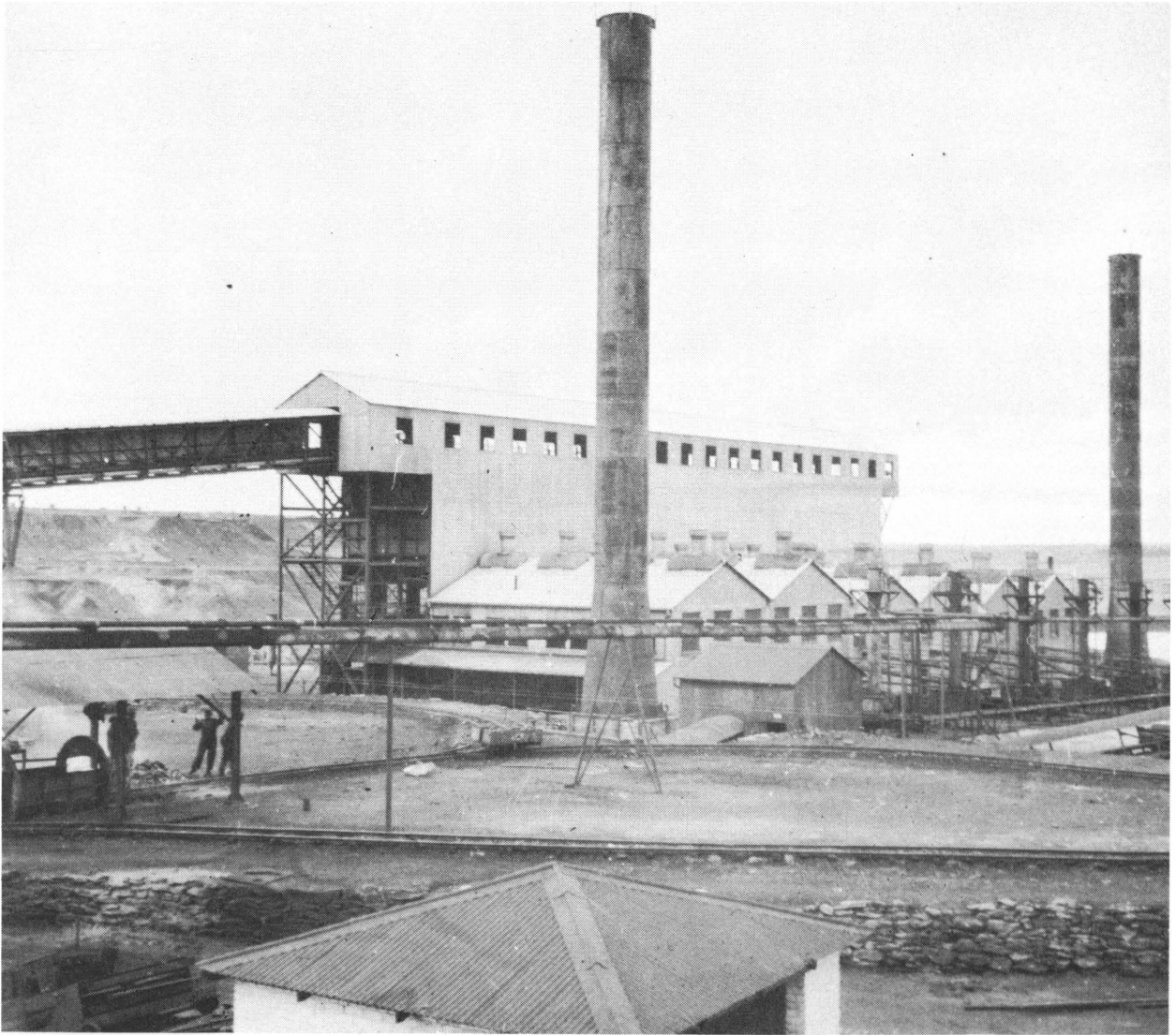


Figure 11. - Houses for Salerno retorts 5 to 10, Ermelo, Transvaal, Union of South Africa.

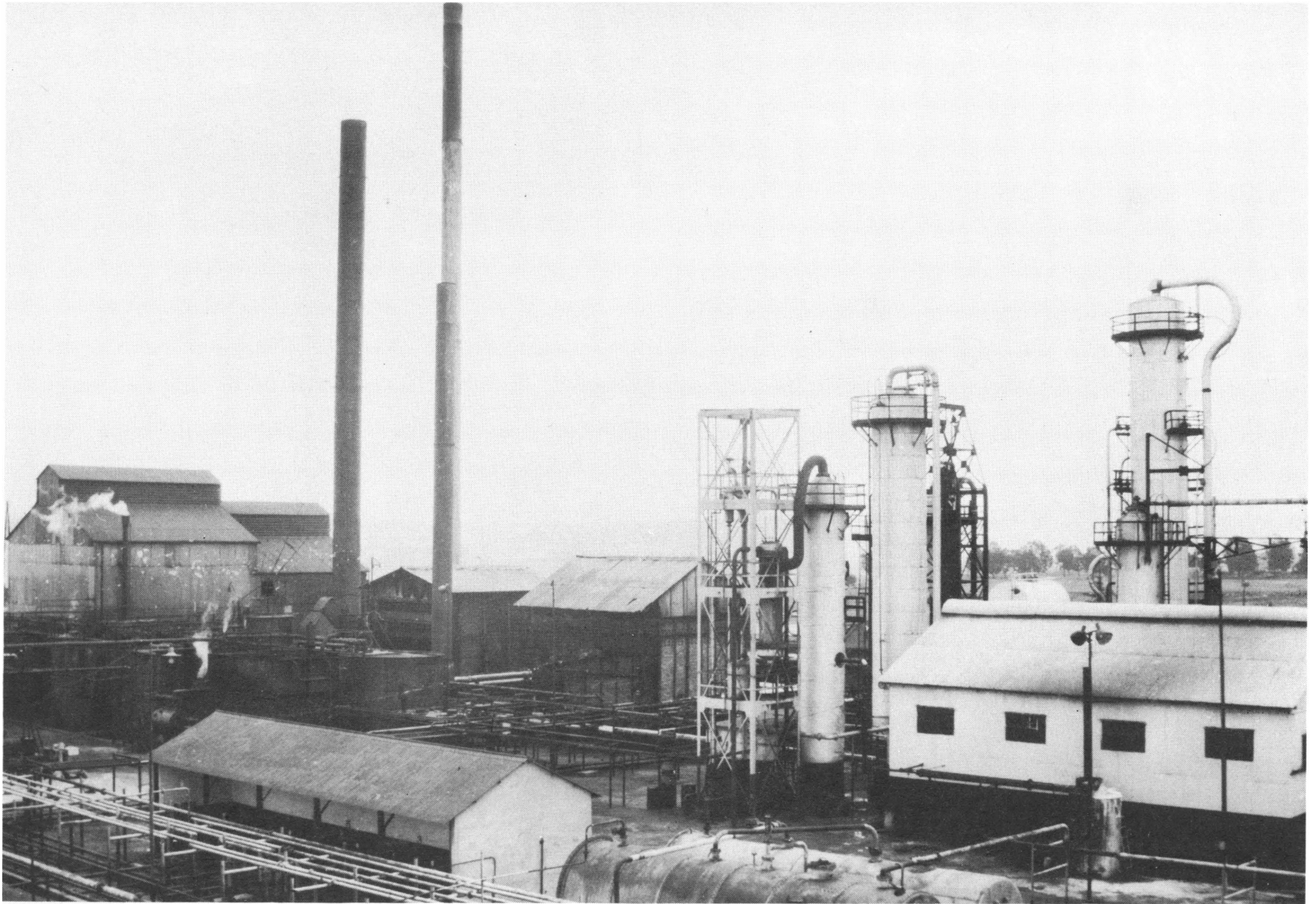


Figure 12. - South African Torbanite Mining and Refining Co., shale-oil refinery at Boksburg North, Transvaal.

