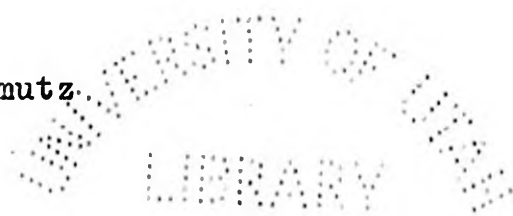


OIL RESERVES IN THE OIL SHALE AND COAL DEPOSITS OF UTAH
And the Economic Factors Affecting Their Utilization

By

E.
D. Clarence Schmutz.



A thesis submitted to the Faculty of the
University of Utah in partial fulfillment of the re-
quirements for the degree of Master of Arts.

May 18, 1932

Approved by _____

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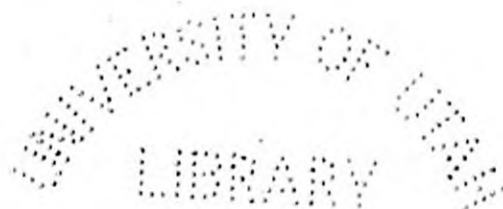
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OIL RESERVES IN THE OIL SHALE AND COAL DEPOSITS OF UTAH
And the Economic Factors Affecting their Utilization

INTRODUCTION

Purpose of Study

The great importance of fuels and their utilization to the industrial and domestic progress of cities and nations, has directed the attention of many of our leading scientists, engineers, and forward looking people to new ways by which our fuel resources can be so utilized to bring many benefits to the general scale and plane of living. Utah is fortunate in having received many years of state and federal cooperative study of her oil shale and coal resources, with respect to their by-products.

These studies have proved the reserves of oil in oil shales and coals of Utah to be very extensive, and many times greater than any of the present proved petroleum fields.

Recent research and experimental evidences are changing with respect to the order of development of the oil shale and coal reserves. It has been the generally accepted idea that oil shale was a more likely source of oil than coal. Industrial activity, also, has tended more in the development

of oil shales than coal for production of oil in the past. But later developments in the manufacture of oil from coal are tending to reverse the situation.

The common argument in relation to developments of an industry for the manufacture of oil from shales and coal is, that these reserves be saved as an emergency supply in times of national stress or exhaustion of petroleum reserves. The argument is unsound and not based upon good economic reasoning, in respect to development and utilization of the resources for the good of the public in general.

Sufficient evidence will be presented to prove that there are localities in which most advantageous economies will be had in development of an industry for manufacture of oil from these reserves.

It has been the attempt to show that such is the case in some parts of Utah, and that in these districts manufacture of oil from oil shale and coal can be done profitably. Such procedure would not agitate the present marketing conditions of petroleum, but would tend to alleviate many of the present problems, if developed under the proper organization.

A solution of the "smoke problem" in the cities may also be had by the distillation of oil and other products from coal, with little loss in the value of the raw material for heating purposes.

Consideration of the problems connected with the pro-

duction of oil from oil shales and coals has been divided into separate chapters, because of the different methods used in the process and relationship of the products yielded.

For those who are familiar with the methods of distillation and manufacture of products from oil shale and coal, the descriptive reading material may be eliminated by reference to the table of contents and following the topic headings. Those unfamiliar with these procedures will find it most advantageous to read fully the descriptive material, in order to receive a thorough understanding of problems involved.

Economic Importance of Petroleum

Petroleum is claimed to be the oldest natural product used by man, but its use was very limited until about 1859, because of the limited supply. Oil and oil products were known and used before this date in large quantities, but this product was the oil distilled from coals and oil shales.¹

The first discovery of oil by drilling was in Pennsylvania, 1859, at a depth of about 70 feet.² The discovery was quite accidental, but in a short time many other wells were

1. See History of Oil Shale, Coal.

2. Oil, American Petroleum Institute, page 29

drilled and many miles of pipe line were laid for the purpose of conducting the oil to refineries. The industry has grown rapidly and is one of the most important in the nation. The estimated total investment in 1906 was eight hundred million dollars, and in 1931 it exceeded twelve billion according to the Federal Trade Commission.

In 1930 there were estimated to have been more than one million five hundred thousand men employed in the petroleum industry.¹

The following table will illustrate the amount of Petroleum products manufactured in one year in the United States and Utah:

Table A--- Production of Petroleum and Petroleum Products, 1930

Product	United States ²	Utah ³
Crude petroleum from wells, bbls	980,000,000	8,000
Gasoline, Mfg. from petroleum, barrels	377,000,000	1,330,000
Kerosene, mfg, from petroleum, barrels	60,000,000	125,000
Lubricating oils, barrels	35,000,000	100,000
Gas and oil fuels, value	\$425,000,000	\$ 100,000

1. World Almanac, 1931
2. Idem
3. Utah Oil Refining Company

The industry is so inter-related with others that it would have disastrous effects, if the products of petroleum were suddenly taken out of use.

Substitutes for Petroleum

A seriously disturbing feature of the petroleum industry is that the supply of petroleum is very undeterminable. This fact and the high price of the products in some localities have encouraged considerable investigation for a substitute should the reserve become exhausted. In a few instances oil fields have been thought to be depleted, but deeper wells and extensions of the ones already drilled have opened up new supplies more abundant than the first. However, the chief source of difficulty at present in the petroleum fields is the fact that there is an almost uncontrollable over-production, which has caused tremendous unrecoverable losses of this product.

Possible substitutes for petroleum are as listed by Mr. Martin Gavin,¹ electricity, alcohol, and the by-products of oil shale and coal. He also states that the first two may never be of great consequence in this respect.

1. Oil Shales, Dept. Int. Bulletin 210, page 60.

Electricity is being used by railroads and trolley lines and is a chief source of domestic heat, but for the aeroplane, automobile, and ships, the great storage and transmission line difficulties will eliminate it from these fields of use. As a matter of fact, great quantities of petroleum products are utilized by the electrical industry itself.

Alcohol may be used for fuel in engines designed for compression higher than those ordinarily used with gasoline. A mixture of alcohol and benzene will make a very good motor fuel, but the difficulty of handling will retard its use. Alcohol evaporates so rapidly that it is difficult to keep it in a fuel tank.

Mr. Abraham says, "That there is probably sufficient reserves for the production of alcohol to last the American people for one Sunday afternoon outing in their automobiles."¹

Shale oil is generally considered first in order and the most likely substitute for petroleum. However, the developments in distillation of oil from coal may cause a change in the situation in certain territories. There is no appreciable difference in shale oil and oil from coal, except that the yield of oil per ton is generally greater from oil shale. This is

1. Asphalts and Allied Substances, Abraham, page 156.

not the case with cannel coal.

The subject will be considered in detail in Chapters two and three, but it may be well to note at this time that in the distillation of oil from coal, there are other by-products associated in the production that may cause a change in the importance of the position of oil as a source of productive revenue.

The current demand for the by-products associated in the distillation of these materials will have considerable weight in determining whether one will be utilized in preference to the other.

There is an appreciable amount of petroleum produced in the state. The total amount of the petroleum consumed in the manufacture of gasoline and kerosene in 1914 was 1,000,000 barrels. A considerable quantity of refined gasoline is imported into Utah, and some of the gasoline manufactured in the state is exported.

The following table will show the production and consumption of gasoline over a period of years to 1914.

Courtesy of Utah Oil Refining Company.

CHAPTER I

The Petroleum Situation in Utah

The average consumption of petroleum in Utah for the year 1930 was 7,500 barrels daily.¹ From this amount of petroleum there was for the year a total of 1,300,000 barrels. (55,930,000 gallons) of gasoline produced. Approximately two and seven tenths barrels (111.7 gallons) were produced per person in the state, as compared to three and one tenth barrels (130.2 gallons) for the United States. The per capita consumption for the State of Utah for the same year was two and nine tenths barrels (118.6 gallons).

There is no appreciable amount of petroleum produced in the state. The total amount of the petroleum consumed in the manufacture of gasoline as shown in Table No. 2 was imported. A considerable quantity of refined gasoline is imported into Utah, and some of the gasoline manufactured in the state is exported.

The following tables will show the monthly production and consumption of gasoline over a period of years to il-

1. Courtesy of Utah Oil Refining Company.

NET TAXABLE GALLONS OF GASOLINE SOLD IN UTAH, 1923 to 1931
Units -- 1,000,000 gallons

Month	1923	1924	1925	1926	1927	1928	1929	1930	1931
Jan.	.52	2.08	1.09	2.49	2.63	2.78	3.11	3.71	3.79
Feb.	1.04	1.25	1.79	2.01	2.02	2.73	3.65	3.51	3.79
Mar.	1.83	2.07	2.63	2.56	2.36	3.81	3.70	4.13	3.53
Apr.	2.67	1.90	1.39	2.77	2.51	3.44	4.38	5.85	4.57
May	2.67	2.53	2.84	3.74	3.59	4.66	5.55	5.52	5.51
June	2.78	2.81	3.52	3.61	4.11	4.78	5.51	5.86	5.21
July	2.54	2.88	3.99	3.61	4.70	4.99	6.07	6.65	6.20
Aug.	2.39	3.16	2.52	3.99	4.28	4.89	6.12	5.89	7.29
Sept.	2.51	2.57	3.00	3.69	4.05	4.78	5.44	5.46	5.82
Oct.	2.34	2.58	3.08	3.19	4.39	4.26	5.33	5.32	5.36
Nov.	1.83	2.51	2.49	2.92	3.23	3.59	4.65	4.44	4.92
Dec.	1.89	2.86	2.87	2.54	2.88	3.10	4.03	3.79	4.79
Tot.	21.01	29.18	31.21	36.92	40.75	47.81	57.54	60.13	60.74

Table No. 1a

GALLONS OF GASOLINE MANUFACTURED IN UTAH SINCE 1923
Units -- 1,000,000 gallons

Month	1923	1924	1925	1926	1927	1928	1929	1930	1931
Jan.		2.39	2.59	2.68	3.84	4.47	3.91	4.06	4.24
Feb.		2.46	2.53	2.19	3.11	4.03	2.93	3.52	4.61
Mar.	2.77	4.15	1.31	3.37	3.63	4.08	4.27	4.25	3.99
Apr.	3.13	4.13	2.38	3.38	3.50	4.16	4.27	4.29	4.23
May	2.55	3.49	2.46	3.52	3.58	4.95	4.78	4.96	4.45
June	2.53	3.19	2.42	3.71	3.39	4.40	5.38	5.02	4.60
July	2.28	2.85	2.62	3.41	3.72	5.00	4.50	4.78	4.25
Aug.	2.35	3.24	2.43	3.81	3.80	4.96	5.33	5.64	4.55
Sept.	2.15	2.89	2.66	3.51	4.17	4.71	5.35	5.79	4.01
Oct.	2.58	2.78	2.87	3.19	4.56	4.43	5.89	4.66	4.04
Nov.	2.37	2.58	3.22	3.36	4.23	4.38	4.93	4.73	1.93
Dec.	2.61	3.05	3.15	3.48	4.27	3.88	4.57	4.24	4.15
Tot.	25.42	37.20	30.64	36.61	45.80	53.45	55.13	55.93	49.05

Table No. 1b

Source of Tables -- Office of the Secretary of State.

GASOLINE CONSUMED AND MANUFACTURED IN UTAH -- 1923 to 1931¹
- in millions gallons -

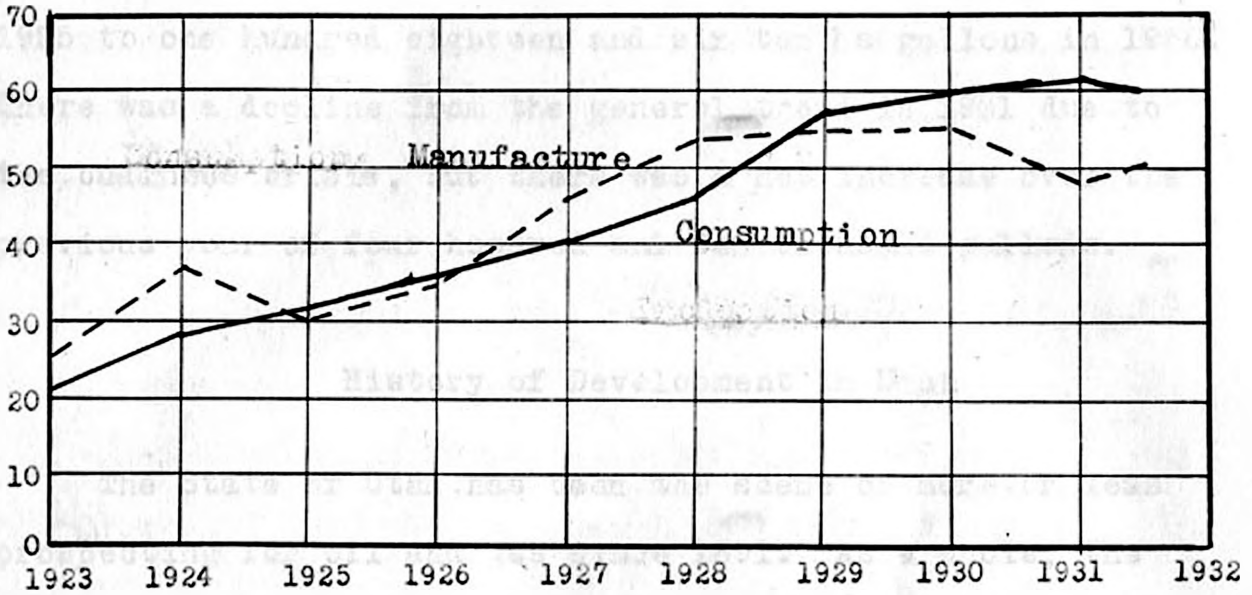


Table No. 2

The Utah Oil Refining Company is the only petroleum refining organization of any importance in the State of Utah. Not all the gasoline manufactured in the state is consumed here. There is considerable amounts of the manufactured gasoline exported to surrounding states. Large amounts of refined gasoline are imported into Utah by the various distributing companies.

The total amount of the crude petroleum consumed in the manufacture of the gasoline, as shown in the table, was imported from surrounding states. Except for a small production in the Virgin field, Utah is entirely dependent upon external sources for the supply of petroleum at the present time.

1. Information gathered at the Office of the Secretary of State.

illustrate the growth of the industry. The per capita consumption increased from approximately sixty two gallons in 1925 to one hundred eighteen and six tenths gallons in 1930. There was a decline from the general trend in 1931 due to the business crisis, but there was a net increase over the previous year of four hundred and ten thousand gallons.

History of Development in Utah

The State of Utah has been the scene of more or less prospecting for oil and gas since 1891. As a whole, the results have been disappointing. A small production of oil from the Virgin Field in the southwestern corner of the state is the only commercial result. In the southeastern corner of the State, in San Juan county, a small amount was discovered, but this locality is so isolated that the oil was used locally for drilling fuel.

The neighboring States of Wyoming, Colorado and New Mexico have producing oil fields, some of which are quite near the Utah border. However, there are no important oil pools so far discovered in Utah, despite a large number of favorable structures and much drilling. The quest has, however, disclosed eight gas fields, but they are so far removed from important consuming centers that only two

are being used, one at Cisco, for the manufacture of carbon black, and the other is in Ashley Valley. The gas from the Ashley Valley well is piped to Vernal, Utah and sold for commercial consumption.¹

Helium was found in the territory in Grand county, also carbon dioxide gas used for production of dry ice, but is as yet too expensive, because of inefficiency in utilization, to be commercially adopted.

Probably the first oil well drilled in Utah was by Bamberger and Millis near the town of Green River in 1891. The well was drilled to a depth of 1,000 feet, but no oil was found. Soon after this, there were twenty or more wells drilled near Farmington, north of Salt Lake City, some being drilled 2,000 feet deep. Shallow wells produced some gas but no oil. Attempts were made to furnish Salt Lake City with gas from this field. These were successful for about nineteen months, during which time 136 million cubic feet of gas were obtained, but the endeavor was abandoned about 1897.²

In 1907 oil was discovered near the town of Virgin, by Patrick Holehan.³ There was a short lived "boom" but no further discoveries at the time.

1. History of Gas and Oil Activities in Utah, R. N. Larsen, page 3.
2. Idem, page 2
3. Idem, page 2

Drilling began in the San Juan region, near Mexican Hat, and in 1908 oil was discovered. The well was claimed to be a gusher, throwing oil seventy feet into the air. Activity continued until 1912 with no other favorable results. Most of the wells in this territory were shallow. There were more than seventy-five wells drilled, many gave oil showings sufficient to hold the claims, but only six were found to produce notable quantities. These producing wells were all within a radius of one and one quarter mile of a common corner.¹

The oil is a paraffin base from about three to seven percent by volume, specific gravity of about .85, average. It is dark green to black in color and very low in content of sulphur, about one to four tenths percent.²

There are several oil seeps along the canyon walls of the San Juan river. These seeps are very small, but the oil coming from them gives an indication of being high in gasoline content.³ This field is about 400 hundred miles from Salt Lake City and about 170 miles from the nearest railroad, at Thompson, Utah.

In 1911 and 1912 drilling was begun in the Uinta Basin,

1. U.S.G.S. Bulletin 751, page 125
2. U.S.G.S. Bulletin 431, page 125
3. U.S.G.S. Bulletin 751, 140

Green River, Deseret, and the upper portion of San Juan County. With the opening up of large areas to prospecting under the oil and gas permits in 1920, activity was begun by numerous large companies. Favorable oil and gas showings, oil seepages, exposures of saturated oil sands and shales, and large suitable structures gave rise to the hope that some of the major structures of that territory contained profitable oil pools. The results of the prospecting in this territory, however, have been expensive and disappointing to date.

The first well started by a major company was the Circle Cliffs well, drilled by the Ohio Oil Company, 1921. In the same year drilling began at Farnham, Huntington, Salt Wash, San Rafael Swell, and Caineville. Among the wells reporting favorable results of oil were the Crescent Eagle, Moab, and Cane Creek wells. The spectacular showing of the Frank Shafer well at Cane Creek in 1925, probably added more impetus to the prospecting than any other. A drilling campaign resulted in the next two years in the southeastern part of the state, but wildcat activity somewhat lessened in 1929 and 1930.¹

Near the Green River field and to the north and west there was considerable activity carried on in search of oil in the territory known as the San Rafael Swell. It is

believed that this field is connected with the Green River area. There were more than forty five wells drilled in this field, the most of which were completely dry.

The geological structure of the San Rafael Swell was considered very favorable for oil prospecting. Three deep test wells were drilled. The Carter Oil Company drilled to 3035 feet; drilling began in July 1921. The Utah Oil Refining Company drilled another in 1923, to the depth of 3120 feet. Gas was struck in this well. It was found to be noncombustible, chiefly carbondioxide, with notable quantities of helium. Accordingly, the entire area was closed as Helium Reserve No. 1, March 21, 1924.¹

The Virgin field, near Virgin City, is the only Commercial producing oil field in the State of Utah, at the present time. Oil is found there at shallow depths, from five hundred to seven hundred feet. The oil must all be pumped and only in limited quantities. There are some wells from which thirty barrels have been pumped per day, but the average will not exceed ten for the producing wells in the field. From the records of shipment from the well, which were obtained by visiting the field, the total amount of the oil shipped in 1931 did not exceed 8,000 barrels, the most of which was used for roads and heating purposes. There is a refinery in Cedar City, some

1. History of Oil and Gas - Utah - page 4



fifty miles away and some of the oil is refined into gasoline which is distributed to the local market by the Utah Parks Oil Company. The gravity of the oil in this field is about .85 and it is of a paraffin base.

This field is situated on the upper crest of the Hurricane Fault, and oil men and geologists are agreed that the quantity is likely to be very limited. The average cost of drilling wells in the field will not exceed \$1,000.00, now that the formation is fairly well known.

