

CONTENTS

	<u>Page</u>
Preface	1
Introduction	1

PART II

Mining, Oil-Shale Experimental Mine, Rifle, Colo.	1
Oil-Shale resources	1
Selective Mine	2
Underground Quarry	2
Mining research	4
Estimated cost for commercial mining	11
Processing, Oil-Shale Demonstration Plant, Rifle, Colo.	15
Pilot-plant activities	15
Gas-combustion process	16
Description of pilot plant	16
Control of mist formation	17
Evaluation run	18
Gas-air mixer studies	21
Oil-recovery studies	22
Intermediate-size pilot plant	22
Gas-flow process	23
Miscellaneous studies	23
Pressure-drop tests	23
Sampling raw shale	23
Refining program	24
Crushing, conveying, and storage of oil shale	24
Demonstration retorting plant	24
Demonstration shale-oil refinery	26
Thermal operations	26
Coking	27
Recycle cracking	29
Viscosity breaking	32
Reforming	34
Treatment of products	34
Gasoline	35
Diesel fuel	36
Byproduct studies	40
Road materials	40
Tar acids and tar bases	40
Coke	41
Future refining studies	41
Cooperative agreements	42
Industry-scale oil-shale project	43
Case I - Oil-shale processing with thermal refining	44
Case II - Oil-shale processing with mild hydrogenation	46
Cost estimate	48
Plant service laboratory	56
Oil-shale assays	56
Analyses of crude shale oil	57
Development of methods	57
Process studies	59
Laboratory facilities	59

CONTENTS (Cont.)

	<u>Page</u>
Processing, Oil-Shale Demonstration Plant, Rifle, Colo. (Cont.)	
Functions and facilities other than mining and processing	59
Design, construction, and maintenance	59
Health and safety	60
Administration	60
Research and Development, Petroleum and Oil-Shale Experiment Station, Laramie, Wyo.	63
Oil-shale retorting research	63
Entrained-solids retort	64
Products from high-temperature retorting	64
Shale-oil refining research	66
Properties of thermally cracked gasoline	66
Hydrotreating of heavy naphtha	68
Acid-treating shale-oil naphtha	69
Solvent extraction	70
Catalytic cracking	71
Hydrogenation	71
Characteristics of asphaltic residuums from shale oil	72
Oil-shale research and analysis	74
Assays and miscellaneous analyses	74
Characteristics of organic material in Colorado oil shale	75
Shale-oil research and analysis	77
Oils from high-temperature retorting	78
Primary N-T-U naphtha	79
N-T-U gas-oil fraction	82
Development of analytical methods	82
Byproduct-utilization research	83
Separation of paraffin and olefin waxes	83
Tar acids	83
Tar bases	84
Appendix. Bibliography of papers and reports presented or published in 1951	85

TABLES

1. Summary of test data on percussion-drill rods	6
2. Summary of test data for air pressure versus drilling rate in per- cussion drilling	7
3. Capital cost for preparing an oil-shale mine to produce, crush, and convey 19,200 tons per calendar day	12
4. Operating costs for mining, crushing, and conveying 19,200 tons of oil shale per calendar day	13
5. Gas-combustion pilot plant; properties of shale feed; 4-day evalua- tion run	18
6. Gas-combustion pilot plant; operating conditions and product-yield data; 4-day evaluation run	19
7. Gas-combustion pilot plant; properties of retort products; 4-day evaluation run	20
8. Characteristics of shale-oil pitch	27
9. Recycle delayed coking of crude shale oil	28
10. Product-gas analyses	29

TABLES (Cont.)