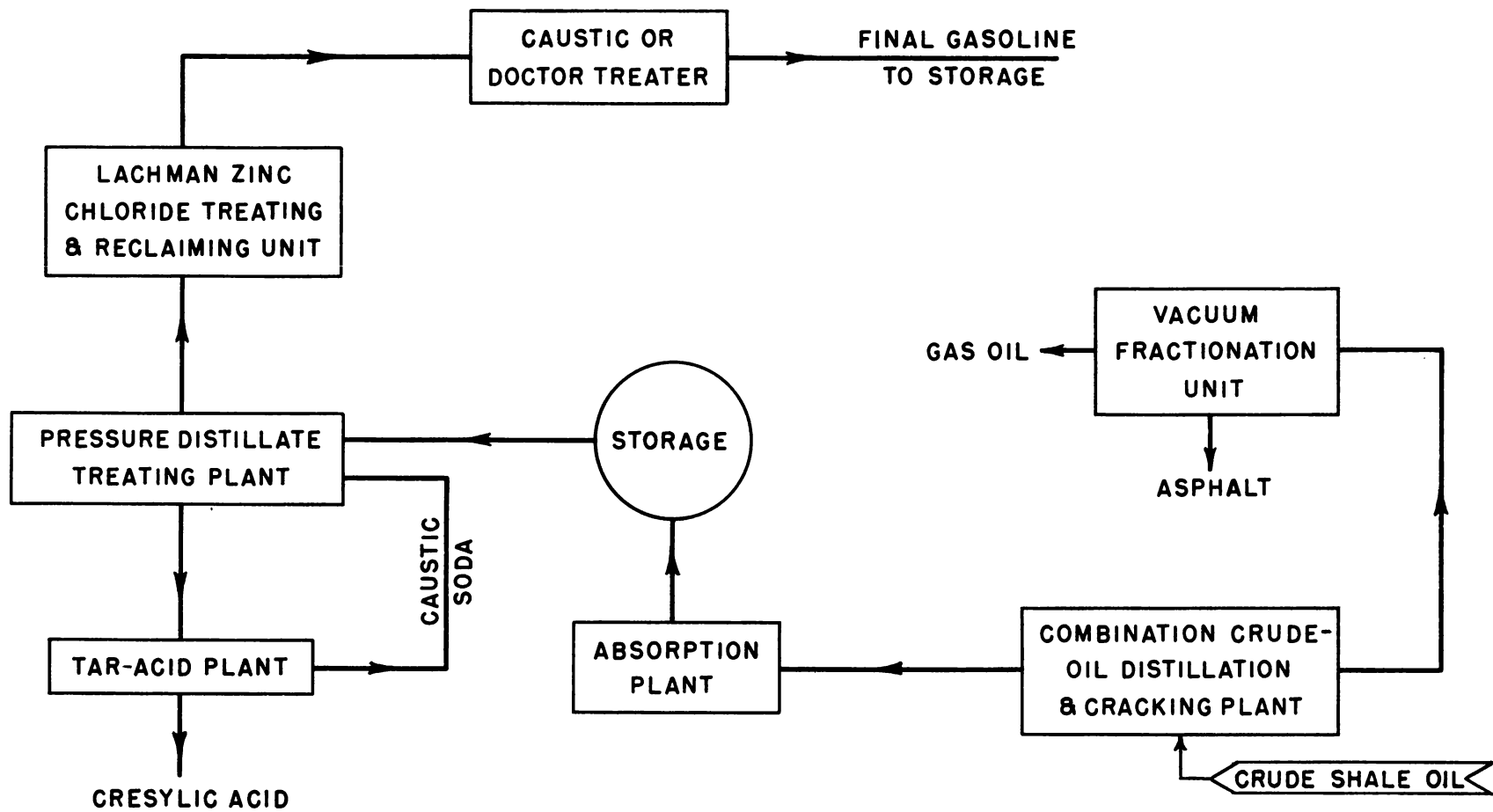


Figure 13. - Flow diagram of shale-oil refinery.

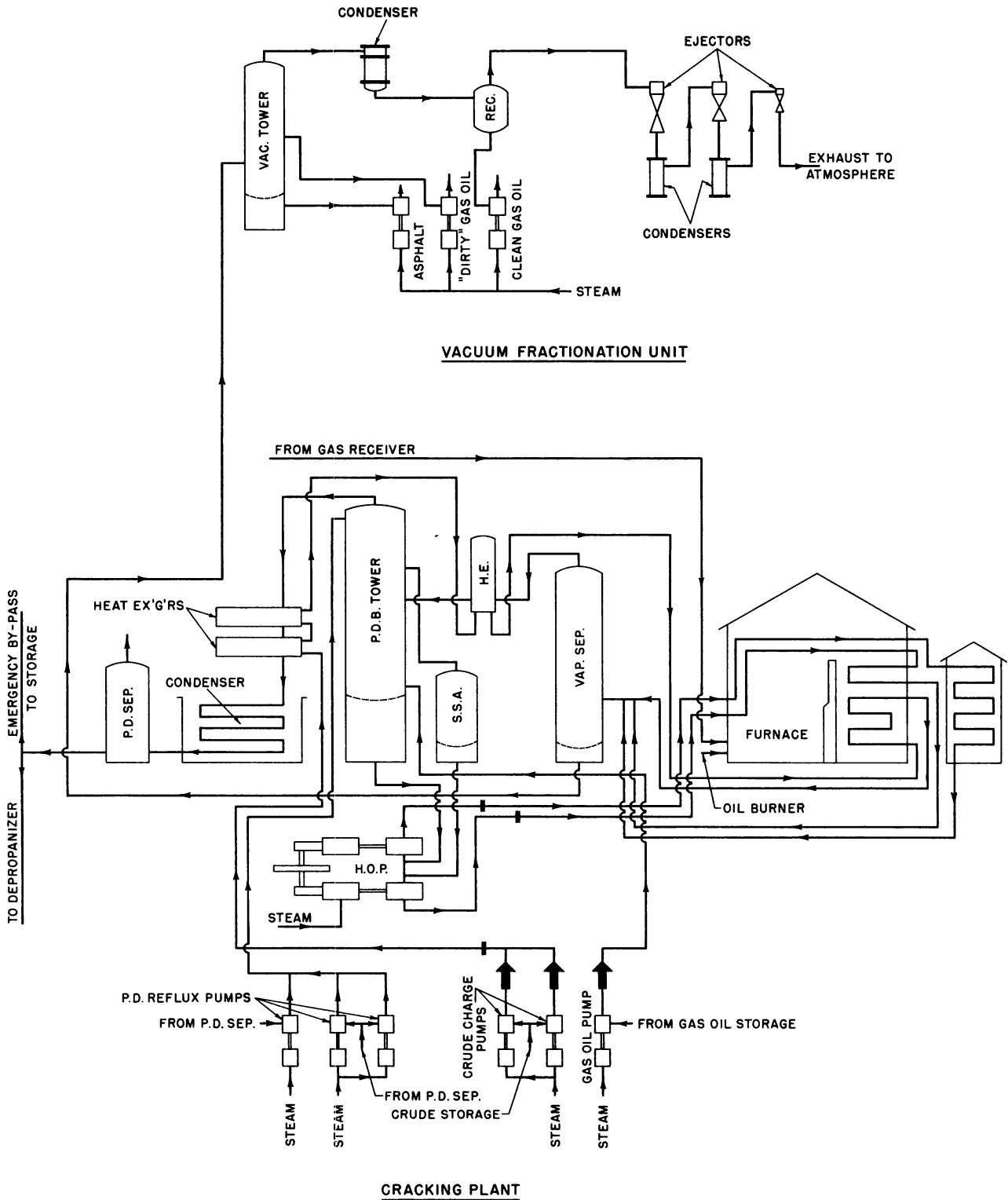


Figure 14. - Flow diagram of combination crude-oil distillation and cracking plant.