About twenty miles to the west and south of the Virgin Field there have been attempts to find oil, on what is known as Virgin Dome. One hole was drilled to the depth of about 3000 feet, but no oil was found in commercial quantity. Work was begun in 1915 and on Dec. 30th 1931 it was learned by the author that they cased the well to test for production, but so far the test has been unsuccessful.

In 1929 the Mid-American well No. 1 was started on the Bloomington Dome, about 7 miles south of St. George. The well was drilled to 2900 feet when it was capped and the machinery moved about two miles further south. The first well was reported as being off structure. The new location was drilled to a depth of 3200 feet when drilling was stopped to case and test for commercial production, but there has been no favorable report to the present time, al-

though at the time, it was reported that very good showings were had. Other wells are being drilled but have not reached formation levels.

The following tables are presented to more fully illustrate the extensive explorations for petroleum in Utah and the results of these drillings.

RESUME OF THE YEARLY DRILLING ACTIVITY, 1891 to 1932, UTAH

<u>Yearly Total Wells Drilled</u>				<u>Accumulated Wells Drilled, Total</u>					
<u>Year</u>	<u>Oil Gas</u>		<u>Dry</u>	<u>Total</u>	<u>Producing</u>		<u>Shut In or Abandoned</u>		
	<u>Oil</u>	<u>Gas</u>			<u>Oil</u>	<u>Gas</u>	<u>Dry</u>	<u>Total No.</u>	
1891			1	1			1		1
1893-4			20	20			21		21
1899			2	2			23		23
1900			3	3			26		26
1902			1	1			27		27
1904			2	2			29		29
1907	3		15	15		3 X	44		47
1908	1		9	10		4	53		57
1909	2		10	12		6	63		69
1910	2		10	12		6	73		81
1911			18	18		8	91		99
1912			18	18		8	109		117
1913			3	3		8	112		120
1914			1	1		8	113		121
1915			1	1		8	114		122
1917			1	1		8	115		123
1918			3	3		8	118		126
1919			2	2		8	120		128
1920			4	4		6	124		132
1921			14	14		8	138		146
1922	1		13	14		9	151		160
1923	2		6	8		11	157		168
1924	4	3	15	22		15	3	172	190
1925	5	3	14	22		20	6	186	212
1926	1	3	13	17		21	9	199	239
1927	2	4	29	35	3	6	20	7	228
1928	4	7	20	31	6	10	21	10	248
1929	10	1	20	31	8	9	29	12	268
1930	11	1	10	22	10	5	39	17	278
1931	4		8	12	14				290
Total	52	22	286	360					360 6

Explanatory Notes:

1. Twenty wells near Farmington furnished some lake bed gas after 1893-4 which was piped to Salt Lake City. Not listed as producers.
2. All oil wells listed are in the Virgin and San Juan fields. Details of erratic production previous to 1927 not known. Oil used locally or for fuel previous to 1927. Production of individual wells from one to thirty barrels daily.
3. Figures are as of end of year.
- X. Some pumping done between 1907 and 1926, details unable to obtain.

Table No. 3

Table No. 4 --- Classification of the Wells Drilled in Utah,
By Depth--- Counties.¹

Depths -- in feet--				num- ber	Total under	500'	num- ber
Wells between	0'	and	500'	80			80
"	500'	and	1000'	148	"	1000'	2228
"	1000'	"	2000'	56	"	2000'	284
"	2000'	"	3000'	41	"	3000'	325
"	3000'	"	4000'	21	"	4000'	346
"	4000'	"	5000'	7	"	5000'	353
"	5000'	"	6000'	7	"	6000'	360
No wells over 6000'							

Counties--	<u>No. of Wells</u>		<u>No. of Wells</u>
Washington	110	Duchesne	1
San Juan	74	Juab	1
Grand	60	Kane	1
Salt Lake	22	Tooele	1
Emery	17	Beaver	0
Uintah	24	Cache	0
Boxelder	13	Davis	0
Millard	8	Iron	0
Utah	6	Morgan	0
Carbon	5	Piute	0
Daggett	5	Rich	0
Wayne	5	Sevier	0
Garfield	3	Wasatch	0
San Pete	2	Weber	0
Summit	2		
		Total	360

1. History of Oil and gas Activities in Utah, R. M. Larsen
page 12.

-21-
STATE OF UTAH

SHOWING OIL & GAS FIELDS & TOTAL NUMBER OF WELLS STARTED IN EACH COUNTY & FIELD

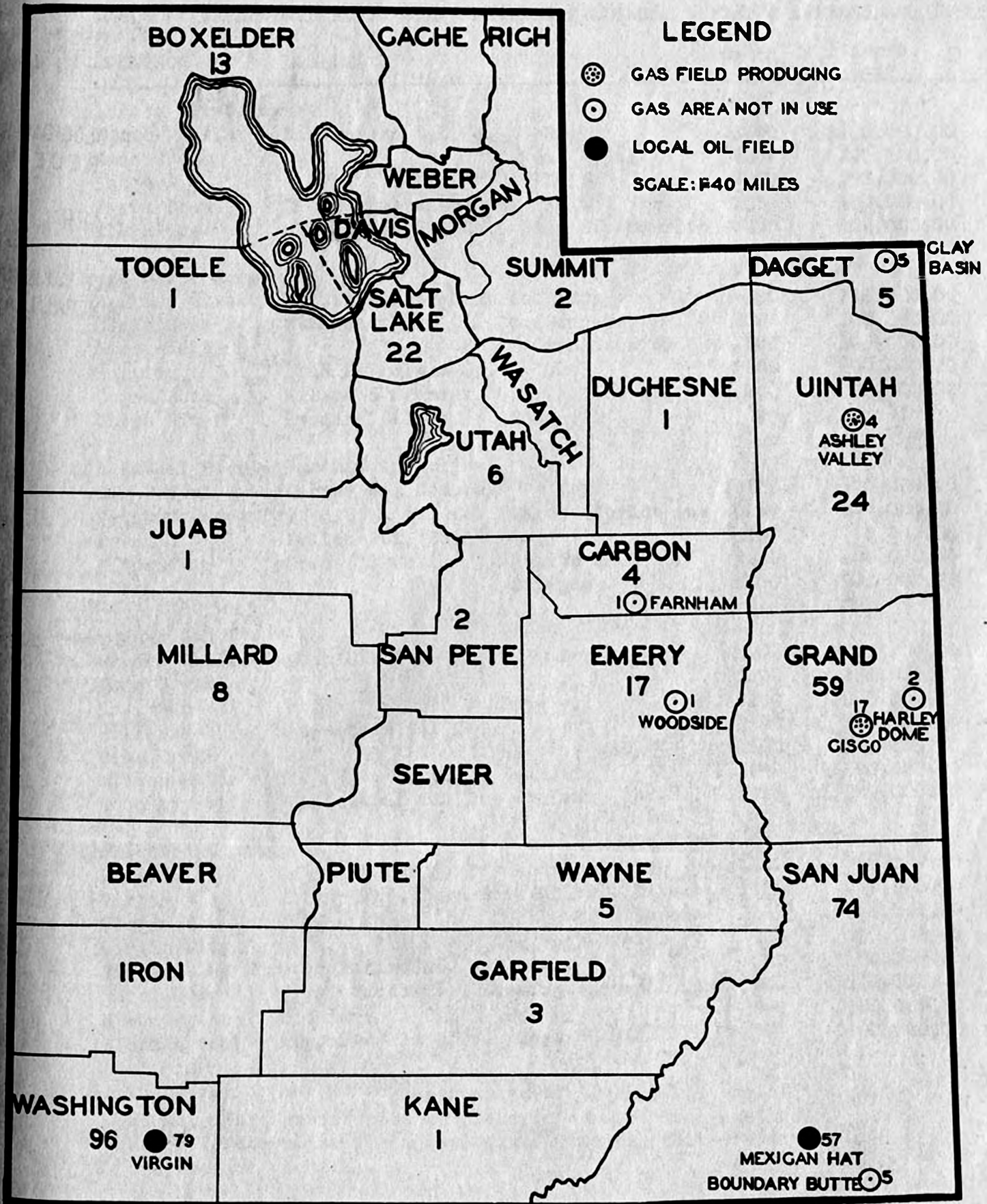


Table No. 5

U.S. GEOLOGICAL SURVEY
MIDWEST N° 8721

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U. S. Geological Survey
Midwest, Wyoming.

GEOLOGICAL SURV
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SALT LAKE CITY
MINERAL LEASING

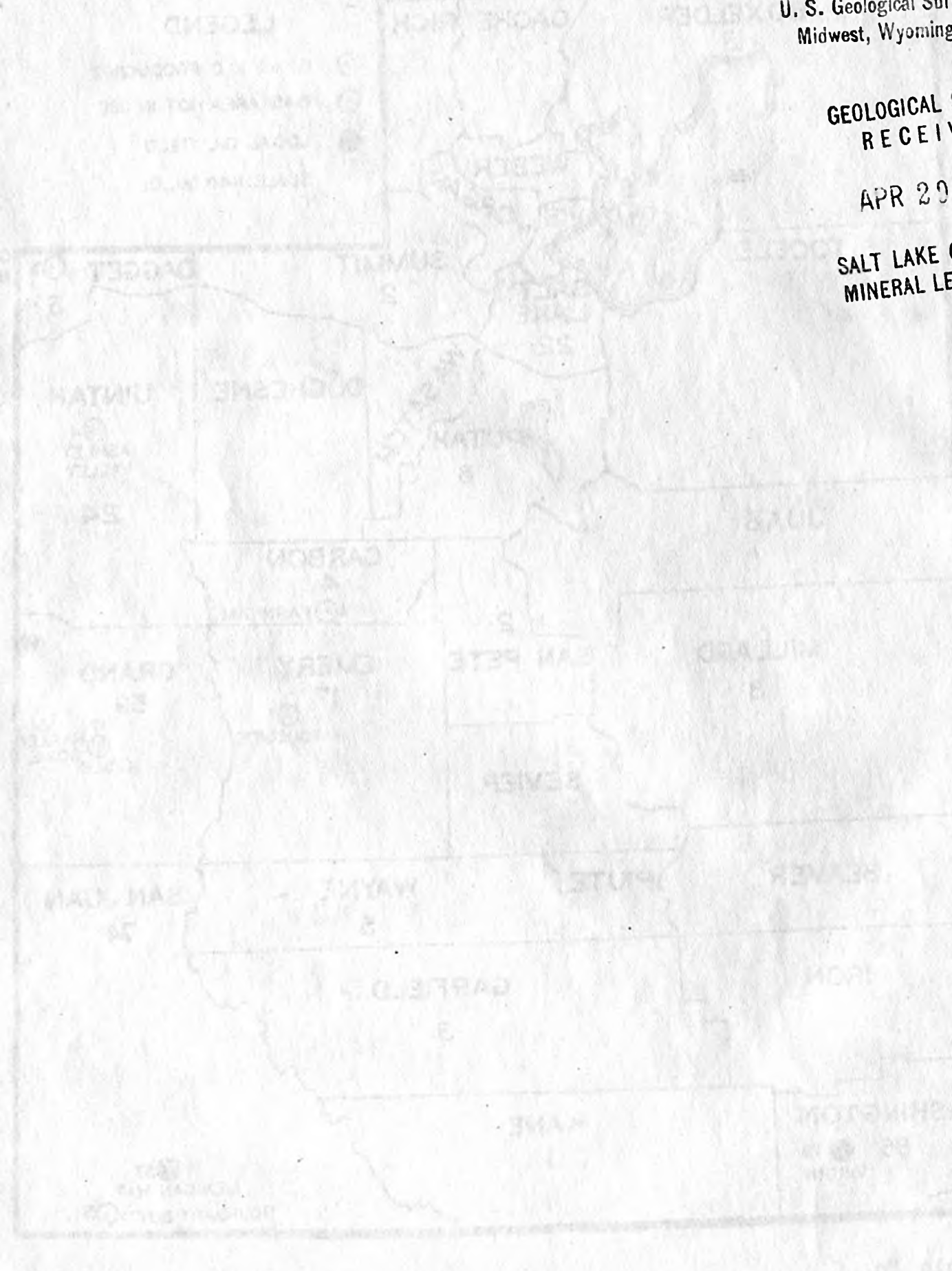


Table No. 6

TABLE OF WELLS DRILLED IN UTAH, SHOWING FINDINGS, DEPTH, & APPROXIMATE COST ^T

LOCATION	DRILLED BY	FINDINGS	Depth in ft.	Appro. Cost
Colorado River Area:				
Buster Valley	Midwestern Oil Co.	Dry	3600	\$100,000.00
Cane Creek	" " "	Oil & Salt	5200	200,000.00
Shafer	" " "	Salt	5000	125,000.00
Harts Draw	Empire Petroleum Co	Salt	3250	100,000.00
Elk Ridge	Midwestern Oil Co.	Blue Mt. Granite	4000	150,000.00
Green River Area:				
Barrier Creek	Phillips Petroleum Co.	Dry	4500	150,000.00
Cedar Mesa	Utah Southern Oil Co.	Granite	3000	100,000.00
Lime Ridge	" " "	" Granite & CO	2500	100,000.00
Hulkits	Utah Petroleum Co.	Gas	2000	100,000.00
Organ Rock	Wilson & Cranmer	Dry, little gas	1600	90,000.00
Green River	Leonard Oil Co.	Show oil	?	?
San Rafael Swell--Farnham Anticline:				
San Rafael	Carter Oil Company	Dry	3100	100,000.00
Farnham (near Price)	Utah Oil Co.	Carbon dioxide gas	3260	220,000.00
Farnham	Fulton Pet. Co.	"	3100	60,000.00
Woodside	Utah Oil Co.	Helium & CO	3250	130,000.00
Cisco	" " "	Oil-gas	2000	100,000.00
San Juan County:				
Circle Cliffs	Ohio Oil Co.	Dry	3200	200,000.00
Cane Creek	" " "	"	2600	250,000.00
Chalk Creek	" " "	Show oil	3200	200,000.00
Hill Creek	Midwestern Oil Co.	Dry	2300	90,000.00
Cane Creek	" " "	Showing oil	4800	200,000.00
Mitten Butte	Utah Pet. Corp.	Granite	1640	90,000.00
Boundry Butte	Continental Oil	Dry PrePenn	5610	250,000.00
Washington County:				
Virgin	J. P. Thomss	Dry Menkopi lime	1227	80,000.00
Virgin	Virgin Pet. Corp	Showing oil, Kaibab	1410	70,000.00
Virgin	" " "	" " " Super	2195	100,000.00
Virgin City	" " "	Oil, commercial	700	20,000.00
Virgin City	Utah Parks Pet. Co.	Oil "	600	20,000.00
Harrisburg	Virgin Dome Oil	Showing, Redwell lime	3400	200,000.00
Bloomington	MidAmerican Oil	Dry	2800	150,000.00
Bloomington	Arrowhead Pet. Co.	Showing oil	3000	100,000.00

not

The above may or may not be representative of the explorations of the state but were only those where complete information was available.

T- Mr. Ed. Watson, ex-field geologist, Utah Oil Co.

? - Information doubtful.

Production

So far, actual production of oil in the State of Utah has been confined to the Virgin and San Juan fields, as mentioned previously.

The Virgin field produced oil in 1907 from several of the first wells drilled. The financial panic of that year caused a lapse in activity until 1918. Detailed information on the production previous to 1927 is unavailable. When the wells were actively pumping, the yearly production may have been greater before than since 1927. Some of the early wells drilled have been reported to have yielded 30 barrels per day.

Wells drilled since 1927 have averaged five barrels a day, with only one well pumping more than 15 barrels per day for the first month. The oil occurs near the base of the Moenkopi formation (Lower Triassic) between 525 and 825 feet beneath the surface. The producing wells are mainly in two adjoining sections.¹

The Production of Oil From the Virgin Field, in the Last Five Years ²

	1927	1928	1929	1930 ¹	1931
Government	1325	2200	3400	3000	
Private	450	1100	4200	5000	
Total	1775	3300	7600	8000	8000³

1. History of Oil and Gas in Utah, R.M. Larsen, Page 16
2. Idem
3. Estimate from field at Virgin

The San Juan Field has produced a total of 16,000 bbls., according to Mr. W. E. Nevills of Bluff, Utah. Half of this was produced in 1903 to 1910 and half in 1924. Most of this production came from three wells in one section. The oil occurs in several sands near the base of the Permian and top of the Pennsylvanian formations. The sands appear to be pockety, and are at depths between 200 and 700 feet in the producing area.

All likely formations in Utah have been quite thoroughly tested. According to Dr. F. J. Pack, University of Utah, there is but two small areas that might be more thoroughly explored. These are: the area near St George, where drilling is being conducted at the present time, and the area just south of the Uinta mountains. It is also, "very unlikely," according to Dr. Pack, "that there is any oil at depth not as yet reached by the tests that have been made."

Production of petroleum in Utah from wells then, is and very likely will continue to be small and with the exception of the small quantity produced in the Virgin field, Utah is at the present time dependent upon the neighboring states for her supply of petroleum. This fact has a direct bearing upon the attitude to be taken in the development of an industry within the state for the distillation of oil from the reserves of oil shale and coal.

CHAPTER II

OIL SHALE

Origin of Oil Shales

Black shales containing volatile matter, and therefore capable of yielding inflammable gases and oil, occur in the sedimentary formations of practically all geological ages. But in limiting the term to "oil shale", we include only those shales capable of yielding oil by destructive distillation. There are variations in the grades of oil shales, varying in amount of oil and other by-products, even within the same beds. Some shales yield oil by application of the ordinary solvents of petroleum, but are not true oil shales, the bituminous material having leached into the shale after it was deposited. The oil shales, which are to be included in this study, are the true "oil shales", the bituminous material yielding oil only to decomposition by heat in the absence of air. Such shales are those found in Scotland, New South Wales, France, Nova Scotia, Colorado, Wyoming, and Utah. These are shales in which the bituminous matter was intimately mingled with the organic material at the time of deposition.

The general similarity of the geology of oil shales to that of coals suggest that the geological conditions

and processes favorable for the deposition or making of one were also required for the making of the other. Both were formed in swamps, lagoons, deltas, estuaries and lakes. A few coal and oil shale deposits were probably formed largely or wholly under marine conditions.¹

Characteristics

Oil shales are usually brown or blackish brown in color, varying according to the quality of the shale, the time of exposure to the elements, the amount of bituminous matter and the type of foreign material which it impregnates.³

Mr. M.J. Gavin defines oil shales as a "compact, laminated rock of sedimentary origin, yielding over 33 per cent of ash and containing organic matter that yields oil when distilled, but not appreciably when extracted with the ordinary solvents of petroleum!"²

G.H. Ashley says that "The line between a coal and a shale has never been sharply drawn", but he makes the suggestion, "That material which, when burned, breaks down and yields an ash that goes thru the grate bars and shows no tendency to maintain its original shape is a coal, and that material which on burning yields an ash that tends to maintain its

1. Oil Shales -- McKee -- Chapter 2

2. U.S. Dept. Interior, Bulletin 210 page 26

3. L. C. Karrick, U. S. Bureau of Mines, Bulletin 249

original shape is a shale. The exact percentage of ash that should distinguish a coal from a shale has not yet been given, but until more exact figures are available it is suggested that material that yields less than 33 per cent of ash be considered a coal."¹

Rich oil shale of good quality, in certain grades, resembles good hard wood or leather, and an experienced man can tell its quality by the way it curls when cut with a sharp knife. Other shales are too tough and stone-like to be cut at all and must be broken.