Page

11. Coke analysis (moisture-free)	29
12. Recycle cracking of N-T-U crude shale oil	31
13. Recycle cracking of mixture of light and heavy gas oil	32
14. Viscosity breaking of crude shale oil	33
15. Thermal reforming of shale-oil naphtha	35
16. Cold sulfuric acid treatment of recycle cracked naphtha	37
17. Cold sulfuric acid treatment of light and heavy naphthas from re-cycle cracking of viscosity-broken crude shale oil	38
18. Cold sulfuric acid treatment of light gas oil from coking N-T-U shale oil	39
19. Characteristics of road oils produced from shale-oil residuum	41
20. Raw material and product summary for 250,000-barrel-per-calendar day operation; Case I - Oil-shale processing with thermal refining ..	45
20A. Properties of major products from oil-shale processing with thermal refining	46
21. Raw material and product summary for 250,000-barrel-per-calendar day operation; Case II - Oil-shale processing with mild hydrogenation.	47
21A. Properties of major products from oil-shale processing with mild hydrogenation	48
22. Estimated capital requirement for 250,000-barrel-per-calendar day operation; Case I - Oil-shale processing with thermal refining ..	49
22A. Estimated capital requirement for 250,000-barrel-per-calendar day operation; Case II - Oil-shale processing with mild hydrogenation.	50
23. Estimated daily operating costs for 250,000-barrel-per-calendar day operation; Case I - Oil-shale processing with thermal refining ..	51
23A. Estimated daily operating costs for 250,000-barrel-per-calendar day operation; Case II - Oil-shale processing with mild hydrogenation.	52
24. Estimated cost of gasoline from 250,000-barrel-per-calendar day operation; Case I - Oil-shale processing with thermal refining ...	53
24A. Estimated cost of gasoline from 250,000-barrel-per-calendar day operation; Case II - Oil-shale processing with mild hydrogenation.	54
25. Estimated metals, manpower, and time requirements for 250,000-barrel-per-calendar day operation; Case I - Oil-shale processing with thermal refining	55
25A. Estimated metals, manpower, and time requirements for 250,000-barrel-per-calendar day operation; Case II - Oil-shale processing with mild hydrogenation	56
26. Assays of oil shale from mining operations	57
27. Characterization of crude shale oils	58
28. Potential production of some chemicals from a 20,000-ton-per-day high-temperature retorting plant	65
29. Octane blending value of tar acid-tar base components of shale gasoline	67
30. Properties of low- and high-boiling fractions of thermally cracked gasolines	68
31. Properties of hydrotreated heavy naphtha and blended gasoline	69
32. Properties of raffinates from light gas oil	71
33. Properties of 100-penetration asphalts from shale oil	72
34. Properties of residual 100-penetration asphalts from shale oil and petroleum	73
35. Distribution of organic carbon in products obtained by oxidation of materials	76
36. Degradation products from Colorado kerogen	76
37. Content of some aromatic compounds in crude shale oils produced at 1,200°, 1,500°, and 1,700° F.	79
38. Composition of phenols extracted from 1,200° and 1,500° F. oils	79
39. Aromatics in N-T-U primary neutral naphtha	80
40. Sulfur and nitrogen compounds identified in primary N-T-U naphtha ..	81

ILLUSTRATIONS

Follows
page

Fig.

1. Evolution of an oil-shale industry	Frontispiece
2. Mine yard and road near Rifle, Colo., are carved in cliffs and talus slopes of oil shale. Road descends 5-1/2 miles over zigzag course to processing plant thousands of feet below in Colorado River Valley	2
3. Isometric drawing of Underground Quarry	2
4. Vertical blast holes for breaking bench level are drilled with this jumbo, which mounts four percussion-type air drills, each having a 15-foot feed carriage	2
5. This four-drill jumbo is used to drill horizontal blast holes in 27- by 60-foot headings of Underground Quarry. A mobile utility station (left) supplies necessary com- pressed air and water for drilling	2
6. Mobile blasters' platform, mounted on modified fork-lift truck, is used in top heading to elevate men into position for charging explosives into holes and for scaling loose rock from roof and pillars	2
7. A 65-foot telescoping platform partly extended for scaling roof and pillar walls from bench level	2
8. 1,800 tons of broken oil shale	2
9. Drilling rate versus air pressure (percussion drilling) ..	6
10. Blows per minute versus air pressure (percussion drilling)..	6
11. Drilling rate versus blows per minute (percussion drilling). 12. Blows per inch of penetration versus air pressure (percus-	8
sion drilling)	8
13. Hydraulic rotary-test-drill unit positioned for drilling horizontal holes	8
14. A few of many bits tested with rotary drill	8
15. Rotary-drill test bit, designed by Tool Specialty Co., that ^{uses} _{KUBIC} employs two grades of tungsten carbide inserts	8
16. Isometric drawing of test room, showing stratascope holes, geophones, and sag-measuring stations	10
17. Isometric drawing of test room, showing caved sections	10
18. Plan of Underground Quarry, showing stratascope holes	10
19. Oil-Shale Demonstration Plant project	13
20. Plant area, with residential area in background	16
21. Pilot-plant area, showing spent-shale disposal pile and spent-shale cars, new building addition (taller part), and original pilot-plant building	16
22. Flow diagram of Gas-Combustion pilot plant for retorting oil shale	16
23. Gas-combustion pilot plant	16
24. Material and heat balances, gas-combustion pilot plant	20
25. Isometric section of center-type gas-air mixer, gas-combus- tion process	20
26. Isometric section of wall-type gas-air mixer, gas-combustion process	20
27. Effect of shale rate on gas-combustion-retort operation	20