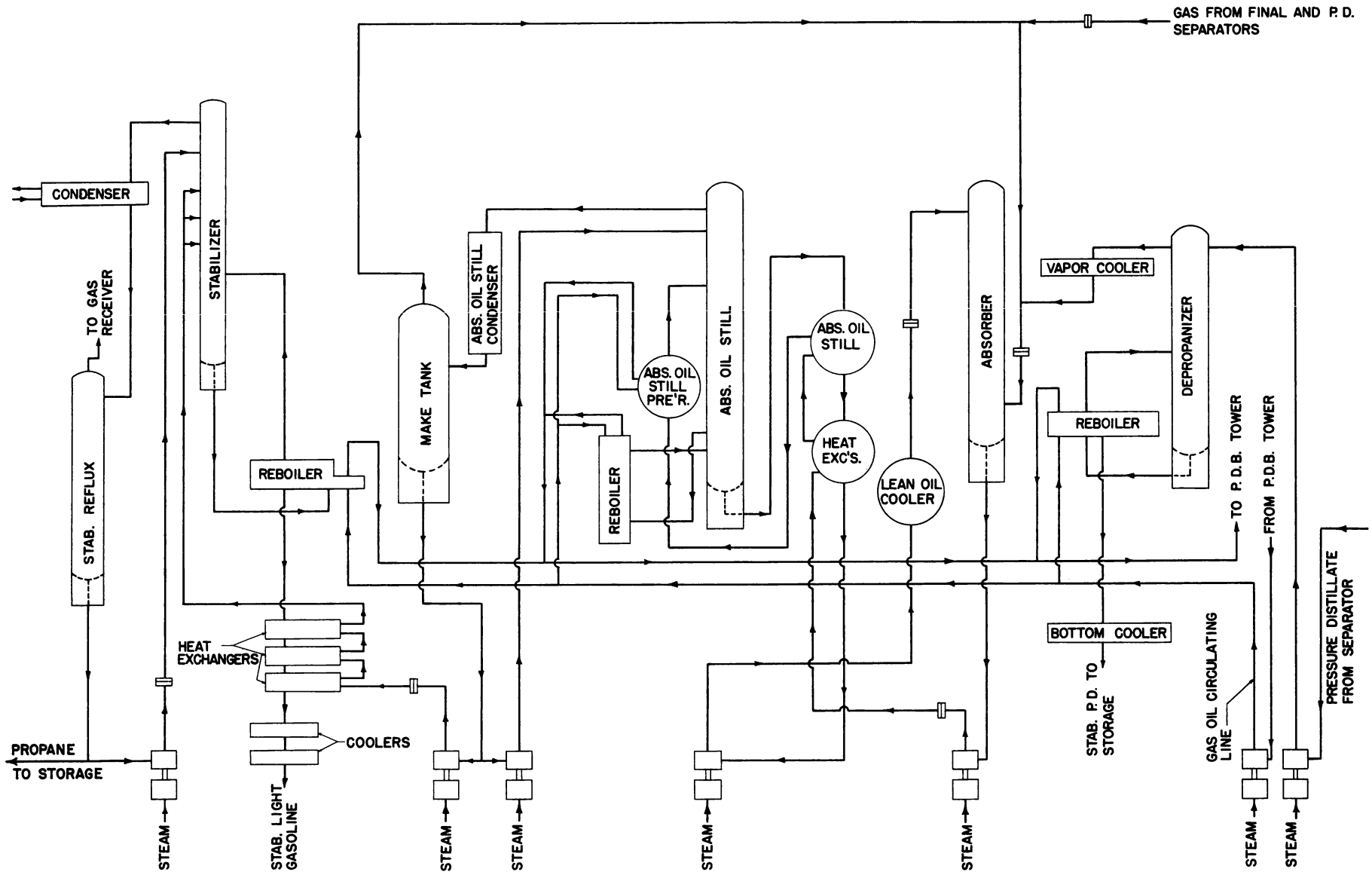


Figure 15. - Flow diagram of absorption plant.

Crude Oil Distillation and Cracking

The combination crude-oil distillation and thermal cracking unit is of Winkler-Koch design, but a number of revisions have been made in arrangement and operation. A flow diagram of the distillation and cracking units is shown in figure 14. It has 3 separate tube stills, 1 for crude shale oil and 1 each for the gas-oil and light-oil cracking stocks. The light-oil and crude-oil tube stills are heated in the same furnace, and the gas-oil still has its separate smaller furnace. The tubes in all 3 stills are 3 inches internal diameter and 26 feet long. The light-oil still is made up of 52 lengths of tubing, and the gas-oil still has 82 lengths of tubing. The streams from the 3 stills are reduced to 65 pounds per square inch outlet pressure and mixed before injection into the vapor separator or vaporizer tower.

Crude shale oil from storage is pumped through 3 heat exchangers and then through the tube still at a cold-oil velocity of about 3 feet per second, where the temperature of the oil is raised to 700°F.

The gas-oil cracking stock is pumped at a velocity of about 8 feet per second from the bottom of the pressure-distillate bubble tower through its pipe still, where its temperature is raised to 880°F. Portions of the overhead and side-stream cuts from the vacuum tower, not required for asphalt cutback stocks, are introduced into the bubble tower, from which they reach the cracking-stock charges.

The light-oil cracking stock is taken as a side stream from the pressure-distillate bubble tower. This cracking stock has a boiling range similar to a kerosine, and usually a portion of the stream is withdrawn for asphalt cutback stock. The remaining cracking stock is pumped through its pipe still at a cold-liquid velocity of 6 feet per second. The transfer temperature of the oil is maintained at 980°F.

As mentioned previously, the three hot-oil streams are mixed and then injected into the vapor separator where the vaporized products pass overhead to the pressure-distillate bubble tower and the unvaporized residuum passes hot to the vacuum tower.

Light-oil and gas-oil cracking stocks are removed as a side stream and bottoms, respectively, from the bubble tower. The overhead vapors pass through two crude-oil heat exchangers, a condenser, and a pressure distillate-gas separator to the depropanizer. A flow diagram of the absorption plant and stabilizing units is shown in figure 15. Stabilized gasoline from the bottom of the depropanizer is pumped to storage for chemical treatment. The overhead gases from the depropanizer, together with the off gases from the pressure distillate separator and other wet plant gases, pass through an absorption, distillation, and stabilization system where a light, stabilized gasoline, propane, and dry gas are separated.

Vacuum Distillation

The hot residuum from the vaporizer of the combination crude distillation-cracking unit is run directly to a Winkler-Koch vacuum tower, from which a gas-oil overhead, a "dirty" gas-oil side stream, and asphaltic bottoms are produced. An absolute pressure of about 3 inches of mercury is maintained on the vacuum tower, using 3 steam ejectors and condensers. The asphaltic bottoms usually have a consistency of about 100 penetration and are marketed either as road oils or cutback asphalts of slow-, medium-, or rapid-curing types. The vacuum gas oils are used either as cracking stocks or as cutback solvents.

Chemical Treating of Pressure Distillate

The stabilized pressure distillate is caustic washed, washed with dilute sulfuric acid, contacted in the vapor phase with zinc chloride (Lachman process), and finally washed again with caustic soda, giving a finished gasoline that is blended with benzol and alcohol to produce motor fuel.

The first caustic soda washing is done in 3 stages, as shown in figure 16, using a 20-percent caustic solution and adding makeup alkali to maintain this strength. The caustic solution and pressure distillate are agitated by mechanical paddle-type mixers, then separated in large settling tanks. This treatment removes hydrogen sulfide, low-boiling mercaptans, and tar acids from the pressure distillate. The tar acid-caustic mixture is pumped to "cresylate" storage for subsequent refining in the tar-acid plant.

The caustic-washed pressure distillate is mixed with 20 percent sulfuric acid; the mixture is agitated, and then separated in large settling tanks. The distillate receives two similar additional acid treatments by counter-current flow of acid to distillate using the pumps and circulating system shown in figure 16. The acid strength is maintained at 20 percent by frequent additions of new acid. The acid requirements are small, as little chemical action takes place other than neutralization of the tar bases, which average 0.8 percent. The overall loss of the pressure distillate by caustic and acid washing averages 3.5 percent.

Lachman Process. - The caustic- and acid-washed pressure distillate undergoes further treatment by the Lachman process,^{17/} primarily to reduce its gum content and to improve its color and gum stability in storage. The pressure distillate is revaporized, contacted with boiling zinc chloride solution at 300°F., and fractionated into a gasoline overhead and polymer residue in a final bubble tower. The zinc chloride solution in the contact tower is maintained at a concentration of 50 percent, which was found to be the most suitable strength for treating the pressure distillate. The sludge accumulator, settling tanks, filter press, and concentrating tank shown in figure 17 are used to purify, reclaim, and reconcentrate the zinc chloride solution.

^{17/} Lachman, A., A New Method of Refining Gasoline: Proc. 12th Ann. Meet. Am. Petrol. Inst., sec. III (Refining), 1931, pp. 63-73.