History of The Oil Shale Industry

The production of tars by the dry distillation of wood was known at least as early as the latter part of the seventeenth century. About this time coal was distilled in England for the production of oil and tar, and later coke. In 1694, Hancock, Eele, and Portlock distilled "oyle from a kind of stone"², possibly oil shale. Bituminous coal and oil shale were distilled as early as 1761 for the production of oils to be used for Materia Medica.³ But it was not until the discovery of the possibilities of the production

1. U.S. Geo. Survey Bulletin 659 page 26
2. Shale Oil & Tars- Scheitham - p.1 See also History of Coal following this Study.
3. Dept. Of the Interior Bulletin 210- page 50

of paraffin and petroleum-like oils from the shales in 1830 that there was any very active production of oil from the oil shales.

It was in France, 1830, where it was first developed that paraffin could be obtained by distillation of shale oil, but it was 1838 before it really began. In 1839, Selligie exhibited at a French fair samples of shale oil product: light oils, burning oils, heavy oils, and paraffin.¹ The French industry grew until 1864, when it was practically paralyzed by importation of cheap petroleum, from which it has never fully recovered.

Although the oil shale industry in Scotland is the most highly developed at the present time, it was not until 1850 that any development began. That year a plant for the distillation of oil from "boghead coal" was erected by James Young. In 1862 this coal became exhausted and the oil shales were used for the production of oil and other products.

Since 1851, over 140 different companies have entered the oil shale industry in Scotland, but in 1910 there existed but six large, active companies. These companies are still in operation, but are consolidated or united into one large holding company, "The Scotch Oil Shales Ltd."²

1. Oil Shales-- McKee pages 50-53.

2. Report of Scotch Shale Industry, 1925, page 3.

Cheap petroleum in 1864 had like effects on the oil shale industry in Scotland as in other countries and only the largest, most favorably situated companies have been able to exist. Naturally the best shales were used first and there has been a decrease in the yield of oil per ton even with the improvements in methods of distillation. The ammonium sulphate production per ton, however, has been nearly doubled. The following table illustrates the various changes from 1886 to 1925:¹

Table No. 6a---By-product Yield of Scottish Oil Shales
1886 - 1925.

	<u>1886</u>	<u>1890</u>	<u>1900</u>	<u>1910</u>	<u>1925</u>
Shale production, 1000 long tons	1,728	2,212	2,282	3,130	3,080
Yield of Am. Sulphate, lbs. per ton	23.4	25.0	36.6	42.2	42.4
Yield of Oil, gals. per ton	31.2	34.7	28.4	25.0	23.0

The shale industry was also developed in Australia in 1865. Some of the shales yielded as high as 170 gallons of oil per long ton. Others averaged from 90 to 100 gallons. The oil from these high grade shales was also very easily refined, the specific gravity being about 0.85, A. P. I. Petroleum was also imported into Australia in competition with shale oil production, and the British Government found it necessary to subsidize the industry to keep it alive. In 1919 the shale industries of Australia received from the British treasury, as a bonus, £ 26,406. In 1923 the stills

1. See Report of Scotch Shale Industry, 1925.

were all shut down and the refineries converted to refining petroleum.¹

History of Oil Shale Industry in United States

In 1860 there were fifty-three oil shale companies in the United States, largely in Pennsylvania and Kentucky, producing oil by distillation of various kinds of bituminous substances. Many of them operated under licenses from the Young Company of Scotland. The methods used were crude and the materials treated varied from bituminous and cannel coals to true oil shales. The desired product was "coal oil", to be used as fuel and lamp oil. The industry was paralyzed by the discovery of petroleum in 1859 and has not recovered to any marked extent. The retorting stills were abandoned, and the refineries converted to refining petroleum, or scrapped.²

Oil shales were distilled in Utah by the Mormons as early as 1875 or '80, and the remains of an old still can be found near Juab.³ Other developments in Utah have been promoted since and will be discussed later.

Since the discovery of petroleum there has been practically no commercially successful development in the shale industry. Except for one or two experimental plants by the

1. Dept. Interior-- Bulletin 210 page 56
2. Dept. Interior-- Bull. 210 -- also Eng. & Mines Journal, Vol.88, pages 152
3. Oil Shales-- McKee, page 22.

United States Bureau of Mines, and one privately operated plant at Elko, Nevada,¹ the oil-shale industry can hardly be said to have existed in the United States, except in the literature of promotion concerns. In 1914 Woodruff and Day² published the results of an investigation of the oil shales of the Green River formation in Colorado, followed by other governmental reports of Winchester.³ They claimed that oil could be extracted from the deposits in Colorado, Wyoming, and Utah. This developed considerable interest in the possibilities of an oil shale industry. Companies came into existence like toad stools and claims were staked and patented, but only one approached the commercial scale and that was the one mentioned at Elko. From 1918 to 1920 there was further excitement and activity in the promotion of the shale industry and many attempts were made to commercialize this resource. There were also many fake promotion companies that did much harm to the industry, as is registered in an Oil Shale Conference held in Denver in January, 1924.⁴

In this recent development of the oil shale industry, Nevada holds the record for having the first commercial sized oil shale plant to run continuously. There have, however,

1. The Catlin Shale Products Company
2. U.S. Geo. Sur. Bull. 641 Report of Woodruff and Day.
3. U.S. Geo. Survey Bulletin 729.
4. Col. Sch. Mines Quarterly Jan. 1924.

been many other plants established. The Monarch Oil Shale Company began operations in 1924 at Debeque, Colorado. The Bureau of Mines established an experimental plant at Rullinson, Colorado, 1925, and operated in 1927 and again in 1929.

The main activity in Utah, aside from the work of the station of the Bureau of Mines, at Salt Lake City, was at Watson. The Ute Oil Company, with holdings on the White River, was organized in 1919. The first attempt failed, but it was reorganized in 1924. This company held on patent, nine claims of rich oil shale land. Two veins, 26 feet in thickness which can be worked as a single vein, underlie the entire property. There is, in addition, probably more than a hundred feet of unproven shale in this deposit. Tests from these properties show an average yield of 30 to 50 gallons per ton. The Watson Company, in 1924, held by patents and registers' certificates 5,560 acres of such land at Watson, and 65,000 acres of which full assessment work had been done in the Uintah County near Watson.¹

Oil Shale Deposits in Utah

Oil shales of the Green River formation occur in

1. Oil Shales -- McKee, page 139.

northwestern Colorado, southwestern Wyoming, and northeastern Utah in Uinta, Duchesne, Carbon and Wasatch counties. Of the three states, Utah contains the largest deposits now known.

In Eocene time a lake basin occupied these regions. In the Tertiary period there was another large lake to the south of this basin. It was during these times that the shales were deposited. From the sediments of the inflows of these lakes the basins were built up and the Wasatch, Green River, Bridger, and Uinta formations were deposited, having a total thickness of several thousand feet, all of which of course, do not yield oil.¹

During the deposition of the upper half of the Green River formation the geological conditions were, at times, favorable for the formation of the oil shales, and they occur in bands and strata ranging from 75 to 80 feet in thickness. In many instances they are sharply set off from the underlying and overlying strata, while in others there is a gradual transition from rock practically free from bituminous matter to layers which will yield on the average as high as 60 to 80 gallons of oil per ton, and from this again to almost barren rock. Thin layers may be found

1. Information obtained from Dr. F.J. Pack.

that will yield 90 gallons of oil per ton, and strata from three to ten feet in thickness which will average 60 to 70 gallons.¹ These shales will yield upwards of 20 pounds of ammonium sulphate per ton.

The oil shales in Utah and surrounding territory are comparatively much above the average in their yield of by-products as shown in the following tables.

Table No. 7-- Yield of Shale Oil and Ammonia From Various Oil Shales²

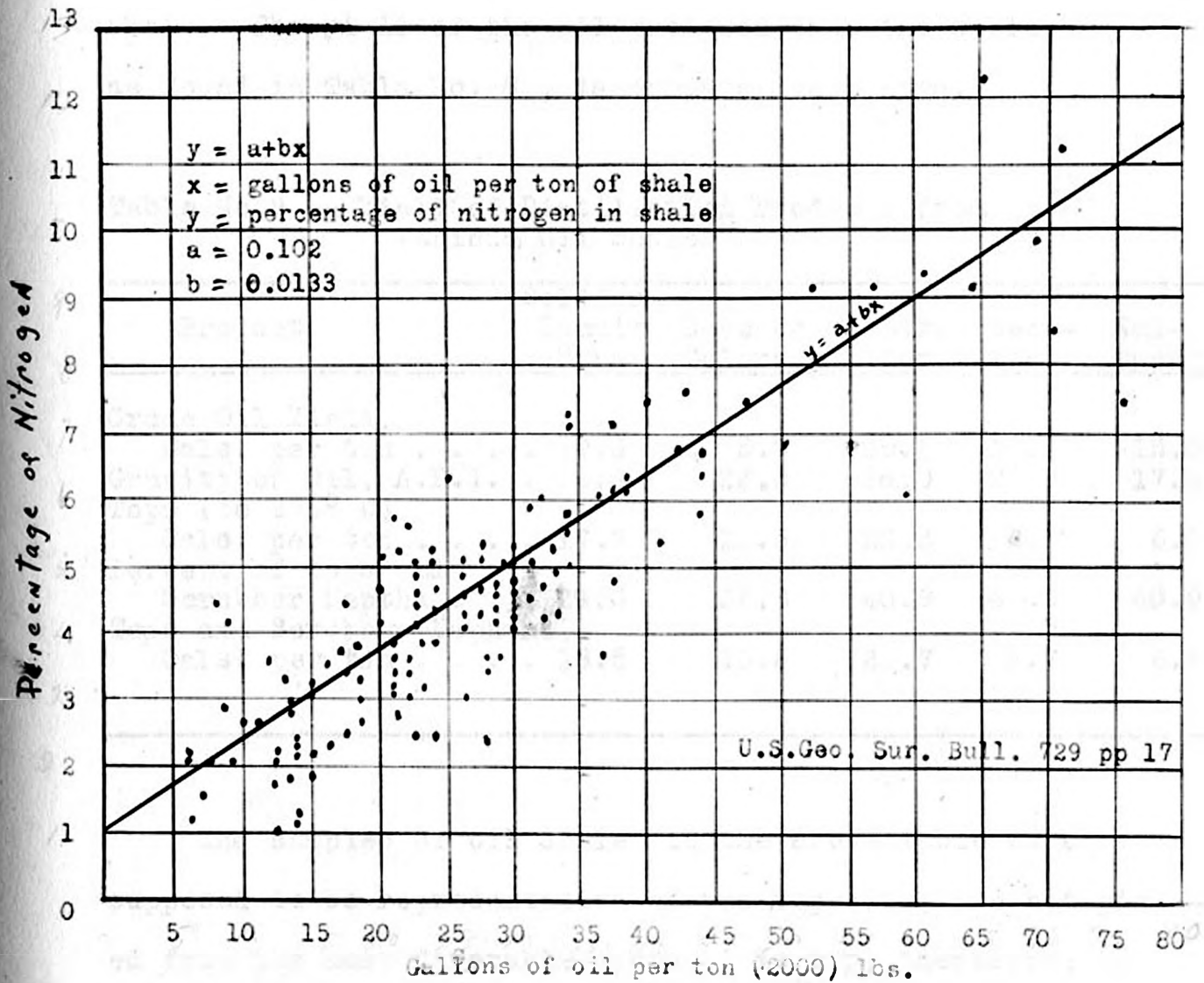
Deposits	Yield per ton of Shale	
	Tar, gals.	Ammonia, lbs.
Lothian, Scotland	10 to 55	6 to 70
Kimmeridge, England	10 to 40	10 to 50
Coorangitia, New South Wales.	14 to 150	20 to 30
Orepuki, New Zealand.	20 to 40	
Albert, New Brunswick	30 to 50	67 to 100
Arcadia, Nova Scotia	4 to 25	0 to 10
Kukkerteite, Estonia	70 to 80	5 to 15
United States:		
Eastern States	4 to 45	0 to 10
Colorado and Wyoming ³	15 to 90	22 to 34 ⁴
Utah ³	15 to 90	20 to 50 ⁴

Table No. 8 shows how the yields of these two products correlate with each other as found from samples of oil shale in Utah. The yield of nitrogen, the source of ammonium sulphate

1. Oil Shale -- McKee-- pages 64- 67
2. U.S. Geo. Sur. Bull. 210, page 28
3. Oil Shale-- McKee, page 64
4. The Columbia Steel Corporation, Provo, reports that

Table No. 8

CORRELATION OF NITROGEN IN OIL SHALE OF THE GREEN RIVER FORMATION
And the Yield of Oil From the Same Shale



Nitrogen in shale is desirable, it is the source of the Sul/Ammonium. Its presence in no way deteriorates from the quality of the shale oil, as does sulphur, but bears a marked relation with the yield of oil. This close relation shows that the nitrogen is also largely organic rather than mineral. The sulphur in the shale, appears to bear no relation to the oil yield, and is derived largely from inorganic matter in the shale. If this is the case, then it should be less difficult to prevent it from entering the shale oil to damage the compounds. U.S. Geo. Sur. B. 729 p 17

Many Utah shales are free from sulphur, some have limited amounts, much less than Colorado. U.S. Geo. Sur. B. 729 p 69-71

bears a close relationship to the quantity of oil in the shale. The yield of the oil produced from the shale, as found in Table No. 8 , is comparatively high.

Table No.9 -- Yield of Distillation Products from Various Oil Shales

Product	Soldier Summit Utah	Debeque Colorado	Elko Nev.	Scot-land	Ken-tucky
Crude Oil Yield,					
Gals. per ton	49.5	35.7	59.1	16.4	15.0
Gravity of Oil, A.P.I. .	24.3	23.5	28.0	28.8	17.8
Tops (to 275° C)					
Gals. per ton	17.7	13.5	22.2	6.1	6.1
Percent of tops and					
Scrubber Naptha . . .	29.6	37.8	40.9	40.9	40.9
Tops and Scrubber Naphtha,					
Gals. per ton	18.5	13.6	25.7	6.7	6.7

The samples of oil shale in the above table were supposed to be representative of the deposits, and not picked from the most favorable spots. It may, therefore, be assumed that the Utah shales are very high in comparison to other shales in yield of by-products.

from actual production in their coke plant, a yield of twenty to twenty-five pounds of ammonium sulphate per ton of shale. This yield is in the absence of the use of steam, which is not conducive to the highest efficiency in ammonia production. 5. American Petroleum, Supply and Demand, page 144.

A comparison of the yield of the Scottish oil shale with that of Uintah Basin, Utah, will be found in the following table:

Table No.10--- Fractionation of Uintah Basin and Scottish Shale Oil¹

Product	Percent, by volume	
	Uintah Basin ²	Scotland ¹
Naphtha, (gasoline) . . .	7 to 12	9.9
Kerosene	28 to 50	30.
Asphalt5 to 4.1	
Paraffin	1.6 to 9.2	9.5
Sulphur4 to 1.4	1.5
Nitrogen9 to 2.2	3

It will be noted that the yield of products from Scotch shale oil and that which may be produced from the Uinta Basin is very similar. However, the light oil yield may be greater in the Uintah shale oil.

Since the publication of the bulletin from which this table was taken, they have discovered a new method of treating a crude before distilling. The process is called cracking. By this method the yield of gasoline may be increased to 70 percent of the crude.

The size of the deposits of oil shale in Utah is

1. Calculated from tables in U.S. Dept. Int. Bull. 210
2. U.S. Geo. Survey Bulletin 691, page 43

tremendous. To give the number of acres and the number of tons of shale that will yield an average of so many gallons of oil and the number of pounds of ammonium sulphate per ton would be meaningless.

A comparison of the quantity of petroleum that has been produced since the discovery of this product and the amount of shale oil that is held in reserve in the oil shale deposits of Utah, is given by Dr. R. H. McKee. In his book on Oil Shales, published in 1925, he says, "Since the discovery of petroleum in Pennsylvania in 1859, the United States has produced about ten billion barrels of oil from wells, which constitutes about two thirds of the world's production, and that there is sufficient oil in the oil shales of workable beds in the Green River formation of Utah alone to furnish ten times the amount" (one hundred billion barrels.) This amount would be sufficient to last the whole United States for one hundred years at the rate of petroleum production of 1929; the greatest productive year in the history of the petroleum industry. He further states, "That there is an equal amount in each of the adjoining states, Colorado and Wyoming." On the basis of twenty pounds per ton, the estimated reserves of ammonium sulphate in Utah would be 184,318,000 short tons.

The richest oil shale deposits in Utah are those around Soldier Summit and Watson. The estimated tons of shale that

will yield more than 15 gallons of oil per ton, and of which 60 per cent may be commercially taken, is approximately 92,159,000,000 tons.¹

The number of acres that are underlain with oil shales of commercial grades, the quality ranging from 15 to 90 gallons per ton, are 2,696,000 for Utah alone, of which 85,584 are set aside for Naval Reserve. The area of Colorado and Wyoming are 896,000 and 460,000 acres respectively.²

The author has found differences in the estimations of amounts of the possible supply of oil in the shale deposits of the western states by different writers. Some were much higher and some lower than the figures quoted, but due to the fact that most of the leading oil shale experts have contributed to the source of information referred to, it is most likely that the figures therein found are more nearly correct.

The personnel of authors of this book, "Oil Shale", is as follows: R. H. McKee, Ph.D., LL.D.; S. S. Ellis, M.E.; M. J. Gavin, B.S., M.E.; R. D. George, M.A., LL.D.; R. T. Godwin, Ph.D.; W. A. Hamor, M.A.; L. C. Karrick, M.S.; and E. E. Lyder, Ph. D.

1. U. S. Geo. Survey, Bulletin 729, page 102

2. Oil Shale, McKee, page 80

The Retorts Used for Distillation

The retorts have, and likely will continue to be modified to increase their efficiency, add to their duration, and the speed of treatment. The general tendency in Scotland has been toward the Pumpherston and the Henderson type retorts. The nature and principles of the two retorts are in major points similar, and the technical differences will not be herein discussed. A clear differentiation and description is given of both in "Asphalts and Allied Substances" by Abraham, third edition, pages 252 to 256.

The Pumpherston retort is cylindrical and requires 1800° F. at the bottom. The Henderson is rectangular and requires 1500° F. at the bottom, for the complete distillation of the shale. Four retort cylinders constitute an oven. Each retort measures about 30 feet in height, with a large iron hopper at the top for charging. The shale is introduced from the hopper into the upper cylindrical cast iron portion of the retort, which is about 11 feet high, two feet in diameter at the top and two feet six inches at the bottom. It is in this portion of the retort that the actual distillation takes place, at about 900° F., with the formation of gas and oil. Distillation is caused by the hot gases from the lower portion of the retort which is constructed of fire brick. There is no other heat applied to the upper portion of the cylinder.

The lower portion of this chamber is heated externally

to about 1800° F., The source of heat is usually by gas and waste oil produced in distillation. A cross section of this portion of retort would show a cylindrical, or square (if the Henderson type) shaft of shale about 20 feet high, enlarging to about three feet in diameter at the bottom. The shale is supposed to be completely spent or retorted by the time it is worked to the bottom of this cylinder and is discharged mechanically into a funnel shaped hopper, by a revolving scraper, or toothed cylinder. This hopper converges in such a manner that the spent shale from all four columns in the oven can be emptied into cars and conveyed away by a single rail line. The scraper works continuously allowing for a fresh supply of shale from the hoppers above. The speed or time of distillation of the shale is regulated by the speed of this scraper. The spent shale is of little value and constitutes an expense in its disposal.

The hot vapors pass out at the top of the retort through ducts into headers. A slight vacuum is maintained in the retort and steam is admitted into the bottom of the fire-brick portion. The steam serves to convert the nitrogen into ammonia, increases the velocity of the discharge, reduces the chance of secondary decomposition of the vapors, increases the yield of paraffin products, and equalizes the distribution of the temperature.

Methods of Recovering Shale Oil

The vapors which leave the retorts are passed through air-cooled pipes, or most usually, a tower of pipes around which cold water is circulated. This method tends to speed the cooling and preheat the water used in the steam plant. Cooling condenses most of the tar and ammoniacal liquor out of the vapor. The incondensable vapors are next passed through a scrubber, filled with coke or a checker-work of wood, and finally through a naphtha scrubber where they are washed with an "intermediate oil" obtained in distilling the shale oil having a high boiling point and a specific gravity of .845. This oil extracts any light naphtha not previously condensed, amounting to about 2 gallons per ton of shale. The naphtha is then separated from the scrubber oil by heating the mixture in a still and condensing the distillate, which is the naphtha (gasoline) and sometimes referred to as motor spirit.

The crude tar and ammoniacal liquor are allowed to flow from the condensers to separating tanks, where, upon standing, the tar rises to the surface and is drawn off and piped to the refinery. The ammoniacal liquid is taken to the ammonium plant and processed for conversion into salts, which are used for fertilizer.

Products Obtained and the Yield

By destructively distilling the Kimmeridge shales of England and the Lothian shales of Scotland, the following products are obtained:¹

1. Non-condensable gases, averaging 9800 cu. ft. per ton (2000 Lbs.)
2. Ammoniacal liquor yielding an average of 40 lbs. of ammonium sulphate per ton.
3. Shale tar, averaging 22 gallons per ton.
4. Scrubber naphtha, averaging 4.0 gallons per ton.
5. Spent shale, averaging between 75 and 85 per cent of the raw shale and containing about 2½ percent unconsumed carbon.

-- See Table No. 11.

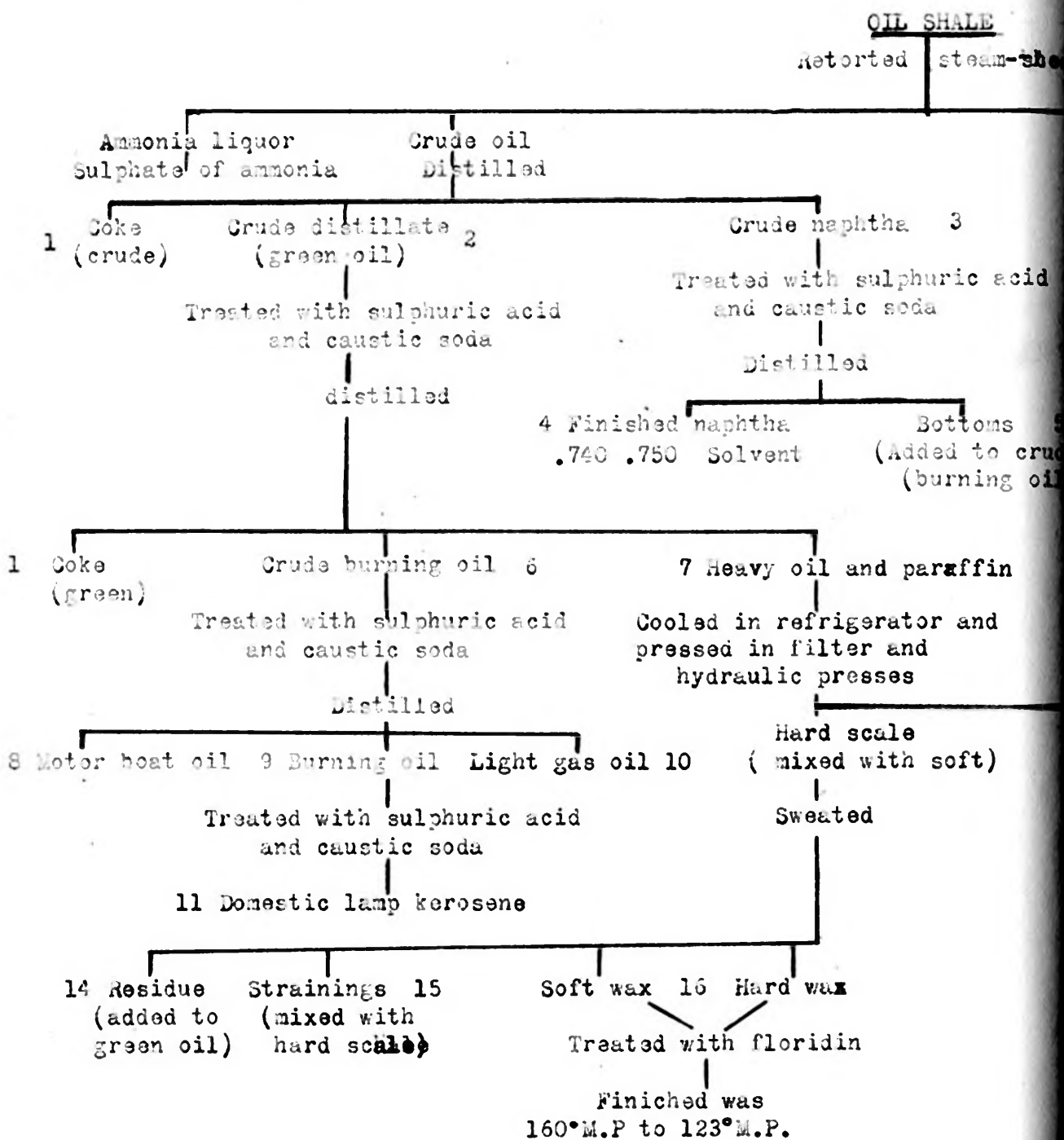
Gas

The non-condensable gases are most usually utilized at the still for heating purposes. It is most economically used in this manner. The quality is rather low, from 175 to 300 B.t.u. per cu. foot, and when the process is continuous this source furnishes the greater portion of the heat.

1. Asphalts and Allies Substances, Abraham, also Dept. of Interior Bulletin 210, page 80.

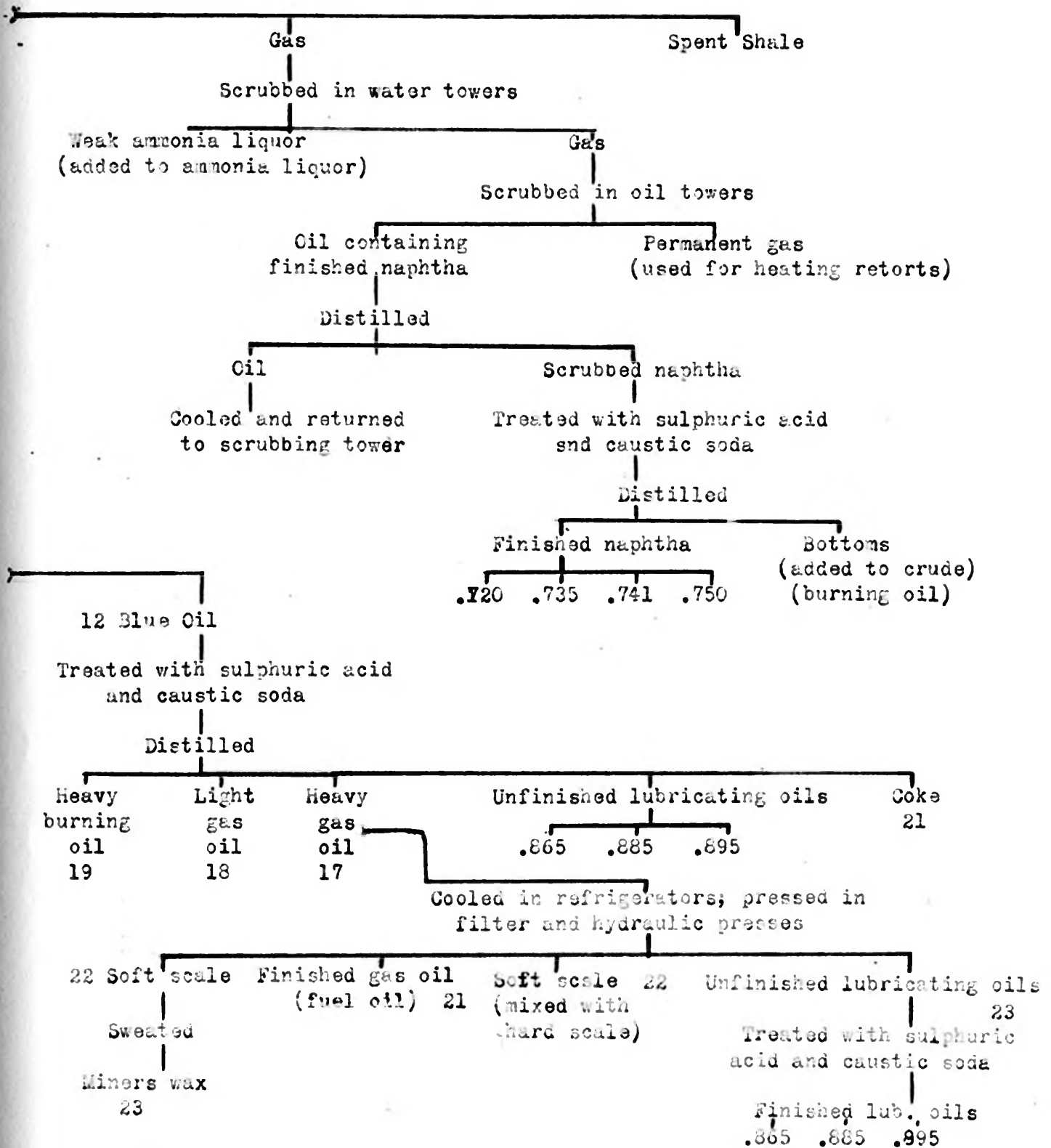
Table No. 11

CHART SHOWING THE PROCESS OF DISTILLATION OF OIL SHALE AND REFINING OF SHALE OIL



Note---The heavy lines indicate the resulting product in process. Material on the opposite page is continueds from this page.

CHART SHOWING THE PROCESS OF DISTILLATION OF OIL SHALE AND REFINING OF SHALE OIL



Description of Procedure Chart
Table No. 11

"The diagram gives the ordinary procedure at a shale oil refinery. The crude products of shale distillation are ammonia liquor, crude oil, gas and spent shale. The gas, as mentioned before, is scrubbed for ammonia and naphtha and the scrubber oil, containing the naphtha, is distilled and crude naphtha recovered therefrom. The crude naphtha is then treated with acid and alkali and redistilled, giving various grades of finished naphtha and still bottom, which are added to the crude burning oil from the crude.

The crude oil, as the diagram shows, is first distilled giving (1) coke, (2) a crude distillate, green oil, and (3) crude naphtha. The naphtha is treated with acid and soda, and yields (4) several finished naphthas, and (5) bottoms, which are added to the crude burning oil fraction of the crude distillate.

The crude distillate is treated with acid and soda and again distilled yielding (1) coke, (6) crude burning oil, to which is added (5) bottoms from crude naphtha distillation, and (7) heavy oil containing paraffin wax. The crude burning oil (6) is chemically treated and fractionated into (8) motor boat oil (a distillate fuel for internal-combustion motors of the Diesel type), burning oil (9) and light gas or distillate fuel oil(10). The burning oil is again treated and

yields the finished lamp oil or kerosene (11). The heavy oil carrying paraffin wax (7) is cooled in refrigerators, pressed in filter and hydraulic presses, and yields blue oil (12) and hard paraffin scale (13), which is mixed with soft scale (22), obtained in the further processing of the blue oil. The hard scale (13) is sweated in a sweating house and yields an oil (14) which is added to the green oil (2), or crude distillate: wax is mixed with strainings (15), which is added to more hard scale (13), and again sweated; and various grades of waxes (16), which are melted and filtered, or treated with fuller's earth, after which they are ready for the market.

The blue oil (12) is treated with acid and alkali, and subsequently distilled to coke, yielding finished heavy burning oil (19), light gas oil (18), heavy gas oil (17), unfinished lubricants (20), and coke (21). A residual oil is also obtained and used in making greases. The heavy gas oil (17) is separately cooled and pressed, yielding finished gas or fuel oil (24) and soft scale (22), or wax, which is sweated, the final product being miners' wax (23); or the soft scale (22) is mixed with hard scale for the production of finished wax. The unfinished lubricating oils (20) are also separately treated in a similar manner, yielding like products, and lubricating oils (25), which are again treated with acid and alkali before being ready for the market.

The diagram and description are necessarily brief and perhaps incomplete, because some of the processes overlap. The Scrubber naphtha is handled separately as noted on the diagram. It yields on fractionation still bottoms which are added to the crude burning oil."¹

1. This description and diagram were taken from, Dept. of the Interior, Bureau of Mines Bulletin, 210, by Martin J. Gavin, 1924. "Oil Shale."

Ammoniacal Liquor

The ammoniacal liquor obtained from the process is treated with steam under a pressure of 20 to 30 pounds in a tower filled with baffle plates. The liquor is run in at the top and the steam introduced at the bottom. The ammonia is expelled in the gaseous state and recovered by passing it into sulphuric acid contained in a vessel. (the "cracker box"). The acid used in this purpose is usually the waste product from the refinery process. Crystals of ammonium sulphate separate when the liquor becomes sufficiently concentrated, and after being dried are marketed as such. In this manner the ammonia is separated from the other nitrogenous bases, including pyridine, contained in the aqueous liquor.

Shale Oil

Shale oil usually appears black in main, with a greenish fluorescence. It is similar in composition to lignite tar, although differing from the latter in containing a larger percentage of nitrogen (1.1 to 1.5 %). Members of the paraffin and olefin series constitute 80 to 90 per cent by weight of the tar, and small quantities of cresols and phenols are present. The percentage of phenols contained in the shale tar is very much smaller proportionately than

that present in peat or lignite tars.

The value of the shale tar is in its refinement into petroleum-like products, the chief of which is the high anti-knock gasoline yielded.¹

Scrubber Naphtha

The first liquor to condense out of the hot gases as they come off the retort is the naphtha or gasoline. This liquor is cleansed and becomes a valuable product for market. According to Mr. L. C. Karrick and demonstrations recorded in the report of the Industrial Commission of Utah, June, 1930, this gasoline is much better in anti-knock qualities than any of the ethyl treated gasolines.

This gasoline is mixed with and is the same quality as the gasoline obtained from refining of the shale tar.

Spent Shale

The residue of the shale, when the distillation is complete, must be dumped out of the way of the plant workings. When shales are not distilled with the application of a little or by the sole use of steam (as will be described in coals) there is a little of the ammonium sulphate left in the spent shale, but where steam is used the shale is entirely valueless.

1. Ind. Com. of Utah. Bulletin 4, 1930, page 149

Paraffin Wax

In Scotland the wax is one of the chief commercial products of the industry. The shale oils are, as stated before, relatively high in paraffin, which when processed makes a valuable commodity. The current price in Utah for wax at the refinery is four cents per pound carload shipment, and six cents in 100 lb. bags. It is a product produced in the refining process, a residue after the light oils have been driven off. The process is similar to that of extraction from petroleum of the paraffin containing oils. Paraffin manufacture is largely adjustable to demand, the amount produced is dependent somewhat upon the methods used in distillation of crude oil.

Refining of Shale Oil

Shale tar may be distilled either intermittently or continuously. In either case the process consists in heating the tar in a still to expel the moisture, whereupon either plain or superheated steam is introduced through a perforated pipe under a pressure of between 10 to 40 lbs.. The oil is distilled to coke and the following products are separated:¹

1. Dept. Interior, Bulletin 125 page 23

1. Non-condensable gases, ranging from one to two cu.ft. per gallon of shale tar.
2. Crude naphtha having a specific gravity of 0.74 to 0.76.
3. So called "crude distillate", or "once-run oil" representing the fraction between the crude naphtha and the coke.
4. A residue of coke approximating 3% by weight of the shale tar.

The steam is shut off towards the end of the distillation, after the "once-run oil" has passed over.

The stills used in Scotland for shale oil refining are of the vertical type from 2000 to 2500 gallons capacity, constructed of hemispherical cast-iron bottom, and soft malleable-iron cylindrical body to which is attached a dome shaped top bearing the exit pipe. Each still is connected with its own condenser.

The refined once-run oil is fractioned either by an intermittent or continuous steam distillation process, the following products being recovered:¹

1. Heavy naphtha gravity between 0.75 and 0.77.
2. Illuminating oils gravity between 0.78 and 0.85, and a flash point of 125° F.
3. Gas-oil and fuel-oils varying in gravity between 0.85 and 0.87 having a flash point higher than 150° F. These oils are used as fuels, or for manufacture of water-gas or enriching illuminating gas.
4. Lubricating oils having a gravity from 0.87 to 0.91.
5. Paraffin wax, which is purified by recrystallization or "sweating" having a fusing-point between 110° and 130° F.
6. Still grease, which represents the distillate passing

1. Dept. Interior, Bulletin 123, page 27.

over at the close of the distillation.

7. Still coke, which remains in the still at the close of the operation.

The various distillates, with the exception of the still gases, are refined further with sulphuric acid and caustic soda, similar to the method used for treating the once-run oil. The crude paraffin wax is refined by the sweating process. The various steps of the process are illustrated in the preceding table (No.11 pages 44-45).

Application of the Methods Used in Scotland to United States.

In view of the fact that for different types of shale best results from distillation of the material will necessitate a difference in the method of distillation, also, a change in the temperature and duration of heating will materially effect the yield of the by-products. Methods used in Scotland, where the production of ammonia is perhaps the most important product, and the shale deposits being of such a nature that high yields are possible, will be somewhat different than the methods used in America where the most important product will be good lubricating oils and high test gasoline. The changes necessary, however, for the production of these different quality products will be ^{of} a comparative but minor nature, the major principle remaining unchanged.

It will be kept in mind that the Scotch producers are

not "Uno animo" with regards to detailed methods, but the experience of seventy five years activity has taught them great lessons that the American producer can profitably take advantage of. The changes in the Scotch industry were many in the first sixty five years, but there have been few changes in the latter fifteen or twenty. They must have reached a satisfactory efficiency for their types of shale.¹

To try to discuss the most efficient method for retorting shale in this study would, in the writer's estimation, be folly. That is a problem which will have to be worked out in the finer details by each individual concern for their particular locality, shale deposit, and product desired or in demand at the time. The important technological features referred to in the beginning of this chapter which pertain to the Scottish industry, and the outstanding developments of the United States in recent years, will be technically applicable to any commercial shale oil enterprise.

Certain retorting conditions produce a high yield of oil, but the oil may be of relatively poor quality. Other conditions may give a smaller amount of oil, but of so much better quality that it will yield a larger quantity of refined products. Certain methods of retorting will

1. U. S. Dept. Interior, Bulletin 210.

leave most of the nitrogen in the spent shale, from which it can be recovered as ammonia or ammonium compounds if desired. Other conditions will cause more nitrogen compounds to appear in the oil, from which they must be removed in refining. Certain oils of poor quality can be greatly improved by preliminary refining. Relatively slight changes in conditions of retorting some times have important influences on the nature of the oil produced, and the result of a change may differ in degree with different shales. This means then, in general, that those conditions and methods that produce at lowest cost the maximum quantity of products, for which there is the greatest demand, or for which the greatest demand can be created at the time of production, must be adjusted to time and plant location, kinds of shale, and resolves itself into an individual problem for each producer and he will have to adjust and choose those processes most applicable to his particular situation.

Some of the important problems for solution in the establishment of an oil shale industry, that will be common to every producer, are: labor supply, supplies (machinery equipment, tools, etc.), transportation, marketing of the shale products, plant location with respect to complete operations, water supply, living quarters for the workers and their families, mining of shale and transportation

to retorts, disposal of spent shale and climatic conditions of the territory where the shale is to be utilized.