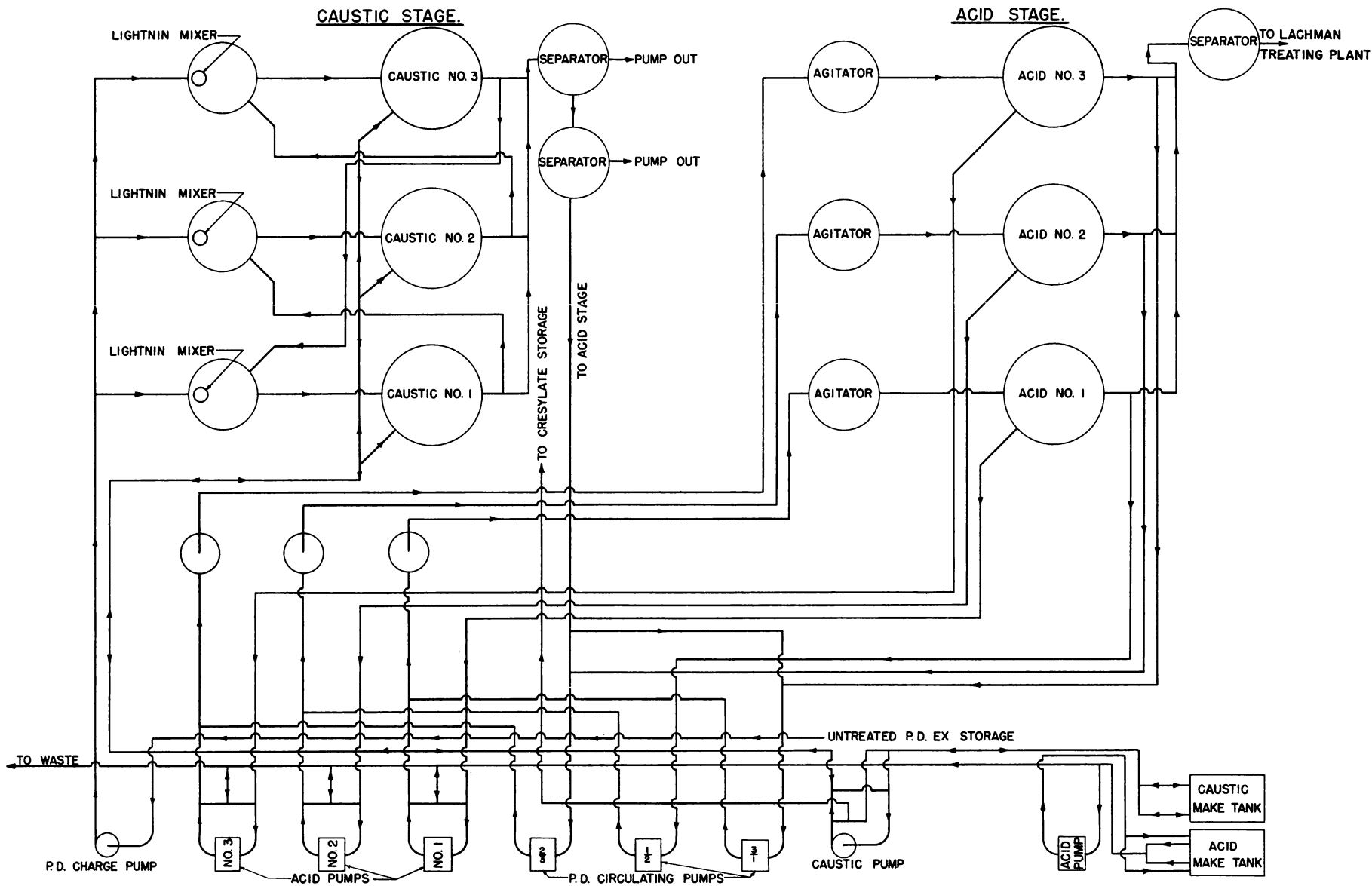


Figure 16. - Flow diagram of pressure-distillate treating plant.

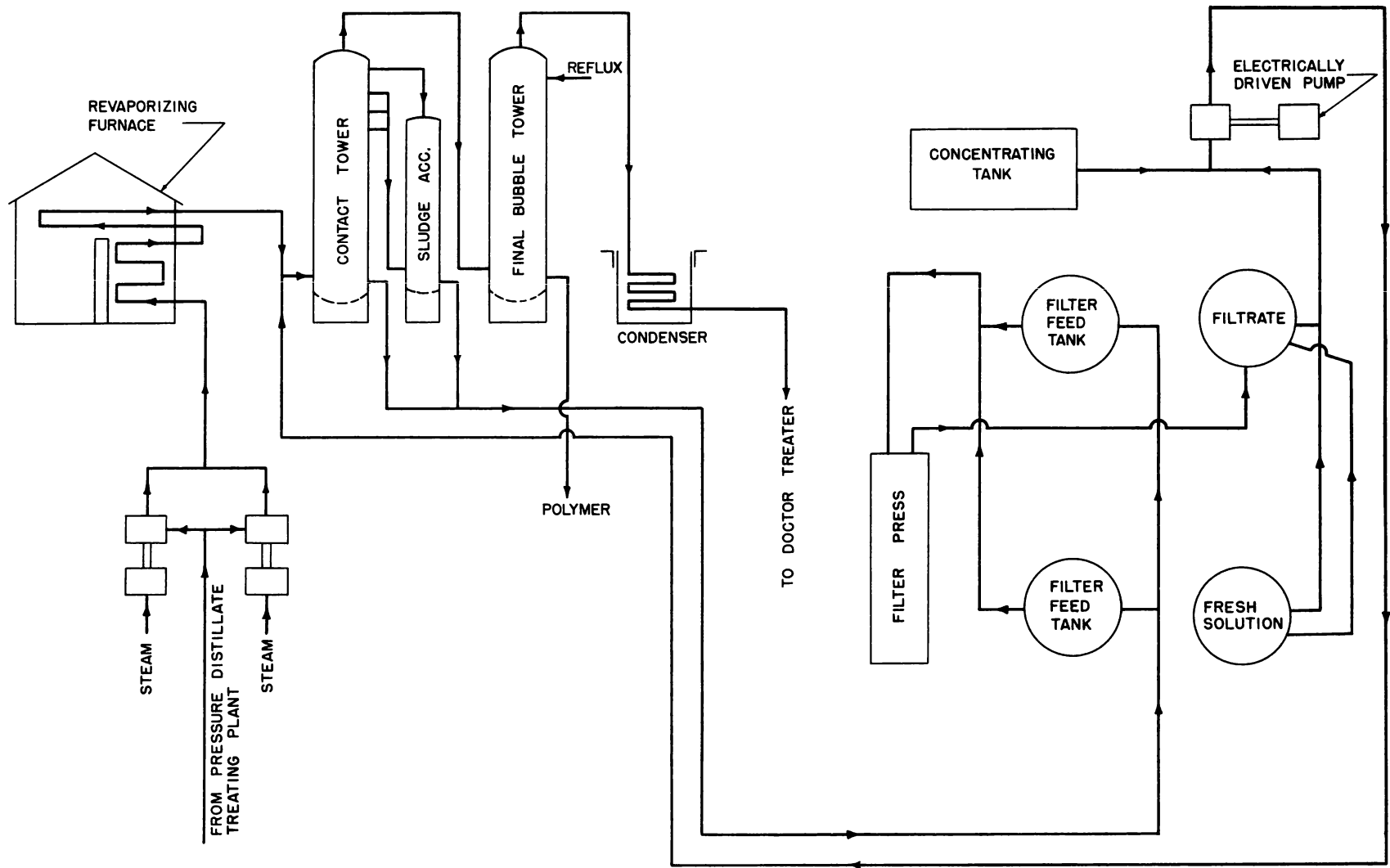


Figure 17. - Lachman zinc chloride treating and reclaiming unit.

A total loss of 12 percent results from treatment of the washed pressure distillate by the Lachman process. Of this loss, 90 to 92 percent is recovered as a polymer oil, which is recharged to the distillation unit with the crude oil.

The treated gasoline from the Lachman unit is given a final caustic wash (formerly doctor treatment was used, but caustic wash has been found to be equally satisfactory) in batches of about 30,000 gallons each. A loss of about 0.5 percent usually occurs during this final treatment.

The yield of pressure distillate from the combination topping-cracking unit averages 49 percent of the crude-oil charge. Considering normal treating losses to the pressure distillate to be 3.5 percent by caustic and acid washing, 12 percent by Lachman treating, and 0.5 percent by final caustic washing, an average recovery of about 41.5 percent of gasoline is obtained from the crude oil. An additional 2 percent of gasoline is recovered from the absorption plant, giving an overall gasoline yield of 43.5 percent, based on the crude-oil charge.

Products and Markets

At the time of the authors' visit to the refinery, an increased demand for asphaltic products resulted in a slight change in operating conditions to produce larger quantities of asphalts and cutback solvents and a smaller quantity of gasoline, giving an average yield of products somewhat as follows:

	Percent
Gasoline (400°F. end point)	43.5
Asphalts (various grades)	38.0
Kerosine (540°F. end point)	4.0
Gas oil (cutback solvent)	4.0
Gas	6.5
Coke and loss	4.0

The treated gasoline, as produced at the refinery, has a motor octane number ranging from 56 to 58 and contains about 0.3 percent sulfur and 0.1 percent nitrogen. Detailed analyses of refinery products are given later in the report. The gasoline is blended with 12-1/2 percent benzol and 12-1/2 percent ethyl alcohol (99+ percent) to produce a motor fuel having a motor octane number of 70 or higher. Tetraethyllead is not used.