Some of these problems that may be particularly difficult to the establishment of a shale industry in Utah will be discussed.

Disposal of Spent Shale

The fact that the spent shale is equal to about 75 percent of the original volume of the raw shale, the problem of disposal of this waste product may be a burdensome one. The disposal of this may in some cases equal the expense or even exceed that of bringing the raw shale to the retort. For example, the shale deposit may be and in many instances is in Utah, as well as the adjoining states, high on the side or the top of a canyon wall or plateau and the plant location may be at the base of the slope or cliffs. In such cases the shale may be very cheaply transported from the quarries to the retorts by trolley, or cable line, or a chute. In such instances the spent shale can be carried away and disposed of by gravity. Not all deposits will be so favorably situated, however, and the residue may require considerable transportation in its disposal to adequate distance from the plant. In fact it may even require that it be elevated into great stacks where conditions are not favorable, as is the case in Scotland and

great mountains of the material are thus built up.

A difficulty in the western country, where conditions are such that the plant may be on a higher elevation than the surrounding country and thus lessen the burden in respect to disposal of waste, is that usually the lack of water will make this sort of arrangement impractical.

Labor Supply

The establishment of such an industry in the State of Utah from the stand point of labor supply would be very beneficial to the development of the state, either in the industry itself or other activity stimulated thereby. There has been for the last number of years an exodus of about twenty per cent of the young people in order that they may find employment.¹ The available supply of labor in Utah is as high a type as found anywhere in the United States and, therefore, the rate of wages paid to them will have to be commensurate to this standard.

It is quite unlikely that the labor supply would be a serious problem for the establishment of an oil shale industry from the standpoint of number of laborers. It will require approximately one man per ton of shale mined and processed per day.

1. A. B. Young, Salt Lake City, Utah.

Transportation, Supplies, Equipment and Tools

Transportation facilities to other parts of the country are very favorable although comparatively high rates are charged. There are three important rail lines to the coast and two transcontinental lines converging into Utah points.

Supplies and equipment that could not be locally obtained would be affected by this disadvantage in freight rates, however, there could be supplied locally all but a small part of the most technical equipment.

Living Quarters and Climatic Conditions

Living quarters for the workers will be a problem only with respects to water supply and will be included in the discussion of water supply.

The climatic conditions are favorable to year round working.

Marketing of Oil Shale Products.

If the oil shale products are put on the market separately and in competition with the petroleum industries it will likely require a great amount of capital to demonstrate and educate the people to the use of them. The petroleum industries are in a much more advantageous position for the distribution and marketing of these products than in any other organization, that could be substituted.

There is no industry so favorable and economically situated as the petroleum industry in the development of the shale oil manufacturing.

Due to prejudicial influences the introduction of shale oil products will likely require a sacrifice either in the price for the same quality, or a better quality of goods at an equal price. Distribution organizations will have to be established and facilities and accommodations equal to those of petroleum. The great number of distributing stations is becoming one of the most difficult problems of the petroleum industry with the present situation and the introduction of more from another enterprise would no doubt effect the prices of both products to a more narrow margin of profit.

Water Supply

The question of adequate water supply, in many of the possible locations, is a serious problem, and will require considerable deliberation on the part of the entrepreneur. This is not such a difficult problem in many places in the eastern part of the United States, or Scotland, but particularly is it one in Utah. In a few places water may be obtained by drilling and developing springs, in other places it may be had by diverting water from streams or impounding of the flood water. These two methods will tend to make the problem more costly and difficult in determination and location of the plant.

Irrigation in the west, especially Utah, has and is using nearly all the available water from most of the small streams. It may be next to impossible to obtain sufficient water at or near the deposit of shale, and therefore, the shale will have to be transported to the nearest available water supply.

It is estimated that it will require from one hundred fifty to two hundred fifty gallons of water for every ton of shale treated.¹ This includes only the operations of the retorting and refining units. In addition there must be water for mining, also large quantities must be supplied for domestic uses at the plants and mines.

The per capita water requirements for mining, construction and operating plants, varies according to climatic conditions and type of workmen, usually from six to one hundred fifty gallons daily.² At the Scottish shale works about one hundred gallons are required per person daily, and there is about one person to each ton of shale treated at the plant per day.

Economies may be effected in the amount of water required for refining and retorting through the condensation and reuse

1. Oil Shale, McKee, page 146

2. Uses of Water in the Oil shale Industry, Jakoskey, pp.28

of the steam, but this process may add, somewhat to the costs of production. A more complete discussion of the condensation of steam will^{be} found in the discussion on the distillation of oil from coals in this study.

The amount of water used as steam in retorting shales by the Scottish method will probably be less than by the method (to be later described) for treating coal for the production of oils and other products. But it may prove more satisfactory to use such coal treating methods for shales, because of certain advantages attained through applying lower temperatures, incident to securing better quality and higher yield of oils and other by-products. Mr. L. C. Karrick, former oil-shale technologist and government research man for Utah, says, "That such methods could be used in the distillation of western shales with as good or better results as obtained by the Scottish method."

The amount of water used in retorting will depend upon the type of process chosen, the richness of the shales, the scale of operation, and methods of condensation of vapors.

Naturally, dry distillation will require less water than with the use of steam. Also atmospheric condensation will use less water than the spray pool or cooling tower. However, the dry distillation methods lack many of the advantages for good quality of oil and ammonia that are obtained by the methods which use steam.¹

1. Uses of Water in Shale Industry. Jokosby, page 30

The Scottish type of retort of large size requires for steam about four gallons of water per gallon of oil produced. For a one thousand barrel (42,000 gallons) daily oil production, about four thousand barrels (168,000 gallons) of water will be used for steam.¹ This steam is, however, exhausted from the electrical power house engines and is therefore a relatively inexpensive source of process steam. This estimate does not include or take into account condensation and re-use of the water.

Actual figures converted into United States measures, given by personal communication to M. J. Gavin, from the Scottish Oil Ltd., Glasgow,² are as follows:

Through put of shales	tens	560
Oil recovered	gallons	12,000
Ammonium sulphate production.	pounds	20,000
Water required	gallons	90,000

These requirements, based upon this record of actual practice are seven and one half gallons of water per gallon of oil produced, this includes the equivalent of 1.66 pounds of ammonium sulphate per gallon of oil, also, complete refinement of the product into a finished state, There is no condensing and re-use of steam or water.

1. Uses of Water in the Oil Shale Industry, Jakosby, page 20
2. Idem page 21.

It will be noted how the use of water per gallon of oil is reduced by the increased output of the plant. For the plant illustrated, of one thousand barrel capacity, the water requirement was four to one, but that for the smaller plant, five hundred sixty tons of shale (12,000 gals. of oil), the requirement was seven and one half to one. Production of ammonium sulphate is not allowed for in the first plant.

Purification and filtration of the steam and cooling water is possible so as to render it suitable for boiler and other plant uses.¹ Figures are not available as to these costs because there has been no practical application, to the knowledge of the writer, in America or elsewhere. However, water used in refining of petroleum is recoverable and made fit for re-use at comparatively small costs, according to several engineers questioned upon the subject.

Methods of water purification for power plant and industrial uses have been greatly developed in recent years, also many new corrosive-resisting metals are now available so that the re-use of plant waste water need not be considered a serious problem at the present time.

It may be interesting to note the water requirements for refining shale oil. A Scottish refinery with a daily capacity of ten thousand imperial gallons of crude oil requires about twenty five thousand imperial gallons of water, one fifth of

1. Uses of Water in Oil Shale Industry, Jokosby, page 26

which is recoverable, making a per gallon of oil requirement of two gallons of water,¹ for the complete processing, including finishing of the various products. Information obtained from Utah Oil Refining regarding the amount of water required in refining for a 5,000 barrel plant was 2,300,000 gallons, or eleven gallons of water per gallon of oil.

The water problem will be a large consideration in the location of the shale plant, and the cost of obtaining it at the most favorable shale deposits will have to be allocated with the transportation of the shale to available water. In some places water may be developed by making reservoirs and impounding run-off flood water, and others by the purchase of surplus water not used for irrigation from streams and lakes.²

It is quite certain that any shale oil manufacturing enterprise can arrange to impound a major portion of the water required for the most of the plant uses in sites close to most of the shale deposits.

Cost of Mining and Retorting

Mining methods must be selected which will meet the peculiar conditions of each locality and the grade and size

1. Uses of Water in the Oil Shale Industry, Jokosby, pp.25
2. The State of Utah gives priority rights to irrigation water where such has been appropriated during irrigation season, and arrangements for the use of this water will depend upon negotiation with these parties having established rights of the

of the shale deposit, also for the type of products desired at the particular time, the retorting methods used and the plant capacity. These adjustments will all have to be solved by engineers for each individual company for its own situation.

The attempt will be in submitting costs of the various mining and retorting activities, where such were obtainable, to let them serve as a basis upon which the foundation of a cost budget may be based. More detailed attempts would, no doubt, be proved incorrect at future dates because of slight changes or improvement of methods and general business conditions and also of the present dearth of such information that is authentic and reliable from developments in the western territory. A helpful guide may be had in the bulletin now in process of publication in the federal printing office, of the experimental developments of the governmental plant at Rullison, Colorado, for operations during 1928-1929. This information will likely be sent out for circulation, but attempts to get any data from it by the author proved futile.

Again then we must consider the industry as in Scotland. It is the most reliable data available at the present time.

The capital investment in the Scottish industry is enor-

streams. Also, pollution of such water to render it unfit for the purpose of those having such rights will be defended by the state. See Utah Statutes.

mous. It is likely because of this, that they have been able to maintain operations in recent years. It is also the opinion of the author that a large and well financed organization will have to be formed before the shale industry can become economical feasible in the United States.

It is estimated by Mr. M. J. Gavin that the costs of an oil shale plant for retorting in United States to be approximately \$52.00 per gallon, or \$2,190.00 per barrel of daily oil output. This is a large sum, perhaps, but Mr. Gavin also says that it is much less than the average investment and development costs per barrel of petroleum.¹ At least it is true for the Utah average.

Mr. Gavin estimates a plant that would produce 96 gallons of oil per day could be built for \$5,000.00 (approximately \$52.00 per gallon).

For a large plant of 1,000 tons shale per day, and a refinery capable of 1,000 barrels of oil per day (24 hours) he estimates a \$2,190,000.00 investment for the retorts and \$1,000,000.00 for refinery, or for a plant sufficient for completely processing 1,000 tons of shale and 1,000 barrels of oil per day would be \$3,190,000.00, not including costs for land of plant site, mine equipment, space for spent shale dump, mine land and organization expense.²

1. Index, Vol. 7, No 73, Jan. 1932

2. Oil Shales, Dept.Int. Bulletin.210 page 90

For comparasion the following quotation from "Index" is presented:¹

" The cost of these (United States) drilling in 1920, the last year for which data are available, amounted to \$503.33 mill., of which \$165.8 mill. were expended on dry holes. The rapidly growing average expenses for drilling in that year were \$33,000.00 per hole. Naturally, the growing depth of the borings makes the cost of drilling increasingly expensive. Drillings which cost a quarter of a million dollars are nowadays not rare. A good idea of the trend of development in this respect is afforded by the following figures for the State of Oklahoma, where the average cost of drilling was: in 1912 \$3,139, in 1919 \$21,353, and in 1928 \$45,574."

At the present time the Scottish industry is under one management. Combinations and consolidations have been made until the Anglo-Persian Oil Co. Ltd. controls the industry.² Prior to 1919 the six large companies then and still in operation, functioned as a unit as the Scotch Oils, Ltd., The total issued capital stock of these six companies amounted to 2,963,307 pounds sterling in common stock and one million shares of preferred, at one pound value each. The preferred stock is held by the Anglo-Persian Oil Co. Ltd.

Transposed into U. S. money, at par exchange, the above would be:

	<u>Sterling</u>	<u>U.S.</u>
Common Stock	£ 2,963,307	\$14,401,671.00
Preferred Stock	1,000,000	4,860,000.00
	<hr/>	<hr/>
Total	<u>£ 3,963,307</u>	<u>\$19,261,671.00</u>

1. Index, Vol. 7, No.73, Jan.1932

2. Report of Scotch Shale Industry, 1925, page 1

The average costs of production of the six companies in Scotland, as determined by chartered accountants in an audit made for Parliament, at the order of His Majesty, 1925,¹ were as follows (transposed at the par rate of exchange, (£ = \$4.86)):

Divisions of Costs:	
Mining, per ton of shale	\$1.77
Retorting, per ton shale	.85
Prod. of Sulphate of Ammonia, per ton of shale	.39
	<hr/>
Total Costs of Handling one Ton of Shale	<u><u>\$2.99</u></u>

The cost of the crude oil at the refinery, as calculated in the same report, was found to be seven and one-third cents per gallon or \$3.06 per barrel (42 gallons), adjustments being made for value of ammonium sulphate and stripped naphtha.

The cost of crude petroleum for the intermountain region for 1925 averaged between \$1.15 and \$1.95 per barrel at the field.³ The average freight to Utah ranged from \$1.15 to \$1.65 and up,² thus making a price range of crude petroleum for that period to Utah refineries of \$2.25 to \$3.60 per barrel. The price of crude 1932 has declined in the sources of the Utah refinery, (Wyoming, Texas, Colorado, etc.), from 1925 to \$0.61

1. Report of Scotch Shale Industry, 1925, page 1
2. Mr. Jensen, Utah Oil Company
3. Nat. Petroleum News, Feb. 1925

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to \$1.05 per barrel (Rocky Mountain Field, Price effective April 4th)¹. The present price of the crude in Utah would be, therefore, including transportation charges, \$1.76 to \$2.70 and up.

From the standpoint of oil production under conditions parallel with those in Scotland, it is clearly seen that oil from wells could advantageously compete in price with the oils manufactured from the oil shale which must be shipped into Salt Lake City, and might appear to prevent the establishment of the industry in Utah.

We must, therefore, study the costs of operation to determine any possible advantages of production and processing of the methods described, with respect to application to conditions in Utah, over those in Scotland. We must, therefore, again refer to the Scottish methods in determining these costs because of the lack of commercial operating data in the United States or Utah.

From the study of the costs of production of the Scottish industry we find that they are in per cent of total production per ton of shale processed:

1. National Petroleum News, March 1932.

Table No. 12--- Including Mining, Retorting, and Ammonium Sulphate Production only:¹

Process	Per cent
Mining	59
Retorting	28
Product of Ammonium Sulphate	13
	100 per cent

Table No. 13--- Including Mining, Retorting, Ammonium Sulphate Production and Refining.²

6 Process	Per cent
Mining	50
Retorting	24
Production of Ammonium Sulphate	11
Refining	15
	100 per cent

It will be seen that a saving of 10 per cent in the cost of mining will equal a 20 per cent saving in retorting, a 35 per cent in refining and nearly 50 per cent saving in

1. Calculated from Report of Scotch Shale Industry, 1925 See also U. S. Geo. Sur. Bull. 729, page 111.
2. Calculated from Report of Scotch Shale Industry, 1925 The cost of refining was computed by multiplying the cost per gallon of oil, in the same, by the average yield per ton (23 gallons) The cost per ton of shale for refining would be 52 cents, approximate.

production of ammonium sulphate. Fortunately, it is in the mining that it is expected that a reduction in expenditures can be effected.

The shale in Scotland is all mined at great depths and must be hauled up to the level, also, the mines must be timbered to support the roof or over burden. There are no thick beds left in Scotland as there are in Utah and neighboring states. In some of the deposits in Utah the over burden is not so thick but that mining will be possible with the steam or electric shovel, which will make for a considerable mining cost reduction. Even with the comparatively cheap labor in Scotland, miners' wages constitute 37 per cent of the mining costs.¹ Large scale machinal application in mining costs will lower this per cent considerably. The reduction of this item may likely be sufficient to insure the success of the industry.

The costs of mining shale in Scotland has been considered as comparative to mining coal there.² It will bring the problem more nearly "home", if we consider the costs of mining coal in Utah for comparative purposes. In the transposition of this relationship, the shale mining will be at a relatively

1. U. S. Dept. Int. Bulletin 210, page 95
2. Idem page 59

less disadvantage in Utah than in Scotland. Because of the peculiarities of the formation and position of the majority of the shale deposits they can be more economically mined than coal. To illustrate more fully: In Scotland at the time this comparison was made, both coal and shale were mined by the open-pit method, but there is a greater proportion of oil shale that can be mined in the same way. It will be well to remember this advantage.

The average costs of mining coal for Utah, as calculated by the Utah Coal Producers Association,¹ for those items applicable to shale industry but not including crushing of the shale to proper sizes, are as follows:

Table No. 14-- Costs of Mining Coal in Utah, Average 1925-1928.

Process	Cost per ton
Mining and Loading at Station	\$ 1.00
Roof Control in Mine	.10
Ventilations and Water (for Mines)	.16
Supervision and Mine Asc.	.02
Mine Expenses not Allocated	.02
Workmen's Compensation and Insurance	.09
Taxes	.10
Depletion (Depreciation)	.15
General Office Expenses	.25
	<hr/>
Total	<u>\$1.89</u>

1. Report of the Utah Coal Producers Association, 1928.

This cost is 12 cents per ton more than that for mining in Scotland, which was \$1.77 per ton of shale.

The figures in the above are, in their application to shale mining, obviously very high, because of several factors. The costs of roof support, control and ventilation expenses in many cases will be much less, if not completely eliminated, as is the case of open-pit mining by the use of large shovels.

Due to the variation in the demand for coal (peak and slump periods) the use of machines is very expensive, because they are only used at about one-third capacity.

With powerful shovels as much as forty feet of overburden may be removed to recover a three foot seam of bituminous coal, and with a seventy-five man crew, a daily per man output of 48 tons was made by the Colstrip mine in Montana, 1928.¹

To the degree that such production can be applied to Utah oil-shale mining, the cost may be reduced. The average daily tonnage for Utah coal mines 1928 was 8.52 per man.² A man at the face in Scotland shales produces about $4\frac{1}{2}$ tons. On the average it requires about .72 pound of powder per ton of shale in Scotland,³ and in Utah a ton of hard coal or rock may be mined on about one pound of powder.

1. Mineral Resources in the United States, Part II pp.481
2. Idem pp.554
3. U. S. Dept. Int. Bulletin 210, page 59

On the basis of per man tonnage, there is an advantage in coal mining of about two to one in favor of Utah, at the present rate of production. On a cost basis, however, this advantage will be reduced because of the difference in the wage scale of the two countries.

The greatest advantage in mining oil shale in Utah, and intermountain territory, is in the application of machinery for large scale production. Deposits where the utilization of the large powerful shovels is possible, the oil shale might be profitably mined for 25 cents per ton.¹

The average costs of mining oil shales in Utah, for a plant of one thousand ton capacity, as estimated by engineers for the Industrial Commission of Utah, are as follows:²

Drilling	per ton	\$0.53
Blasting	" "	0.10
Loading	" "	0.21
Traming	" "	0.05
Crushing	" "	0.08
Total		<u>\$0.97</u>

On the basis of these figures there can be a savings in the mining costs in Utah over those in Scotland of fifty to seventy-five per cent.

1. Col. Sch. Mines, Quarterly, Jan. 1924, page 121. These figures were confirmed by prominent engineers in Salt Lake City, when questioned by the author.
2. Ind. Comm. of Utah Bull. 4 1930, Page 151

Since the discovery of petroleum in large quantities there has been no commercially successful shale oil manufacturing plants in operation in America. And therefore, confirmation of the facts and estimations shown in the preceding pages to a particular situation and actual practice must be carefully, but not too technically correlated with the conditions as they might appear in relationship to each other.