Satmar has a competitive advantage in the motor-fuel market in the Johannesburg area primarily because of its lower transportation costs, as the railroad transportation charge is 7-1/2 pence (\$0.125) per imperial gallon (\$0.104 per U. S. gallon) on imported petroleum motor fuel from the nearest seaport, Durban, to Johannesburg. Although no breakdown or exact cost figures are available, it is estimated that the cost of crude shale oil laid down at the refinery at Boksburg was 5 pence (\$0.083) an imperial gallon (\$0.07 per U. S. gallon) exclusive of taxes, depreciation, insurance, and return on investment. The retail price of motor fuel in Johannesburg at that time was 2 shillings, 4 pence (approximately \$0.47), an imperial gallon (\$0.39 per U. S. gallon), including a tax of 8 pence (\$0.133) an imperial gallon (\$0.11 per U. S. gallon).

The spent caustic soda from pressure distillate treating is processed to separated the tar acids and to recover the caustic soda in the tar-acid plant. The process consists essentially of springing the tar acids from solution in the caustic soda by means of carbon dioxide in combustion gases, separating the acids and purifying them by distillation if a refined cresylic acid product is desired. A flow diagram of the tar-acid plant is shown in figure 18.

About 600 gallons of tar acids are produced a day. Part of this quantity is the crude, undistilled product, that is used largely for flotation oils by the mining industry. The distilled acids are predominantly cresylic and find their way principally into the pharmaceutical market.

The road oils and asphalts are in great demand, being used for road construction throughout southern Africa with good results. Blown asphalts with softening points between 140° and 200°F. also are made when a demand exists.

RAW MATERIALS AND PRODUCTS

Oil Shale

The oil-shale (torbanite) seam at Mooifontein 287, Ermelo district, Transvaal, which is the source of shale for the Satmar plant, is 10 to 36 inches thick and assays 25 to 145 U. S. gallons a short ton. The oil yields are not consistent vertically or horizontally through the seam, but the run-of-mine shale being processed averages about 56 U. S. gallons a ton.

Five selected samples of shales were sent to the Bureau of Mines Petroleum and Oil-Shale Experiment Station, Laramie, Wyo., for assay and analysis, and duplicate samples were analyzed by the Satmar laboratories. Table 1 shows the comparative results of assaying these samples at the two locations.

Although there are differences between the assay results obtained by the Bureau and by Satmar, the differences probably are no greater than would be expected due to the inherent difficulty of sampling heterogeneous solids and the differences of the assay methods. The Bureau assays were made by the modified Fischer retort method,^{18/} which utilizes a cast-aluminum retort and a 100-gram oil-shale charge arranged in 5 layers separated by perforated aluminum disks. The retort is heated to 500°C. over a period of 40 minutes then maintained at this temperature for an additional 20 minutes (a slightly longer heating period is necessary for very rich shales). Satmar^{19/} used a small iron Fischer retort and a charge of 20 grams of minus-28-mesh shale. The shale is heated to 500°C. in 30 minutes at a controlled rate and maintained at that temperature for an additional 15 minutes.

^{18/} Stanfield, K. E., and Frost, I. C., Method of Assaying Oil Shale by a Modified Fischer Retort: Bureau of Mines Rept. of Investigations 4477, 1949, 13 pp.

^{19/} See reference 8.

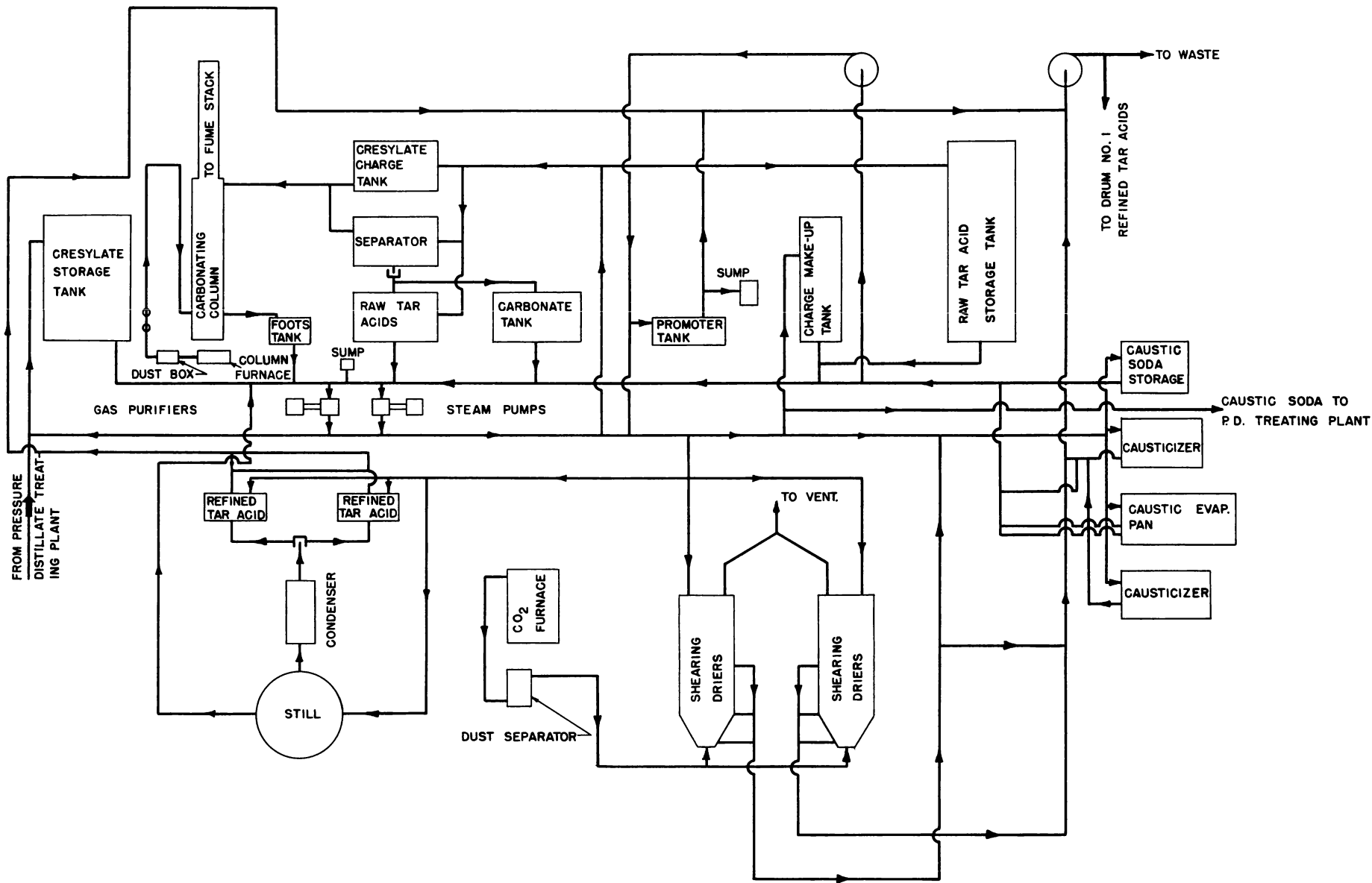


Figure 18. - Flow diagram-tar-acid plant.