It is quite evident from the figures previously given in the mining costs, that oil shale can be mined in Utah 50 to 75 per cent cheaper than it is in Scotland, due very largely to the advantages of larger and richer strata of shale, and the ability to apply large scale machinery to more advantageous proportions.

This advantage may in instances be lessened, due to the disadvantage in Utah of some of the best oil shale deposits being very remote from ample water supply. However, this disadvantage will not be as great as it may at first seem. Cheap electrical power will make it possible to pump water from distant sources at a minimum cost. Electricity costs to the shale industry will be very small as the power for its generation is taken from the same steam generated for retorting the shale.

With this cheap power the water supply for mining and retorting purposes could be pumped for long distances at a very few cents per barrel of oil produced. By condensing the

steam from the retorts and refinery the amount of water could be reduced approximately seventy-five per cent.¹ The costs of the condensing would amount to approximately three cents² per barrel of oil. Estimation of the costs of pumping one million gallons of water, in a seven inch pipe, 1000 feet in the air, by electrical pumps (75 % efficiency) would be \$3.10 per hour.⁴

An example of the cost of producing shale oil on fairly large scale in the United States may be had in the operations at Casmalia, California. This plant of 400 tons daily capacity was operated for many months while treating large deposit of diatomaceous rock impregnated with a natural oil residuum. Also the plant was operated on large quantities of Utah and Colorado oil shales shipped to California. The process, known by the name "N. T. U.", was finally adopted by the U. S. Bureau of Mines and a single commercial scale unit was built and operated at Rullison, Colorado by the Bureau engineers and comparisons were made with a single unit commercial scale retort shipped from Scotland.

The costs applicable to this California plant were ascertained by Mr. L. C. Karrick,³ formerly consulting engineer

1. Estimation of Hydrolic and electrical engineers, U. Of U.
2. Idem.
3. Mr. L. C. Karrick, former Associate Oil Shale Technologist and Petroleum Refinery Engineer, U. S. Bureau of Mines.
4. Estimation obtained from Mr. T. C. Adams, U. of U.

for the Goldfields American Development Co. of New York City, which company shipped about one thousand tons of oil shale from Esthonia for a commercial scale try-out of the process. Mr. Karrick states that a plant, of the gas-producer type, was very simple in design and free from operating difficulties. The summary of costs were as follows:

Mining, haulage, crushing, per ton	==	40	cents
Conversion costs, total	==	35	"
Capital costs, etc.,	==	20	"
		<hr/>	
Total Cost.		90	cents

Mr. Karrick also advises that shale oil production costs in eastern Utah and western Colorado ¹ will not exceed sixty cents total per barrel of oil, provided the shale is treated of in place in stopes or shrinks instead of in re-torts erected to apply the same process. The geology, stratigraphy, and physical properties of the shale deposits are extremely favorable for this plan of shale oil project.

Conclusion

There are two important aspects in the consideration of the economics of distilling oil shales for the production of petroleum products. First, would it be economically possible from the purely profit point of view to ^{the} entrepreneur. Secondly,

1. Report of L. C. Karrick to Secretary of Interior, Jan. 1932

is it economically justifiable from the point of view of proper utilization of natural resources for the public benefit.

The first is the most difficult to determine, because of the lack of definite practical information on the results of commercial operations in the particular locality. The most comprehensive figures are those based upon actual commercial operations of the Scottish industries, although the adjustment of these figures to a situation which is quite different is difficult to do accurately. But we do have the figures and results of the operations at Casmalia, California, which may serve to indicate that shale oil can be produced profitably in competition with petroleum in favored localities such as western Colorado and eastern Utah.

History proves that petroleum has been able to compete advantageously with products of oil shale as evidenced by the introduction of petroleum into those countries where oil shales have been processed extensively for manufacture of petroleum products. The oil shale industry has been paralyzed in most countries for the present by the introduction of the petroleum from wells. This is not because of the superiority of the petroleum,¹ but because of the cheapness with which petroleum is produced after the resource has been once discovered.

1. As a matter of fact the gasoline of the oil shale is claimed to be of superior quality. See Report of Industrial Comm. for Utah, 1930, page 147, Also L. C. Karrick, McKee Oil Shales, page 161.

The shale oil industry of France was for a long time protected by high tariff on petroleum¹ and the industry in Australia² by subsidization. The Scottish industry was able to maintain activity for some time in the face of serious competition with imported petroleum because of great capital investment and application of large scale operations. However, the report of the Scottish industry in 1925 showed a loss of two cents on every gallon of oil produced for the six month period investigated.³ At that time some of the Scottish refining plants had been converted into petroleum refining units.⁴

The disadvantages of inadequate supply of water to be had in Utah are not likely to equalize the apparent advantages in the mining of the oil shale as compared with the cost of mining in Scotland. The difficulty of procuring water, it seems, has been over emphasized. Impounding flood and spring run-off water will tend to alleviate this disadvantage. The topography of the oil shale areas is very favorable, in most cases, for reservoir sites and the purchase of water now used for irrigation will be possible in some instances.

1. Oil Shale, Dept. Int. Bulletin 210, page 50.

2. Idem, page 51.

3. Report of Shale Industry in Scotland 1925, page 4.

4. Idem, page 8.

In addition to this, it should be remembered that the average yield of oil of the Scottish shales was approximately twenty three gallons per ton of shale, as compared to the reported yield of thirty to sixty-five gallons for the shales of Utah. The production of electrical energy at a minimum cost will be another advantage in the distillation of oil from shale in Utah. The Scottish industries produce sufficient for their plant use but not for commercial distribution.

Much has been said concerning the lack of cheap electrical power as being a chief factor in retarding the growth of industrial activity in the state. A partial solution of this might be effected incident to the establishment of an industry for the distillation of oil from shale.

With all the apparent advantages of the production of oil from shale in Utah, it is quite evident that the manufacture of oil from oil shale might be done profitably. The establishment of an oil shale industry in the state would tend to stimulate and encourage development of industrial activity in other fields. The combined effect would tend to retain and employ a great number of young people, who at present find it necessary to leave the state in quest of means of support.

The justification as to economical utilization of natural resources seem to be in favor of the establishment of an

oil shale industry in the State of Utah.

Estimations as to the reserves of natural petroleum is admittedly much less certain and dependable than for shale oil.¹ The quality of oil from shale can be pre-determined, but it is not the case with respect to the new supply of petroleum. The quality of petroleum cannot be known until the expense of developing has been made, nor can the amount be accurately known until the supply is exhausted. Both of these factors can be accurately and inexpensively pre-determined in shale oil production before large development expenditures have been caused.

There are those who maintain that in as much as the supply and quality of the oil shale is well known, that it would be much safer in national emergencies to have these reserves to fall back on, and that they should not be depleted until emergencies arise. But it is for this reason that the industry can not be developed for an emergency. It will require years of operations before any maximum efficiency or large quantity production can be realized, and this experimental period should be passed before the demand for the product becomes urgent.

1. Quotation from "Index", Vol. 7 No. 73 Jan. 1932, page 6.
"Even the most abundant wells and fields on the whole rapidly decrease; 12 large oil fields, whose maximum daily production had amounted to 2,247,450 barrels, showed a falling off of 67 % one year after reaching the peak, and

There is no organization more favorably situated for the development of the oil shale industry than the petroleum interests. Most economical production of oil from shale could be made by this organization. The development of the industry in localities of the intermountain territory might be made without loss to the petroleum industry and result in a reduction in the prices of the products to the consumers. The supply of oil from an oil shale manufacturing industry would be constant and the price more easily and evenly controlled. The losses caused by the radical changes that are so frequent in the present situation might be reduced to the minimum. Shale oil need not be made competitive with natural petroleum but a correlation in the marketing of the two products should be made.

Eventually the supply of petroleum products will depend upon the reserves of oil shale and in places where the production of petroleum is at a disadvantage incident to its distribution, as in Utah, economical utilization of these reserves might be made to great advantage.

of 74 % two years after. This explains why, quite apart from the increasing demand for petroleum products, new wells must be constantly drilled, and why apprehensions are frequently expressed regarding the future conservation of the world's oil resources."

CHAPTER III

COAL

Origin of Coal

It is commonly known today that coals are the result of changes which have taken place in the carbonaceous deposits of decayed vegetable matter.

Coals, like oil-shales, are vegetable matter deposited and decomposed in the absence of air (marine conditions), but the general appearance of the two would indicate that more silt and foreign material was present in the deposition of the material resulting in oil-shale than those of coals, thus resulting in the higher ash yield of oil shales than coals.

The vegetable matter, either during or after decomposition, was covered with sedimentary formation and compressed, the higher the pressure the harder and more compact the material became, that receiving the highest pressure and of greatest age becoming what is known as anthracite coal, and that with little pressure and of youngest origin, peat. Bituminous and sub-bituminous coals are intermediate materials to which less pressure and heat were applied than anthracite, but more than peat.¹ The moisture content is also

diminished according to the degrees of pressure and heat that the materials were subject to.¹

Characteristics of Coal

Coals differ very widely, from anthracite to bituminous, sub-bituminous, cannel, and peat, each yielding different amounts of carbonaceous materials and heat and each having a slightly different texture and hardness. They are all black in color, having a dark luster. They soil your clothes and hands in handling, with the exception of good grades of cannel coal, which do not soil or leave spots.

The moisture content of coal decreases in amount from peat, maximum content, to anthracite. The volatile material content reaches its maximum in sub-bituminous and cannel, and varies inversely to the ageing thereafter. The ash percentages vary somewhat in the types of coal, diminishing slightly in per cent in anthracite. The heating value increases proportionately with the consolidation of the fuel, except for the extreme hard coals. The fixed carbon is also generally proportional to the density of the coal.²

Coals appear most usually in laminated beds, varying in thickness of a few inches to many feet, but are usually quite

1. Technology of Low Temperature Carbonization, Gentry, page 6.
2. Idem, page 7.

uniform in thickness and richness or quality of the coal. Most coals weather away readily when exposed to the elements.

There is a very marked difference in cannel coal and the other coals. In as much as cannel and bituminous coal are the coals most economically adapted to distillation, and of which large quantities are present in Utah,¹ it may be well to keep in mind the differences in the two types of coal.

The main differences are: First, cannel coal is composed of large quantities of the waxy or oil forming bituminous materials. It is believed that cannel beds were deposited at deltas or eddies into which the pollens drifted and where the algae grew more abundantly. Second, the coke from cannel coal (residue after distillation) is of little value, unless mixed with another coal of high coking value, resulting in a blending of the two. Third, cannel yields a larger quantity of gas and crude oil. It is characteristic, in the deposit in Utah, for the cannel coal to be between layers of bituminous coal.

The following tabulation, from U. S. Geo. Survey, Bulletin 659,² will help keep the differences in mind.

1. The amount of cannel coal in Utah is very small in proportion to the amounts of bituminous and sub-bituminous coal.
2. U. S. Geo. Sur. Bulletin 659, page 10.

Typical Characteristics and Distinctions of:

Bituminous Coal

Cannel Coal

- | | |
|---|--|
| 1. Laminated. | 1. Massive. |
| 2. Bright and dull bands | 2. Uniform velvety or satiny luster. |
| 3. Prismatic fracture | 3. Conchoidal fractures. |
| 4. Jointing imperfect. | 4. Jointing regular and striking. |
| 5. More or less friable | 5. Tough and elastic. |
| 6. Disintegrates by weathering | 6. Weathers slowly. |
| 7. Soils hands | 7. Does not soil the hands. |
| 8. Percentage of fixed carbon higher than that of volatile matter . | 8. Percentage of fixed carbon typically lower than that of volatile matter. |
| 9. Derived from wood or peaty deposits, grown in place | 9. Derived mainly from spores, pollen, etc., brought in by wind and water. |
| 10. Basins commonly extensive. | 10. Basins rather small. |
| 11. Commonly yields on distillation less than 10,000 cu. feet of gas per ton. | 11. Commonly yields on distillation more than 10,000 cu. ft. of gas per ton. |
| 12. Candle power of gas usually less than 17. | 12. Candle power of the gas more than 20. |
| 13. Commonly cakes in burning. | 13. Does not cake in burning. |
| 14. Coke usually strong. | 14. Coke pulverulent. |
| 15. Yield of oil on distillation commonly less than one bbl. per ton. | 15. Yield of oil commonly more than 2 barrels to the ton. |
| 16. Less than 5 % hydrogen. | 16. More than 5% hydrogen. |
| 17. Ignites with difficulty. | 17. Ignites readily. |
| 18. Streak commonly black. | 18. Streak commonly brown, oily. |

Cannel, as well as bituminous coals, vary in degree of richness, quantity of yield of by-products, ash content, and smokeless fuel (coke) quality. This is true within the same deposits and strata and in different locations.

Bituminous coal is usually uniform in stratification, but cannel is not and most usually is in varying thicknesses from

A few inches to several feet in short distances.¹

The individual making claims should test thoroughly each location before final decisions.

J. H. Ashley warns "that before expenditures of capital for processing equipment were made the cannel deposit should be tested by drilling, etc., every hundred yards".²

In the utilization of cannel coal, in place of bituminous coal for distillation, the residue (smokeless fuel) quality is sacrificed for the higher yield of oil and gases, but if the two are treated conjointly the cannel will benefit the production of gas and oil and the bituminous coal will tend to improve the residue coke, if a good coking bituminous is used.

Where conditions permit, the distillation of bituminous and high oil yield cannel in mixed batches will, possibly, lend themselves to greater economy in general, than straight batches of either, unless there is high demand for the smokeless fuel and little demand for the oil.

Brief History of Coal Distillation

Because of the lack of a clear differentiation of coals and shales in early history, it is difficult to determine at times, whether oil shale or coal was the article used, but an error as to either will not definitely handicap our consid-

1. The author wishes at this place to note that it is very evid-

eration.

"Coke was an article of commerce among the Chinese before 100 B. C., but was not used in the metallurgy of iron until 1619. A patent was issued to St. John for the first beehive oven in 1620, in England.³ The use was very limited, however, until the blast furnace was adopted for smelting iron ore. By-products from coking coal were not recovered until about 1700. There was, however, very limited conservation of these products until as late as 1900. The by-product ovens were not extensively used in United States until about 1910.⁴

Abraham and Gesner claim to have been the first to manufacture oil from coal, in the United States,⁵ and in 1864 exhibited the use of the oil in lamps. It was known in England and Germany as early as 1662 that, "By distilling coal a black oil and a non-combustible 'spirit' which caught fire at the flame of a candle," could be produced.⁶

The first accurate records of destructive distillation of coal were made in 1726, by Hales. In 1807 there were a few street lamps illuminated by coal gas in Pall Mall, London.

ent, that the cannel coal deposit in Utah is an exception to this peculiarity. Outcroppings of the strata of this coal expose a very regular width for long distances. There are many such exposures along the hillsides where this deposit is located.

2. U.S. Geo. Sur. Bulletin 659, page 15.

3. Tech. of Low Temperature of Carbonization, Gentry, p.3

4. Courtesy of Mr. Hobson, Theses on Coals, 1932

5. Asphalts and Allied Substances, Abraham, page 15.

6. Low Temperature Carbonization, Gentry, page 1.

Cannel coals and bituminous coals were distilled in the United States on a commercial scale in 1855. In 1856, The North American Kerosene Gas Light Company were producing six to seven hundred gallons of oil daily. In 1853 the first lubricating oil was manufactured from coal tar in Waltham, Mass., by the United States Chemical Manufacturing Company. By 1860, The Tucesco Company of Pittsburg, Pa., was operating sixteen 2000 gallon coal stills.¹

The discovery of petroleum had the same paralyzing effect on utilization of coal for by-products as it did on oil shale, but there was a demand for coke in the metallurgical processes which continued to increase and coal was utilized for this product. In the beehive ovens, the coke was the only consideration and until recent years no thought was given to recapture of the by-products, and large economic wastes resulted. This waste has been largely eliminated recently as the old beehive ovens are being replaced by the by-product coke plants.

Coal Deposits in Utah

One sixth of the total area of the State of Utah is underlain with coal in veins of workable thickness. Of this amount about 5000 acres are estimated for the area of the cannel coal. The area of the anthracite coal is not definitely known but

1. Asphalts and Allied Substances, Abraham, pages 17-19

it is not larger than the cannel. The deposits of coal are located in the northern, eastern and southern portions of the state. With the exception of the two mentioned deposits, the cannel deposit near Cedar City, Iron County, and the anthracite deposit near New Harmony, Washington County, the Utah coal is bituminous or sub-bituminous. These two deposits are comparatively small in relation to the total and are included in the total area and tonnage estimate.

Anthracite coal will not yield as much oil and gas as bituminous, but the yield of these products of the cannel will more than offset this.

It was estimated in 1932 that the total reserve of coal in the State of Utah was one hundred seventy nine billion tons, eighty eight billion to the depth of three thousand feet and ninety-one billion from three thousand to six thousand.¹ From the beginning of records to 1930 there had been mined about one hundred twenty-nine million tons, of which forty-three million tons were estimated wasted.² There will be very little or no loss in distillation, because of the small coal being utilized in the process.

The coal deposits of Utah are almost uniformly parallel and of considerable thickness. In many of the deposits the

1. Thesis presented by Mr. Hobson, 1932, U. of U.
2. Idem.

coal seams are quite high on the sides of canyons, plateaus, etc., and will therefore lend themselves to very easy methods of obtaining the material from the ground.

The composition of Utah coal for the manufacture of oil and other by-products is very favorable. The quantity of oil yielded will average about eight gallons in the anthracite to ninety in the cannel.¹ The approximate yield of ammonium sulphate per ton of coal will average upwards of twenty pounds,² from low temperature coke ovens, but less when it is treated in the steam process.

The following table is presented to illustrate the quality of the bituminous coals in Utah. The quantity of oil yield for the "B" test coals are not representative of the states's resource because of the conditions of the coal and the methods of testing, according to Mr. L. C. Karrick, who extensively investigated these coals while with the Bureau of Mines. He estimated that the coal will average from thirty to thirty five gallons. The average for the "A" test coals in the table is 28.3 gallons per ton.

1. Bureau of Mines Bulletin 545, page 43, also 123, page 26-8
2. Idem. page 43.

Table No 15 --- Analysis of Utah Coals from Samples Picked
At Random from Salt Lake City Coal Yards¹

Source of Coal	con- dition	Coke %	Gas, Cu ft. per pound	Oil gals. per ton	Am. Sul lb. per ton	Benzene Gals per ton	Gas B.T. U. per cu. ft.
Clear Creek	A	69	6.25	20.8	5.3	3.1	929
	B	65	3.2	7.5	24.5	3.6	782
Castle Gate	A	70	1.3	25.5	5.6	3.4	963
	B	63	4.5	9.0	26.8	3.5	831
Royal Castle Gate -	A	73	1.0	26.7	6.0	3.6	1020
	B	62	4.0	10.9	28.2	3.2	818
Aberdeen	A	75	1.0	29.8	6.6	3.1.	966
	B	63	3.8	3.0	32.0	2.4	815
Liberty	A	74	1.48	28.1	6.8	3.2	951
	B	69	3.8	3.2		3.9	852
Hi-Heat	A	65	1.3	43.8	5.0	3.5	1123
	B	64	3.8	3.6	24.4	3.0	813
Standard	A	70	1.3	28.9	5.4	3.2	980
	B	57	4.6	11.2	23.3	4.5	844
Pleasant Valley	A	67	1.3	22.1	9.4	3.3	938
	B	66	3.6	1.0	20.4	2.8	810
Wattis	A	63	1.4	32.1	7.1	3.0	1079
	B	64	3.6	2.5	27.6	3.8	867
Sunnyside	A	75	1.2	23.3	5.3	2.5	942
	B	67	3.1	12.5	28.0	2.5	772.
Average		65	2.8	17.2	14.0	3.2	880

The following tables are presented to illustrate the Reserves of coal in U. S. and Utah, and the rates of depletion of these reserves by supposed utilization trends. Explanations will follow each table.

1. Bureau of Mines Bulletin 345 page 80

ESTIMATED TOTAL AVAILABLE RESERVES OF SOFT COAL & LIGNITE IN THE UNITED STATES AS OF 1925, and Depletion Curves Based on the Trend of Necessary Consumption of the Products.

COAL IN TONS													
short tons, units in Millions													
		1920	1925	1930	1935	1940	1945	1950	1955	1960	1965	1970	1975
4,500													
4,000	ESTIMATED TOTAL AVAILABLE RESERVES OF SOFT COAL & LIGNITE IN THE UNITED STATES, AS OF 1925												
3,500													
3,000	1- Reserves remaining after supplying sufficient coal to satisfy the demand (present tendency) for fuel oil, gas and coal based on H. P. Hr. equivalent of fuel oil and coal, corresponds to energy demand for oil and fuel.												
2,500	2- Reserves remaining after supplying sufficient coal to satisfy the demand for coal. Based on present reserves of 4,114 billion tons as estimated by the committee on supply of the American Petroleum Institute.												
2,000													
1,500	3- Reserves remaining after supplying sufficient coal for all gaseous, liquid and solid fuel, and demands replacing coal by the residue coke and assuming 1,100 pounds of coke produced per ton of coal.												
1,000													

Table No. 16

Explanation of Table NO. 16¹

"From the report of the 'Supply Group' of the Committee of Eleven of the American Petroleum Institute, figures are obtained showing the estimated reserves of soft coal and lignite to be four trillion one hundred thirteen billion, eight hundred sixty million (4,113,860,000,000) tons. The oil or tar recoverable from this coal is estimated at five hundred ninety five billion, five hundred million (595,500,000,000) barrels of 42 gallons, capable of yielding one hundred three billion, six hundred million (103,600,000,000) barrels of light motor fuel.

From the table the amounts of coal used up to the end of each five or ten year period have been calculated, and subtracted from the original amount to give the curve marked "Present Tendency", (Curve 2).

A further deduction has been made of the amounts of coal corresponding to the gas and fuel energy demand shown on the table to give the amounts of coal remaining if it should be necessary to use coal in place of the estimated maximum gas and fuel-oil requirements (Curve 1).

Curve 3, represents the reserves after supplying all the coal that would be required to furnish gas, gasoline (benzol),

1. American Petroleum, Supply and Demand, pages 225-226

fuel oil, lubricating oil and coal (coke) in sufficient quantities by distillation, to take care of the estimated maximum requirements for all of these fuels. This was calculated on the following basis:

Gas

It was assumed that sufficient gas will be produced in the course of distillation for liquid fuels, to take care of estimated gas requirements.

Gasoline

The estimated maximum demand for gasoline has been supplied from the estimated recoverable light motor fuel from coal of one hundred three billion, six hundred million (103,600,000,000) barrels which is on the basis of 1.06 gallons per ton of coal and lignite.

Diesel Oil, Fuel Oil, Lubricating Oil

The total quantity of recoverable liquid products from the coal is estimated at five hundred ninety-five billion, five hundred million (595,500,000,000) barrels, an average of 6.08 gallons per ton. From this amount 1.06 gallons per ton or 17.4 per cent is taken as light motor fuel, and the remaining 82.6 per cent of the liquid products is considered suitable for supplying the required, Diesel oil, fuel oil

and lubricating oil. The coal required to supply the maximum gasoline demand, would leave sufficient of the heavier oils to meet all estimated requirements for diesel oil, fuel oil, and lubricating oils, and leave a large surplus.

Coal

It is estimated that from every ton of coal distilled there will be recovered an average of 1,100 pounds of coke. On account of the additional efficiency in the utilization of coke, it is assumed that 1,500 pounds of coke will perform the same amount of work as 2,000 pounds of coal. With these deductions, the necessary amount of coke to supply the estimated coal requirements has been calculated, resulting in a large surplus of coke when producing sufficient motor fuel to satisfy the estimated maximum demand, (Curve 3)."

TOTAL ESTIMATED COAL RESERVES IN UTAH - 1930 - 179 BILLION TONS
Showing Reserves at Different Rates of Consumption

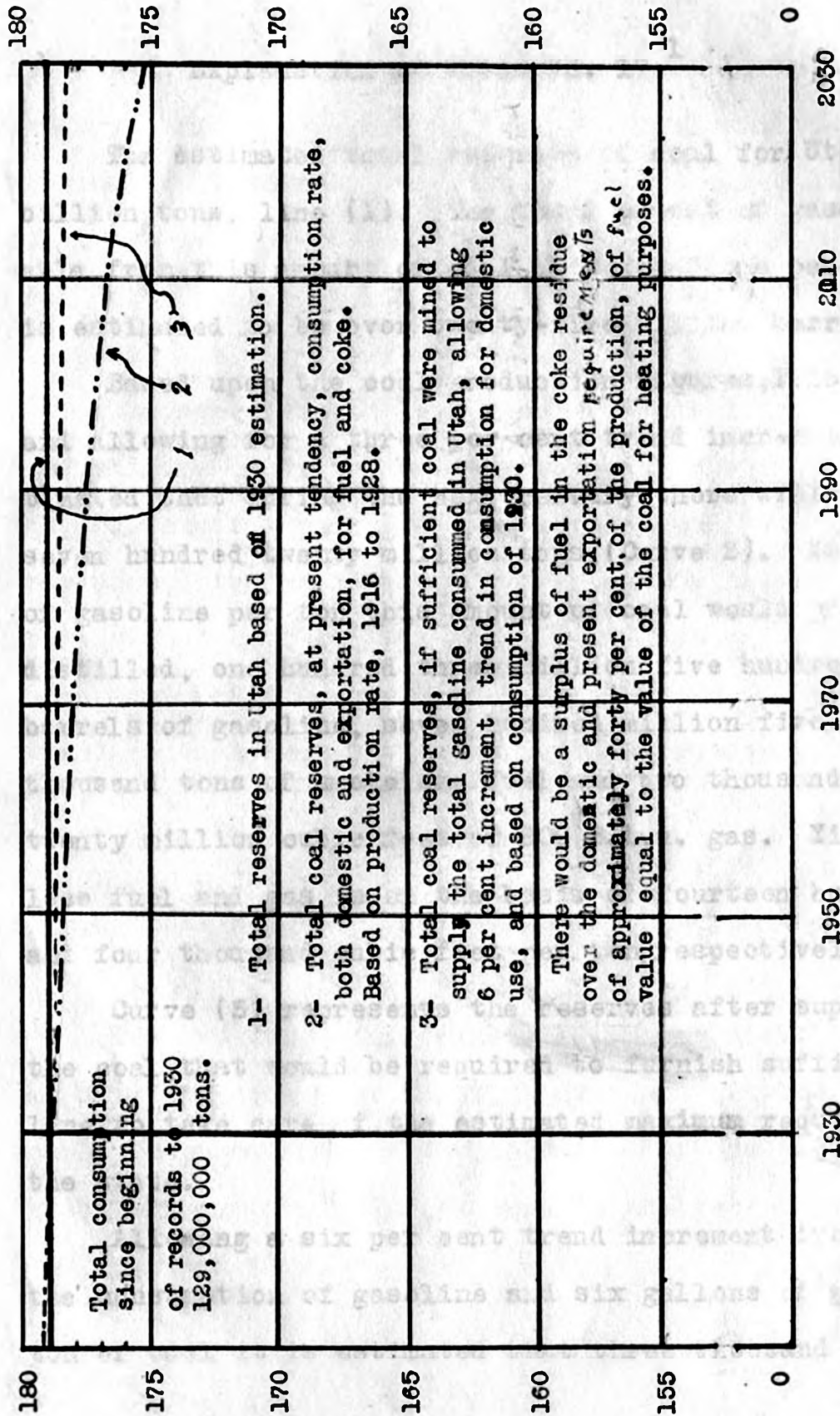


Table No. 17

Explanation of Table No. 17¹

The estimated total reserves of coal for Utah are 179 billion tons, line (1). The total amount of gasoline recoverable from this amount of coal at six gallons per ton of coal,² is estimated to be over twenty-five billion barrels.

Based upon the coal production figures, 1916 to 1928, and allowing for a three per cent trend increment, it is estimated that during the next century there will be mined seven hundred twenty million tons, (Curve 2). At six gallons of gasoline per ton this amount of coal would produce, if distilled, one hundred three million five hundred thousand barrels of gasoline, seven hundred million five hundred thousand tons of smokeless fuel and two thousand six hundred twenty million cubic feet of 800 B.t.u. gas. Yield of smokeless fuel and gas is on the basis of fourteen hundred pounds and four thousand cubic feet per ton, respectively.

Curve (3) represents the reserves after supplying all the coal that would be required to furnish sufficient gasoline to take care of the estimated maximum requirements of the state.

Allowing a six per cent trend increment from 1930 for the consumption of gasoline and six gallons of gasoline per ton of coal it is estimated that three thousand five hundred

1. For the basis of amounts of product yield see "Products Obtained." following.
2. The figures are extremely conservative for the yields of products per ton from Utah Coal.

sixty million tons of coal would be mined during the next century. From this amount of coal there would be produced, besides the gasoline, two billion four hundred ninety two million tons of smokeless fuel, fourteen trillion two hundred forty billion cubic feet of gas, and thirty five billion six hundred million tons of ammonium sulphate.

The preceding table may be criticised because of the inclusion of coal to the depth of six thousand feet. If so, to reduce the depth to three thousand feet would in no way change the estimations given, except those of the total reserves of coal and the total estimated gallons of gasoline that could be produced. Furthermore, coal can be mined at such depths when it becomes necessary.¹

Methods of Manufacture of Oil from Coal

The two essential principles in the distillation of oil from coal are: first, sufficient heat is required to cause decomposition of the molecules of the bituminous material into vapors. The second, is the recapture and condensation of these vapors.

1. The author has personally witnessed the production of coal to the depth of more than five thousand feet, in Dortmund, Germany, 1924.

There are many different types of by-product ovens and methods of manufacture of oil from coal. The differences, however, are in the minor details of operation, methods of heating, etc. To quote Dr. H. C. Porter, on the essential differences of the by-products ovens, "Although possibly, by-product coke oven types may be distinguished by characteristic shape and method of operating--- at present the essential difference lies in the method of heating the oven chamber. In general, the size and shape of the various by-product coke ovens, and their method of operation--- are entirely the same.----- In yield and quality of products there is also no material difference." ¹

Nevertheless, the quality and quantity of the by-products and the residue coke are affected by the methods used in the application of the heat and whether steam is admitted into the retort, also the degree of heat to which the coal is exposed.² The use of steam in the distillation of coal is similar to its use in the distillation of oil shale, viz., to check secondary decomposition of the vapors, increase the yield of ammonia and equalize the temperature throughout the retort.³

1. Coal Carbonization, Porter, page 169.
2. Idem, pages 167 to 210
3. See page 40.

The tendency in distillation of coal has been from high temperature ovens to low-temperature ovens, from the non-use of steam to the use of steam, from eighteen hundred degrees F. to as low as 450 degrees F.¹, and from dry distillation to the entire use of steam as the single source of heat for distillation.²

Mr. L. C. Karrick,³ Salt Lake City, holds patents on the carbonization of coal by the entire use of steam. He is at the present time conducting further experimentation at the University of Utah with the intentions of establishing a plant in cooperation with the University Engineering School for the purpose of distilling coal. These experiments are being written up by graduating engineers and it will be very interesting to watch the outcome of this "Utah Public benefit project".

The process which depends on the sole use of steam for heat, increases the yield of oil and ammonia, also the B.T.u. value of the gas. It also has the advantage of controlling accurately the volatile percentage and fuel value of the coke (smokeless fuel). The smokeless fuel is not used for blast furnace purposes, but it is a superior fuel for domestic uses because of the ease of igniting, ^{and} cleaner to handle. A great advantage in this process is the fact

1. Coal Carbonization, Porter, Chapter 9
2. Report on Methods of Distillation of Coal, Otto Duke.
3. L. C. Karrick, formerly Oil Shale Technologist and

that the steam that is used for the purpose of distillation is first used for the production of electricity. The duality of use makes the steam very cheap for both purposes. A diagrammatic sketch will follow with an explanation of this process (See page 109).

The methods of condensing the vapors and the separation of the products of the vapors are similar to those discussed for oil shales. The methods of conducting the vapors to cooling towers and cooling systems are also very much the same.

The oils are settled out from the ammonical liquor, the gases are scrubbed and the products handled very similarly. Refining of oil from coal is very similar to that of shale oil or petroleum. There is, however, a difference in the products yielded, both chemical and quantitative.

Products Obtained

There are such variations between individual processes and particularly between individual coals that it is difficult to make generalized statements on yields from the distillation of coal. Low temperature processes obtain more oil at the expense of less volume of gas than the high temperature processes. Likewise, the low temperature treatment yields less ammonia and through absence of cracking a higher thermal value of gas which will yield a greater ultimate quantity of light oil.

To present some general idea of the economics of operat-

ing a low temperature carbonization plant, the following table, taken in part from Gentry, Technology of Low Temperature Carbonization,¹ is presented. The assumption is that an average high grade bituminous coal is used for distillation. Classification of the three types are: Type 1, the average externally heated low temperature retort; Type 2, the average internally heated low temperature retort; and Type 3, the reported yield from average bituminous coal from Utah distilled by the use of super heated steam, internally.² The yield per ton is tabulated in the table for each of the products.

Table No. 18 -- Average Yield From Various Types of Carbonization Processes

Product	Yield per ton of Coal		
	Type 1	Type 2	Type 3
Pounds coke	1,450	1,050	1,300
Cubic feet total gas	4,200	34,100	3,000
B.t.u. per cubic foot	835	240	850
Gallons light oil from gas	2.4	0	2.5
Gallons crude oil	25.1	24.6	30
Pounds ammonium sulphate	12.0	37.0	20

1. Technology of Low Temperature Carbonization, Gentry, p.315
2. Courtesy of Mr. L. C. Karrick.

For further analysis of the products yielded from the distillation of coals the results of Drs. Young and Dustan, of the East Ham Technical College is presented. These results were obtained from test runs of two to five tons of coal. The quantities are in net amounts per ton of coal.¹

Cannel Coal No 2

Smokeless fuel, 1400 pounds.
Surplus stripped gas, 5,000 cubic feet
Sulphate of ammonia, 6.5 pounds.
Oil, as per analysis C, 55.5 gallons
Naphtha, from stripping gas, 4.95 gallons

Bituminous Coal

Smokeless fuel, 1400 pounds.
Surplus stripped gas, 5,000 cubic feet.
Sulphate of ammonia, 25.8 pounds.
Oil as per analysis E, 22 gallons
Naphtha, from stripping gas, 2.2 gallons

Analysis C

Water free oil, specific Gravity, 0.916, 55.5 gallons
Light oil, distilled at 170° C., 3.8 gallons.
Middle oil, 14 gallons.
Oil above 270° C., (crude lubricating oil), 20 gallons.
Tar acids, 4 gallons.
Pitch, 150 pounds.

1. Bureau of Mines, T. P. , 123, R. H. Fernald, page 127.

Analysis E

Water-free oil, specific gravity, 1.06, 22 gallons.
Light oil distilled at 170° C., 1.3 gallons
Middle oil, containing 10% tar acids, 5.7 gallons
Oils above 270° C., 4 gallons.
Pitch (bituminous), 90 pounds.

The naphtha obtained by stripping the gas is mixed with the light oil distilled from the crude oil. They are, when treated and cleaned, used for gasoline.

The yield of smokeless fuel from a ton of coal will vary a little according to the coal and the degree, or time of distillation. The yield from low temperature coke processes as shown will not vary much from 1400 pounds.¹ The yield from the steam process for Utah coals will, according to Mr. Karrick, be slightly under this amount. There is slightly more volatile matter in the steam distilled fuel and it is more easily ignited and kept burning. The quality of the steamed coke for domestic fuel is equal or superior to the other, but is not as suitable in the steel or iron smelting furnace because of the friability, it is not as hard and would crush.²

It is very clear that the greatest potential market for the low temperature coke is that of household fuel. This smokeless fuel is ideal for this purpose, since it is clean,

1. Technology of Low Temperature Carbonization, Gentry, p 315
2. Courtesy of Mr. L.C. Karrick, also, Coal Carbonization, Porter, pages 405-406

ignites easily, and burns readily with little attention.

Fireplaces and stoves emit the larger portion of the heat by radiation. An investigation by Dr. Fishenden¹ on the efficiency of the low temperature coke, as compared with ordinary coal proved the superior quality of the smokeless fuel. Three tests were made on various types of open grates. In the first test, a radiation efficiency of 19.7 per cent was obtained for the coke, as compared to 17.3 per cent for bituminous coal. The second test showed the semi-coke to have a radiation efficiency of 24.0 per cent and the bituminous coal 19.5 per cent. The third test gave corresponding figures of 30.8 per cent and 24.2 per cent. This shows an efficiency of 20 to 25 per cent greater for the smokeless fuel.

Three other tests were conducted by Fishenden, in Kitchen boilers. The radiation tests were in the per cent of efficiency of the smoke less fuel/^{to coal} as follows: 17.3 to 13.1; 20.7 to 14.5; and 41.0 to 31.0, for the three tests. In ordinary kitchen ovens, however, the coke did not show any increase in efficiency over coal, but probably in an oven designed to take better advantage of the increased radiation this could be improved.

"The advantage of low temperature coke over coal, aside from its smokeless quality, lies in its superior radiation,

1. Fishenden, Fuel Research Board, Tech. Paper No. 3, 1921

which is most apparent when the distance from the fuel bed to boiler or oven is small. When they are far apart, the advantage of the coke diminishes and the longer and luminous flame of the coal gives better results."¹

The gas produced by the steam process varies with the degree of heat and stripping. A ton of ^{Utah} coal will yield from one thousand cubic feet of 1,025 B.t.u. to 4000 cubic feet of 800 B.t.u. The average yield of gas for Utah coals is about 3500 cubic feet of 800 B.t.u.⁵ By more complete carbonization there can be produced as high as one hundred twelve thousand cubic feet of gas, of 240 B.t.u. per cubic feet.²

The crude oil yield may vary with different types of coal and the method of distillation.³ The average for Utah coals will range from twenty-five to thirty, by the steam distillation method. Laboratory experiments of this crude oil tend to show that it will yield when cracked and treated, about 30 percent of gasoline by volume.

The gasoline is high grade anti-knock motor fuel, ranging with the ethyl treated product of petroleum.⁴

1. Fishenden, Fuel Research Board, Tech. Paper No. 3, 1921
2. Technology of Low Temperature Carbonization, Gentry, p 315
3. Idem.
4. Coal Carbonization, Porter, page 404.
5. Courtesy, Mr. L. C. Karrick

The gasoline distilled from the oil manufactured from coal has a greater horse power productivity than petroleum gasoline. A test by W. O. Hinkley¹ showed that with the same type engine and under the same conditions, the gasoline from coal developed 36 H. P. as compared to 34.5 H. P. for the other.