TABLE 1. - Assay analyses of South African oil shales
 Samples from Mooifontein 287, Ermelo District, Transvaal

Sample number	1		2		3		4		5	
	BM	SATMAR	BM	SATMAR	BM	SATMAR	BM	SATMAR	BM	SATMAR
Assay by										
Yield of products:										
Oil, U.S. gal./s. ton	33.3	31.8	45.6	43.2	45.0	51.6	68.8	65.4	99.8	100.2
Water, do.	8.8	10.8	7.1	7.8	7.4	7.8	5.7	9.6	4.9	7.2
Oil, wt. percent	13.0	11.9	17.6	16.3	17.4	19.5	26.2	24.6	37.8	37.6
Water, do.	3.6	4.5	3.0	3.3	3.0	3.3	2.4	4.0	2.0	3.0
Spent shale, do.	80.3		75.6		75.8		66.8		54.2	
Gas, do.	3.1	3.2	3.4	3.3	3.2	3.6	4.1	3.9	4.8	4.6
Loss, do.	0		.4		.6		.5		1.2	
Total, do.	100.0		100.0		100.0		100.0		100.0	
Properties of spent shale:										
Ignition loss, wt. percent										
raw shale	39.3		32.9		34.9		29.0		20.5	
Ash, do.	41.0		42.7		40.9		37.8		33.7	
Total, do.	80.3		75.6		75.8		66.8		54.2	
Assay gases:										
Vol., cu.ft./ton @ 60°F.										
30 in. Hg. ^{1/}	970	864	970	880	960	976	940	1056	1080	1248
Mass spectrometer analysis, ^{1/}										
vol. percent: ^{1/}										
Methane	28.8		29.8		27.6		28.2		24.6	
Ethane	9.1		11.4		10.5		11.6		12.2	
Propane	2.9		3.8		3.2		4.3		5.1	
Butanes	1.6		2.3		2.4		2.5		3.4	
Pentanes	1.1		1.7		1.6		1.6		2.2	
Hexanes (calc. as n-hexane)	.5		.6		.5		.5		.6	
Ethylene	2.6		3.3		2.4		3.3		4.0	
Propylene	1.8		2.3		2.3		3.1		4.1	
Butenes (calc. as isobutene)	2.2		3.2		3.1		3.8		4.7	
Pentenes (calc. as pentene-1)	1.5		2.2		1.9		2.2		2.9	
Nitrogen	7.6		4.3		3.3		3.3		1.0	
Carbon dioxide	20.4		13.8		15.0		12.2		10.5	
Carbon monoxide	5.3		5.5		7.8		7.7		10.8	
Hydrogen sulfide	2.8		5.1		4.5		4.1		4.5	
Hydrogen	11.8		10.7		13.9		11.6		9.4	
Total	100.0		100.0		100.0		100.0		100.0	

^{1/} On dry air-free basis

Table 2 shows the composition and properties of the five South African oil shales and their assay products and the corresponding properties of a composite oil-shale sample and its products from the Green River formation near Rifle, Colo. The Colorado shale was a composite of 9 samples, which represent the 73-foot-thick Mahogany ledge. The composite sample yielded on assay, in percent, 10.6 oil, 0.7 water, 86.6 spent shale, and 2.1 gas and loss. The oil yield was equivalent to 27.7 U. S. gallons per short ton.

It will be noted that the ash contents determined directly on the raw shales (table 2) are not identical with values obtained indirectly by analyses of the spent shales (table 1). This is attributed to experimental errors due to weighing the assay charge and its products only to 0.1 gram, also to the fact that ignition of raw shale in an oxidizing atmosphere frequently yields higher ash contents than values based upon ignition of spent shales that have undergone pyrolysis under reducing conditions that facilitate the decomposition and removal of sulfur compounds.

The South African shales had much lower specific gravities and higher heating values than the Colorado shale, due largely to their higher organic contents. However, the much higher organic contents of the South African shales did not result in proportionately higher oil yields. This fact is evident among the different South African shales as well as between the African shales and the Colorado shale. For comparative purposes, an approximation of the organic content may be obtained by subtracting the percent ash and mineral CO₂ from 100. For example, samples 1 and 4 contain 55 and 60 percent organic material, respectively, but sample 1 produced only 13.0 percent oil by assay, as compared to 26.2 percent oil produced by sample 4. The Colorado sample, with only 15.4 percent organic matter, produced 10.6 percent oil. These differences in the ratio of organic content to oil yield indicate differences in the composition and constitution of the organic matter in the oil shales. The South African shales differ in this respect from Colorado shales, which have been found to be surprisingly consistent in the composition of their organic components.

The widely differing carbon - hydrogen ratios of the organic components of the shales are further evidence of this variation in constitution. Himus^{20/} suggests that the relatively low hydrogen content of South African shales is due to the presence of large quantities of low-hydrogen debris of a "coaly" nature mixed with the algae.

^{20/} Himus, G. W., Observations on the Composition of Kerogen rocks and the Chemical Constitution of Kerogen: Proc. of 2d Oil Shale and Cannel Coal Conf., The Institute of Petroleum, Manson House, London, 1951.

TABLE 2. - Composition and properties of South African oil shales
compared with Colorado oil shale

Mooifontein 287, Ermelo district, Transvaal

Sample number	1	2	3	4	5	Colorado composite ^{1/}
Properties of shale:						
Specific gravity..60°/60°F.	1.604	1.585	1.604	1.486	1.365	2.160
Heating value... B.t.u./lb.	8,340	8,230	8,610	9,470	11,160	2,590
Coking tendency	None	None	Slight	Slight	Slight	Slight
Ash-fusion point	F. 2,570+	F. 2,570+	F. 2,570+	F. 2,570+	F. 2,570+	
Ash ^{2/} /.....weight....percent	43.32	42.53	44.36	37.56	33.56	65.68
Mineral CO ₂do.	1.72	0.85	2.18	2.23	0.91	18.90
Organic carbon	42.72	43.85	41.56	42.20	52.24	12.43
Hydrogen ^{3/} /.....do.	3.45	3.97	3.74	4.30	6.01	1.77
Nitrogen	0.91	0.89	0.88	0.80	0.84	0.41
Sulfur	0.97	0.89	1.01	0.75	0.74	0.63
C/H ratio	12.38	11.05	11.10	9.82	8.70	7.02
Oil by assay:						
Specific gravity..60°/60°F.	0.942	0.929	0.930	0.915	0.908	0.916
Carbon.....weight..percent	84.98	84.84	84.99	85.13	84.99	84.62
Hydrogen	10.82	11.13	11.11	11.46	11.55	11.48
Sulfur	0.67	0.64	0.63	0.59	0.53	0.59
C/H ratio	7.85	7.62	7.65	7.43	7.36	7.4
Heating value.....B.t.u./lb., gross	17,980	18,150	18,190	18,370	18,540	18,510
Ash analysis, weight-percent:						
SiO ₂	61.86	61.33	60.58	61.16	59.87	42.74
Al ₂ O ₃	31.16	30.53	30.40	30.34	31.70	13.15
Fe ₂ O ₃	4.45	2.92	3.09	2.88	3.24	4.56
CaO	0.25	1.65	1.86	1.68	1.85	23.27
MgO	0.35	1.70	1.67	1.74	0.34	9.97
SO ₃	0.03	0.03	0.03	0.03	0.47	1.81
Na ₂ O	0.10	0.13	0.13	0.18	0.10	3.09
K ₂ O	1.22	1.52	1.36	1.49	1.44	2.33
Total	99.42	99.81	99.12	99.50	99.01	100.92

- 1/ Composite of 9 samples that represent the 73-foot Mahogany ledge, Rifle, Colo. - assay value 27.7 gal./ton.
 2/ Ash obtained by ignition of raw shale to constant weight in an electric muffle furnace at 1,000°C. (1,822°F.).
 3/ Not corrected for possible water of crystallization in mineral matter.

A number of other investigators of the South African deposits have pointed out their "coaly" character and close association with cannel coals. Cunningham-Craig,^{21/} in his discussion of the characteristics and potentialities of the deposits, classifies them as torbanites rather than oil shales

21/ Cunningham-Craig, E. H., The Torbanites of South Africa: Jour. Inst. Petrol. Technol., vol. 16, 1930, pp. 620-625.

because their matrix is carbonaceous and not argillaceous and describes them as being a special development of cannel coal. Bleloch^{22/} states " -- the material contains much less ash than a true oil shale and although the ash content is much greater than of a coal the volatile content is remarkably high. The low percentage of oxygen taken in conjunction with these characteristics and the facies of its deposition, entitles the deposit to be classified as a torbanite." Bleloch also concludes that the oil-forming constituents of the torbanite are largely the bright yellow globules of kerogen (gels) that occur in the dense black matrix but that the matrix constitutes 40 to 50 percent of the material and probably yields a portion of the total products of distillation at high temperature. He describes the matrix as "a finely-divided clay which has absorbed or been impregnated by sufficient carbonaceous matter to give it the dense black color." Recently Schopf^{23/} upon micropetrologic examination of the deposit for the South African Council for Scientific and Industrial Research cited this material as an illustration of how closely coal and torbanite may be related and should be so regarded for purposes of scientific classification.

The properties of the assay oils given in table 2 show no greater differences between the South African and Colorado oils than among the different South African oils themselves. A tendency for the shale organic matter with the higher carbon - hydrogen ratio to produce an oil with a higher carbon to hydrogen ratio is shown by these results, even though the carbon - hydrogen ratio of the oils has been equalized greatly by the conversion process.

The greatest and most consistent differences between the South African and Colorado shales are evident in the inorganic oxide content of their ashes and their mineral carbon dioxide contents, both of which show the highly dolomitic character of the Colorado shale in comparison with the very low content of carbonates in the South African shales. The ratio of silica to alumina also is higher in the Colorado shale. The Colorado shale has a somewhat higher content of the minor oxides of sodium and potassium and sulfates than the South African shales.

Characteristics of Crude Shale Oil and Its Products

Crude Shale Oil

The crude oil produced by the retorting plant at Ermelo contained the gasoline recovered by absorption from the retort gases and subsequent distillation from the absorption oil. Table 3 gives the Bureau of Mines crude shale-oil analysis^{24/} of a sample of this crude oil that was shipped to the Bureau station at Laramie, Wyo.

^{22/} Bleloch, William, The Ermelo Torbanite as a Source of Oils in the Union of South Africa: Jour. Inst. Petrol. Technol., vol. 17, 1931, pp. 521-540.

^{23/} Schopf, J. M., Cannel, Boghead, Torbanite, Oil Shale: Econ. Geol., vol. 44, No. 1, 1949, pp. 68-71.

^{24/} Stevens, R. F., Dinneen, G. U., and Ball, John S., Analysis of Crude Shale Oil: Bureau of Mines Rept. of Investigations 4898, 1952, 20 pp.

TABLE 3. - Bureau of Mines crude shale-oil analysis

Source of sample: Satmar Refinery, Boksburg North, Transvaal, Union of South Africa

SUMMARY OF PROPERTIES

Properties of crude shale oil		Distillation summary					
Specific gravity,	0.906	Naphtha (fractions 1-7).	19.1	Sp.gr.	0.773	°API	51.6
API gravity,	24.7	Light distillate					
Sulfur, percent,	0.64	(fractions 8-11)	16.9	.865		32.1	
Nitrogen, percent,	0.85	Heavy distillate					
Pour point, °F.	55	(fractions 12-15)	32.1	.923		21.8	
Viscosity, S.U.		Residuum	31.8	1.000		10.0	
seconds at 100° F.	63	Loss	0.1				

ANALYTICAL DATA

Distillation at 760 mm. Hg pressure						Naphtha composite (fractions 1-7)	
Fraction No.	Cut at-		Sum, percent	Gravity		Percent	Percent
	°C.	°F.		Specific 60/60°F.	°API 60°F.		
1	50	122	0			Tar acids.....	1.8
2	75	167	0			Tar bases.....	.6
3	100	212	1.8	1.8	0.709	Neutral oil:	
4	125	257	2.9	4.7	.735	Paraffins and	
5	150	302	3.1	7.8	.756	naphthenes..	37.
6	175	347	4.0	11.8	.779	Olefins.....	48.
7	200	392	7.3	19.1	.808	Aromatics*...	15.

*Including sulfur and nitrogen compounds.

Distillation at 40 mm. Hg pressure										
Fraction No.	Cut at-		Percent	Sum, percent	Gravity		Viscosity		Aniline point, °C.	Cloud test, °F.
	°C.	°F.			Specific 60/60°F.	°API 60°F.	K.V., centi-stokes	S.U., sec.		
8	125	257	1.1	20.2	0.832	38.6	-	-	-	below 5
9	150	302	5.6	25.8	.848	35.4	2.1	33	33.4	5
10	175	347	5.3	31.1	.872	30.8	2.8	38	34.4	10
11	200	392	4.9	36.0	.883	28.8	5.2	43	38.4	25
12	225	437	6.5	42.5	.897	26.3	6.6	48		45
13	250	482	6.6	49.1	.907	24.5	10.6	61		65
14	275	527	8.0	57.1	.931	20.5	19.6	96		85
15	300	572	11.0	68.1	.944	18.4	40.5	190		100
Residuum			31.8	99.9	1.000	10.0				

Carbon residue of residuum, 7.1 percent; carbon residue of crude, 2.2 percent.

The naphtha fraction boiling to 392°F. had a sulfur content of 0.43 percent and a nitrogen content of 0.14 percent. The composition of the neutral naphtha after removal of tar acids and bases was determined by silica-gel adsorption.^{25/} The residuum from the distillation had a nitrogen content of 1.30 percent and a sulfur content of 0.55 percent, and was asphaltic in nature. The crude-oil analysis also shows additional properties of the different boiling-range fractions that are indicative of the quality and character of products that may be produced from it.

A second, larger sample of the crude oil was distilled at reduced pressure and fractionated into a naphtha, a gas oil, and a residue. This distillation yielded enough of each of the fractions for extensive tests including engine ratings. Table 4 gives the results of ASTM and other quality tests of the products. The residuum was given the common asphalt tests and the results are compared with those from the two refinery asphalt samples produced by Satmar, shown in table 6.

Satmar Cracked Distillate and Gasoline

Samples of the cracked distillate and treated gasoline from the Satmar refinery were shipped to the Bureau for analysis. The product referred to as cracked distillate was the total stabilized overhead fraction from the main bubble tower so it was made up of both the gasoline boiling-range material present in the original crude oil and the gasoline produced by cracking the light-oil and gas oil. The treated gasoline was produced by treating and redistilling the cracked distillate as previously described.

Table 5 includes the results of various analyses of the two materials showing their properties, composition, and fuel characteristics. The analyses indicate that the principal benefit of the treating procedure was to reduce the tar acid, tar base, and gum contents, remove the high-boiling ends, and increase the vapor pressure. Although the clear octane number was increased slightly by the treatment, the response to tetraethyllead was decreased. Very little sulfur reduction was obtained as the sulfur in the cracked distillate was essentially in the form of thiophene, aromatic sulfide, and residual sulfur compounds, which are little affected by the type of treatment applied. The octane rating was raised to 70 or above, and the sulfur content was reduced by blending 12.5 percent benzol and 12.5 percent alcohol with the treated gasoline to produce the finished motor fuel.

Asphaltic Products

Generally, the properties of residuums from foreign shale oils differ considerably from those of petroleum asphalts and from asphaltic residuums prepared from Colorado crude shale oils. However, the residuums from South African shale oil were quite asphaltic and had temperature susceptibility factors similar to petroleum asphalts. Table 6 shows the results of common asphalt tests and composition determinations made on samples of: (1) A straight-run asphalt; (2) a cracked asphalt produced at the Satmar refinery; and (3) the residuum remaining after the distillation of the crude shale oil at Laramie, Wyo., as shown in table 4.

^{25/} Dinneen, G. U., Bailey, C. W., Smith, J. R., and Ball, J. S., Shale-Oil Naphthas, Analysis of Small Samples by the Silica-Gel Adsorption Method: Ind. Eng. Chem., anal. ed., vol. 19, No. 12, 1947, pp. 992-998.

TABLE 4. - Properties of fractions of South African crude shale oil

Product	Naphtha	Gas oil	Residue
Yield from crude.....volume-percent	22.1	26.7	50.3
Specific gravity..... 60°/60°F.	0.779	0.881	0.982
Degrees API.....	50.2	29.3	12.6
ASTM distillation, °F. at 760 mm.:			
Initial boiling point.....	152	425	
Percent recovered:			
5.....	197	465	
10.....	215	475	
20.....	240	493	
30.....	264	510	
40.....	288	529	
50.....	311	549	
60.....	330	569	
70.....	347	588	
80.....	361	604	
90.....	376	621	
95.....	385	635	
End point.....	402	659	
Recovered.....	99.5	99.0	
Residue.....	0.5	1.0	
Loss.....	0.0	0.0	
Flash point, Pensky-Martens..... °F.		205	455
Color, Saybolt.....	Below -16		
Doctor test.....	Positive		
Corrosion..... 3 hr. at 122°F.	Do.	Negative	
ASTM gum..... mg./100 ml.	66		
ASTM induction period.....minutes at 212°F.	1,500		
Octane rating, ASTM, motor clear.....	44.5		
+ 1 cc. TEL/gal.....	53.7		
+ 3 cc. TEL/gal.....	63.2		
+ 5 cc. TEL/gal.....	67.9		
Octane rating, research, clear.....	57.4		
Cetane number.....		40.9	
Pour point..... °F.		25	
Viscosity:			
Kinematic.....centistokes at 100°F.		4.32	
Saybolt furol.....sec. at 122°F.			132
Water and sediment, centrifuge..volume-percent			0.05
Ash.....percent by weight		0.012	0.017
Ramsbottom carbon residue.....do.		0.12	5.40
Ramsbottom carbon residue on 10 percent bottoms.....percent by weight		0.14	