Another test by Thos. Midgely, Jr. in the laboratories of the General Motors Corporation, proved the superiority of this fuel over other gasolines.²

"The heating value of benzene (gasoline produced from coal) per gallon is 137,000 B. t.u. as against 113,500 B.t.u. for an average gasoline. As to radiator temperature, however, it has been found in comparative engine tests that no appreciable difference therein results, when the usual cooling means are applied. With a leaner mixture the benzene does the work of a richer mixture of gasoline, as carburetor adjustment in comparative engine tests has demonstrated. Under equal conditions mileage per gallon has been increased approximately 20 per cent by the use of benzene as compared to gasoline. ---- Carbon when formed at all is more flocculent and easier to blow out by the exhaust than when formed from gasoline."³

1. J. Soc. Automotive Engineers, 11 359-62, 1922
2. Journ. Ind. Eng. Chem. 14, 894-8, 1922.
3. Coal Carbonization, Porter, page 404-5

As a combined product in the distillation of coal is the production of electricity. There are no accurate figures as to the extra cost of producing this electricity, but it will be very little other than the cost of the machinery. As seen in the diagram, Table No.20 , the steam used to distill the coal is run through the turbines before it is reheated. The extra cost, other than equipment will be the loss in temperature of running the steam through the turbine before it is super heated for distillation.

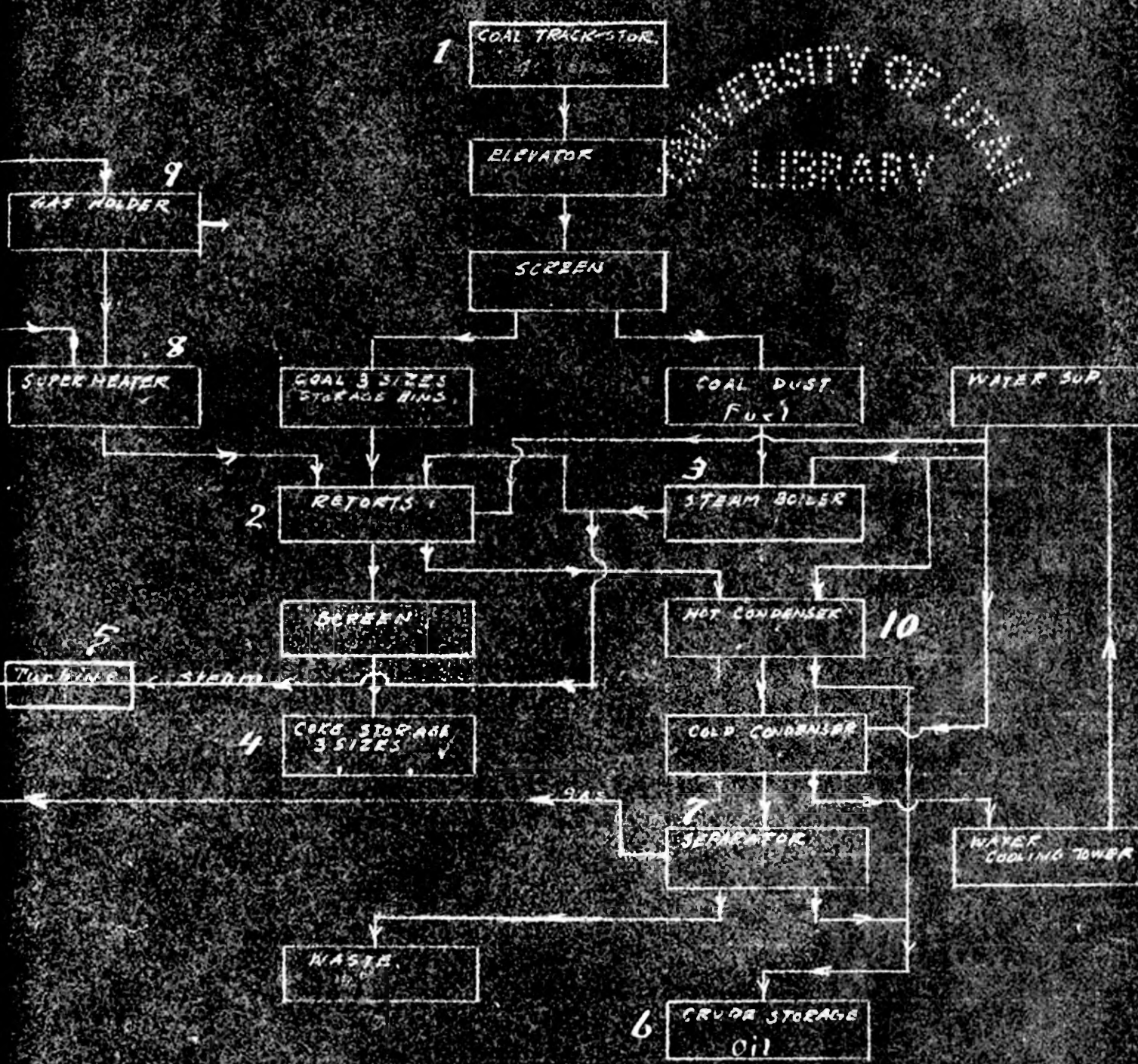
Estimated on the basis of twenty pounds of steam per Kwhr. for production of electricity and 2000 pounds of water for the distillation of one ton of coal, there could be generated 100 Kwhrs. of electricity for every ton of coal treated. A plant large enough for the distillation of 1000 tons of coal per day would justify the installation of electrical equipment for generation of 100,000 Kwhrs., or a 2400 H. P. steam generation plant.¹

Water Requirements for Distillation

The water problem in Utah relative to the establishment of an industry where water is a prime factor in the location of the plant has been discussed in the preceding chapter and

1. Courtesy of Mr. L. C. Karrick and Associate Engineers.

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FLOW DIAGRAM

FOR

KARRICK COAL TREATING PLANT

C.O. Wardrop

Table No 20

Description of Flow Diagram of the Proposed Karrick Coal Treating Plant

Raw coal (1) is screened and the solid coal introduced into the retort(2) where it is distilled, it is then stored (4) for sale as smokeless fuel. The fine and dust coal is used for fuel under the steam boiler (3). The steam from (3) is either directly introduced into the retort (2) or the turbine (5) if electricity is generated. From the turbine the steam is transferred to the superheater (8) then into the retort (2) for distillation of the coal. The hot vapors are conducted into the condenser (10) and (7). Here the naphtha, gas and crude oil are separated. The gas is conducted to the storage tank (9) and held for sale and fuel for the superheater. The oil is stored in (6). Separation of the ammonia is not shown but is taken out in (7) and conducted to a plant for refining and finishing into ammonium sulphate.

will not need repetition.

The total amount of water, as steam, will be greater in the distillation of coal, by the method proposed by Mr. Karrick and associate engineers, than for distillation of oil shales. For the ordinary low temperature coke plants it is, however, much less.

Estimation as to the amount of water that will be required for distillation of the coal and refinement of the oil, given by Mr. Karrick for his method is, about one pound of replacement water for every pound of coal treated. Or for a one thousand ton capacity distillation plant it would require 125,000 gallons of water for replacement of loss in evaporation and contamination.¹ This amount includes the establishment of a 2,400 H. P. electrical unit, in connection with the distillation and the refining of the manufactured oil for gasoline and fuel oil.

Marketing of the products of the distillation of oil from coal must be considered in the location of the distillation plant. At the present freight rates it may be much cheaper to transport the coal from the mine to the market than to transport the products after distillation. This factor in some cases

1. Courtesy, Mr. L. C. Karrick, and Associate Engineers.

will give more advantage to the location of the plant near the market and thereby alleviate the domestic water supply problem.

Cost of Mining

The cost of mining coal as given by the Utah Coal Producers Association, and discussed in the preceding chapter, was \$1.87 per ton. This figure will be greatly reduced with the utilization of the mine machinery and application of more efficient methods of mining. Most of the coal mining is now done by hand labor because the volume of production is insufficient for the efficient utilization of machinery. The expense per ton of coal mined by the machinery now used is high because of the inability of the owners to keep the machinery in constant use.

As shown in Chapter II coal could be produced in Utah for less than a dollar per ton at the mine.

The establishment of coal treating plants in Utah would be a "boon" to the coal mining industry and the people employed in coal mining. At the present rate of production the mines are only being worked at about one half to one third capacity. The mining machinery that is now employed is only utilized at about 50 per cent capacity, however, for peak production periods this machinery is necessary. The establishment of a distillat-

ion plant would tend to reduce the seasonal production peaks.

Costs of Distillation

Estimation as to the cost of distilling coal by the use of steam, as given by Mr. Karrick, is approximately \$1.25 per ton for a large capacity plant including office and interest expenses and depreciation on the distillation, but not for the electrical generation equipment. It does, however, include the cost of the steam delivered to the generators.

This is considerably lower than the estimated cost of low temperature distillation given by Mr. Gentry.¹ He gives the total operating and fixed charges of low temperature carbonization as ranging from \$1.94 to \$2.57. The fixed operating charges for these same type retorts were \$1.29 and \$1.65 per ton.

For a comparison one of the types of low temperature coke ovens estimated by Mr. Gentry,² Type 1, and the plant contemplated for construction in Utah by Mr. Karrick and Associates will be presented. It will be remembered that both types are just estimates, but may serve as a basis for comparison.

1. Technology of Low Temperature Carbonization, Gentry, page 321
2. Idem, page 315.

Table No. 19 --- Table of Operation and Revenue Estimation
of low Temperature Plants.

Product per ton of coal	Type 1		Type 3	
	Yield	Value	Yield	Value
Coke, pounds	1,450	\$5.62	1,300	\$5.17
Gas, Cu. feet	2,400	1.30	3,500	1.62
Oil gallons	25	2.18	30	2.60
Am. Sulphate pounds	12	.25	6	.13
Total receipts		\$9.35		\$ 9.52
Coal		3.25		2.25
Gross Revenue		6.10		7.29
Total operating expenses		1.65		1.25
Net Revenue		4.45		6.02
Reduction for Depreciation, Interest, taxes, Insurance		.92		.92
Estimated Net Profit		\$3.53		\$5.10

The estimated capital cost of Type 1, including retorts, by-product condensing plant, etc., light oil scrubbing plant, etc., and ammonium sulphate plant is \$1,590.00¹ per ton of coal daily. Estimations for the Type 3 are not available but we will assume them to be the same as Type 1.

The prices allowed for the products are the average for the United States, 1926, and are as follows:²

1. Technology of Low Temperature Carbonization, Gentry, page 320
2. Idem, pages 318-321.

Smokeless fuel, per ton	\$7.75
Gas, on the basis of value of B.t.u. per thousand cubic feet.	.54
Oil per gallon	.05
Gasoline, (benzene) per gallon	.23
Ammonium sulphate per pound	.02

The coal price for Type 1 was the average for the United States at the ovens; for Utah, Type 3, price at the mine.¹

From the estimated net profits the freight tariff to the markets for the by-products will have to be deducted. They will average approximately as following:² for coke, \$2.50 per ton for one hundred miles and \$4.50 for four hundred miles; crude oil in tank cars, \$0.19 for one hundred miles and \$0.36³ for seven hundred miles, per hundred pounds; ammonium sulphate per hundred pounds, \$0.20 for one hundred miles and \$0.30 for four hundred miles. The tariff on gasoline is about 25 per cent higher than the tariff on crude oil.

The gas may be piped at low costs for long distances where there is a slight decline and not too many dips and humps in the line, which will cause difficulties from the accumulation of gas at the apexes.

1. Utah Coal Producers Association.--It is estimated that coal could be obtained at the mine in Utah for approximately \$1.00 per ton.
2. Technology of Low temperature Carbonization, Gentry, p 362
3. National Pet. News Dec. 19, 1923, page 58

The freight on the untreated coal is at the present rates but little more than for the smokeless fuel. The advantages, therefore, may be for the location of the plant near the consuming market. Other advantages such as living quarters, laborers, supplies and water may be had in the location of the plant near the consuming centers in Utah.

Indications show from Table No. 19 that the income from the various products manufactured in the distillation of coal is sufficient to justify establishment of an industry, and to insure its success, providing the by-products can be disposed of without too great a sacrifice or expenditure of money.

Conclusion

The situation in Utah, with respect to petroleum production, transportation, disadvantage, etc. and the abundance and quality of the coal reserves, is conducive, it seems, to the establishment of an industry for the manufacture of oil and other products from coal.

It would partially eliminate the waste in burning untreated coal, tend to stimulate other industrial activity, and greatly reduce the cost of mining coal by making it possible to more profitably utilize machine and hand labor.

The costs of treating coal for the manufacture of by-products are estimated to be less by the use of steam, than by other low temperature processes. The quality of the by-products is generally higher, but the residue (smokeless fuel) for use in metallurgical processes is inferior.

Extensive study of the situation in Utah indicates that these products might be produced at a profit under the present mining and distribution conditions.

The quality of the products manufactured from coal in tests made by governmental and private research men, from which the following citations are taken, is very high.

For domestic use the smokeless fuel when burned in an open grate or kitchen boiler, delivers 20 to 25 per cent more

heat than the untreated bituminous coal.¹ The smokeless fuel is also much cleaner to handle. The gas varies, according to the degree of stripping and distillation of the coal, from 150 to 1000 and higher B. t. u. per cubic feet, the greater the B.t.u. value the fewer the cubic feet of gas that can be distilled from the coal. The gasoline obtained in stripping the gas and fractionation of the oil is equal in quality to any of the ethyl treated gasolines. Tests made by Dr. Fishenden,² show that more horsepower is developed in internal combustion motors, and ^{an} increase in mileage of about twenty per cent is obtainable, under the same conditions.

The oil, by experimental tests, indicates that a yield by volume of approximately 25 per cent of gasoline, 10 per cent kerosene and 20 per cent good quality fuel oil may be obtained.³

The establishment of such an industry would not only tend to save the apparent economic waste of these by-products in burning coal, but would aid in the solution of the smoke abatement problem in which there is at present

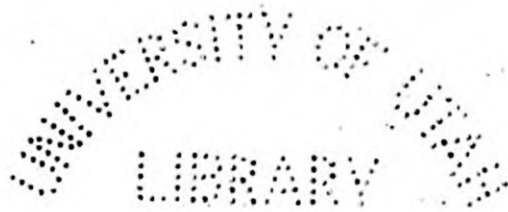
1. Technology of Low Temperature Distillation, Gentry, page 157
2. Coal Carbonization, Porter, page 404.
3. Mr. L. C. Karrick, 1932, Tests in U. of U. Laboratories.

considerable interest. Also, as a complimentary product in the process of distillation of coal, electrical energy can be produced at a minimum cost. Much has been said concerning the lack of cheap electrical power in Utah as the chief limiting factor in retarding industrial development in the state. A partial solution of this difficulty might be found in the establishment of an industry for the manufacture of by-products from coal.

It is estimated that in a 1000 ton daily capacity coal retorting plant there would be sufficient steam generated to develop 100,000 kwhrs. of electrical power, with no extra cost, (except for capital investment of electrical equipment, etc.) other than the loss in temperature of the steam passing through the turbines.¹

Marketing of these products will be in most cases competitive with other products of coal and petroleum. It will likely require considerable demonstration to convert the public to the use of these somewhat new products. Public regulations now in force will likely handicap the distribution of the gas and electrical energy in some of the larger cities. However, if this industry is developed by the proper interests these difficulties might be reduced to a minimum, and in many cases tend to alleviate some of the present difficulties of supplying heat and light to certain territories.

1. L. C. Karrick and Associated Engineers.



Markets and marketing conditions are continually changing and it is therefore very difficult to predict what methods or organizations will be most economically suited for the distribution of these products. The following quotation from Mr. Slosson given at a convention of thirteen nations assembled to discuss fuel and fuel processing, however, fits the circumstances here very appropriately.¹

"There is no world organization that can exercise the right of eminent domain over natural resources and compel a country to stop wasting its coal and oil or to employ its unused land and water power. But all the same, and all the more, we should rejoice when any one discovers how to make a profit out of a waste product or how to make a process more efficient. When a way is found to convert a low grade lignite into a high class motor fuel,... or to clean the air of our industrial towns, or to raise the efficiency of a fuel by low temperature carbonization, he has thereby benefited the human race, living and to come."

1. Technology of Low Temperature Carbonization, Gentry, page 369.

SELECTED BIBLIOGRAPHY

- History of Petroleum in Utah, Unpublished Manuscript, Larsen, 1921
- Petroleum Industry, Past and Present, P.L. Morrow, Sibley Jour. O.19 '30
- Oil Fields in United States, W.A. Ver Wiebe, 1930
- Oil, American Petroleum Institute Bull. 1931
- Marketing, Economy and Manufacture of Petroleum, F.E. Clark, 1930
- Economics of Petroleum Situation, F.W. Black, Inst. of Pet. Tech. Jour. '30
- Bureau of Mines Annual Report, Swanson, 1929
- Oil in Southern Utah, U.S. Geo. Sur. B. 340
- Oil and Gas in Utah, U.S. Geo. Sur. B. 541-d
- Quality of Gasoline Marketed in U.S., Dept. Int. B. 191, Dean & Hill
- Distillation of Petroleum, Rittman & Dean, Dept. Int. B. 125
- Pet. and Nat. Gas in Utah, U.S. Geo. Sur. B. 471-a
- Situation for Potential Production of Pet., Wilde & Moore, 1931
- Selected Readings from Oil and Gas Jour. and Petroleum News.
- Shale Oil Compared with Petroleum, Bur. Mines B. 486
- Shale Oil, Substitute for Petroleum, U.S. Bur. Mines B. 174
- Shale Oil, Desulphurizing Methods, Bur. Mines T.P. 4879
- Oil Shale, Analytical Distillation, U.S. Bur. Mines T.P. 3862
- By-Products of Distillation of Shale Oil, Bur. Mines T.P. 4861
- Oil & Gas Prospects in San Rafael Swell, Utah, 1929, Geo. Sur. B. 806-c
- Oil Shales of Col. & Utah, Woodruff & Day, U.S. Geo. Sur. ^B581
- Oil Shales of the Rocky Mt. Region, Winchester, U.S. Geo. Sur. B. 729
- Oil Shale, M. Gavin, Bur. Mines B. 210
- Oil Shales of the Uintah Basin, Utah, Winchester, Geo. Sur. B. 691

Oil Shale, Day, Hand Book of Pet. Ind., Vol. 1 p 813-94
Oil Shale in Green River, U.S. Geo. Sur. B. 132
Oil Shale, Uintah Basin, U.S. Geo. Sur. B. 691-b & 711-b
Mining Oil Shales, Col. Sch. Mines Quarterly, Supplementary B. 1922
Report of Shale Industry in Scotland, 1925, by Chartered Accountants
Investigation of Gold in Oil Shale, Warley, U.S. Bur. Mines, R.I. 2413
Coal in 1928, U.S. Dept. Com. Bur. Mines, 1930
Mineral Resources of the U.S., 1928, Dept. Com. 1930
Coke and By-Products in 1924, U.S. Bur. Mines, 1927
Fuel Research Board Tech. Paper No. 3, 1921
Converting of Coal into Oil, Fisher & Lessing, 1925
Fuel in Science and Practice, Williams & Gardner, 1925
Low Temperature Distillation, North & Garbe
Wellington & Cooper on Low Temperature Carbonization, 1924
Fuel Research Board Tech. Paper No. 1, 1921 Gray & King
Petroleum, Supply and Demand, American Petroleum Institute, 1930
Technology of Low Temperature Carbonization, Gentry,
Coal Carbonization, H.C. Porter, 1928
Report on Processes of Low Temperature Carbonization, Otto Duke, 1932
Analysis of Utah Coal, U.S. Bur. Mines B. 345
Uses of Water in Shale Oil Industry, Jakosby, U.S. Bur. Mines T.P. 324
Cannel Coal in United States, Bur. Mines B. 322
Cannel Coal, U.S. Bur. Mines B. 123
Bibliography of Petroleum and Allied Substances, U.S. Bur. Mines B. 290
Asphalts and Allied Substances, Abraham, Third Edition
Oil Shale, McKees
Oil Shale, U. S. Bur. Mines, B. 249, L. C. Karrick