TABLE 5. - Properties of South African shale-oil cracked distillate and treated gasoline

Product	Cracked distillate	Treated gasoline
Specific gravity..... 60°/60°F.	0.769	0.737
Degrees API.....	52.4	60.6
Tar acids..... volume percent	2.9	0.4
Tar bases.....do.	1/2.9	1/0.6
Nitrogen content, before tar base removal.....	0.24	0
Nitrogen content, after tar-base removal.....	0.03	0
Hydrocarbon type (tar-acid, tar-base free)		
Paraffins and naphthenes.....volume-percent	46	49
Olefins.....do.	38	40
Aromatics.....do.	16	11
Total sulfur.....weight-percent	0.38	0.36
ASTM distillation, °F., 760 mm:		
Initial boiling point.....	119	100
Percent recovered:		
5.....	164	133
10.....	184	151
20.....	217	180
30.....	240	208
40.....	254	234
50.....	293	257
60.....	316	281
70.....	335	303
80.....	351	326
90.....	367	353
95.....	380	377
End point.....	398	381
Recovered.....	98.0	96.0
Residue.....	0.9	1.1
Loss.....	1.1	2.9
Reid vapor pressure..... p.s.i. at 100°F.	5.3	8.9
Color, Saybolt.....	Below -16	Below -16
Doctor test.....	Negative	Negative
Corrosion, copper strip, 3 hr. at 122°F.	Do.	Do.
ASTM gum..... mg./100 ml. oil	277	3
Copper dish gum.....do.	1,304	21
ASTM induction period..... min. at 212°F.	1,338+	875
Octane rating, ASTM motor, clear.....	56.1	57.9
+ 1 cc TEL/gal.....	61.3	63.0
+ 3 cc TEL/gal.....	67.1	67.0
+ 5 cc TEL/gal.....	72.8	70.6
Octane rating, research, clear.....	67.5	

1/ Values may be high due to polymer removal during extraction.

TABLE 6. - Properties of asphaltic residuums from South African shale oil

Product	Straight-run asphalt	Cracked asphalt	Crude oil residuum
Specific gravity..... 60°/60°F.	1.056	1.090	0.982
Specific gravity..... 70°/70°F.	1.052	1.085	.973
Sulfur..... weight-percent	.48	.57	.49
Nitrogen.....do.	1.30	1.61	1.22
Ash.....do.	.06	.11	.00
Bitumen.....do.	99.73	98.70	99.72
Bitumen soluble in CCl ₄do.	95.22	98.48	99.62
Carbon residue.....do.	22.53	19.83	7.03
Saponification number.....mg. KOH/gm.	2.6	.9	2.8
Flash, °F., Cleveland open cup.....	470	395	440
Fire, °F., Cleveland open cup.....	620	525	495
Softening point..... °F.	101.5	95.0	82.4
Ductility			
At 32°F..... 1 cm./min., cm.	10	100+	1/
At 77°F..... 5 cm./min., cm.	100+	100+	I/
Penetration			
At 32°F., 200g.wt., 60 sec., dmm. ...	23.6	18.8	1/
At 60°F., 100g.wt., 5 sec., dmm. ...	47.3	60.9	I/
At 77°F., 100g.wt., 5 sec., dmm. ...	152.4	226.4	I/
Loss on heating at 325°F.,.....			
..... weight-percent	.57	1.22	2.38
Penetration after loss..... dmm.	32.2	35.6	1/
Oliensis spot test:			
Normal.....	Positive	Positive	Positive
Modified.....	Do.	do.	Do.
Xylene equivalent.....	2/Do.	2/do.	75-80
Viscosity at 210°F., seconds Saybolt...	323(F.)	129.7(F.)	102.9(U.)
Viscosity at 275°F., seconds Saybolt...	39.7(F.)	20.3(F.)	52.7(U.)
Composition, weight-percent: ^{3/}			
Asphaltenes.....	26.5	27.4	7.6
Oils.....	32.3	40.9	53.5
Resins.....	37.0	29.3	36.7
Benzene-insoluble and loss.....	4.2	2.4	2.2
Total.....	100.0	100.0	100.0
Wax ^{4/}	2.5	1.5	3.5

1/ Too soft for test.

2/ Positive when using 100 percent xylene.

3/ Hubbard, Rethel L., and Stanfield, K. E., Determination of Asphaltenes, Oils, and Resins in Asphalt: Anal. Chem., vol. 20, May 1948, pp. 460-65.

4/ Determined by crystallizing the wax from a solution of the oil fraction in 25 ml. of methyl ethyl ketone at 32°F., followed by a similar recrystallization of the wax.

The properties of the three samples are not directly comparable due to their different consistencies. The higher wax content of the straight-run asphalt probably caused it to have a lower ductility at 32°F. than the cracked asphalt. All three samples contained pyridine-soluble carboids, which separated with the benzene-soluble asphaltenes during the constituent analyses. The asphaltene contents of the South African residuums were four to six times those of Spanish and Australian shale-oil residuums, indicating better asphaltic properties.

Research and Development

Satmar maintained small laboratories at both the retorting plant at Ermelo and the refinery at Boksburg North. These laboratories were used principally for analyzing and testing the raw materials and products for the control of plant operations. However, some laboratory research and small pilot-plant experimental work was done at the Ermelo plant on different types of retorting that might be applicable to their shales and on the effect of different retorting conditions on the quantity and quality of oil produced in their Davidson and Salerno retorts. This experimental work indicated to them that abnormally high retorting temperatures or the presence of even small quantities of coal in the retort charge caused lower yields of poorer quality oil.

The refinery control laboratory also has carried on some research particularly for product improvement and for the development of new refinery products. Such studies included the separation and purification of waxes and the possible production of lubricating oils, naphthas, lighter fluids, and uncracked asphalts.

The South African Fuel Research Institute in Pretoria had done considerable research on South African torbanite in the past. The comprehensive studies of Petrick^{26/} are particularly notable. The Council for Scientific and Industrial Research, also in Pretoria, has a fuels section that conducts research on hydrocarbons in petroleum-type materials, which may include shale oils.

In addition to the various studies of South African torbanite and its products cited previously in this report, Neppes^{27/} has made a rather comprehensive study of the properties of numerous Transvaal torbanites and subjected them to microscopic examination, solvent extraction, proximate and ultimate analyses and to carbonization in a horizontal, rotary, laboratory retort. Cracking tests and analyses of the oils produced by carbonization also were described. Egloff^{28/} and associates reported the results of their studies of

^{26/} See footnote 4.

^{27/} Neppes, S. L., A Technical Study of Transvaal Torbinite: Jour. Inst. Petrol., vol. 27, No. 208, 1941, pp. 31-65; addendum, Jour. Inst. Petrol., vol. 28, No. 222, 1942, pp. 104-08.

^{28/} Egloff, Gustav, W lter, J. F., Grote, H. W., and Davis, R. F., Refining Australian and South African Torbanite Oils: 2d Oil Shale and Cannel Coal Conf., Glasgow, Scotland, July 1950, pp. 605-619; Petrol., London, 1951.

South African torbanite oil for the production of gasoline, diesel fuel, and asphalt at the Second Oil Shale and Cannel Coal Conference in July 1950. Their tests also included thermal cracking and sulfuric acid treating of the cracked gasoline. The yields, properties and composition of the products were given.

CONCLUSIONS

The activities of South African Torbanite Mining and Refining Co. (Satmar) in the Union of South Africa constitute an integrated oil-shale operation, from mining and retorting oil shale to refining shale oil and marketing products. The company is a commercial organization, which has operated for the past several years at a profit without subsidy and has paid dividends to stockholders.

The operations in 1947 were based upon a reserve of torbanite (or oil shale) having an average mine assay value of 56 U. S. gallons per short ton and an estimated life of 15 to 20 years at the rate of production during the year 1947.

Oil-shale mining and crushing are directed to the delivery to retorts of the largest practicable proportion of the shale in place. No shale is left in the mine except that contained in pillars needed to support the roof, and no fines are discarded in crushing.

As in almost every oil-shale retorting operation throughout the world, equipment and procedures had to be adapted and developed to meet the particular conditions at Ermelo. Coal is available at low cost, and conservation of heat in the retorting process at the expense of oil yield is not justified.

Refining is conducted to yield the largest practicable quantity of motor gasoline and asphaltic products for use in road surfacing. The motor-gasoline component made at the refinery at Boksburg North is blended with indigenous alcohol and benzol to make a finished motor gasoline. Tetraethyllead is not used in the blend.

