

OILFIELD RESEARCH LABORATORIES

536 NORTH HIGHLAND - CHANUTE, KANSAS - PHONE HE1-2650

February 22, 1966

CRA, Incorporated
Box 445
Wellington, Kansas

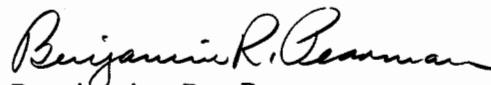
Gentlemen:

Enclosed herewith is the report of the analysis of the Rotary core taken from the Woodward Lease, Well No. 21, Bourbon County, Kansas, and submitted to our laboratory on February 16, 1966.

Your business is greatly appreciated.

Very truly yours,

OILFIELD RESEARCH LABORATORIES


Benjamin R. Pearman

BRP:rf

3 c. - Wellington, Kansas
1 c. - Muskogee, Oklahoma
1 c. - Independence, Kansas

Oilfield Research Laboratories

GENERAL INFORMATION & SUMMARY

Company CRA, Inc. Lease Woodward Well No. 21

Location 2215' EWL & 2120' NSL, SW $\frac{1}{4}$

Section 12 Twp. 25S Rge. 21E County Bourbon State Kansas

Name of Sand - - - - - Bartlesville

Top of Core - - - - - 609.0

Bottom of Core - - - - - 668.0

Top of Sand - - - - (Analyzed) - - - - 619.0

Bottom of Sand - - - - (Analyzed) - - - - 668.0

Total Feet of Permeable Sand - - - - - 46.8

Total Feet of Floodable Sand - - - - - 21.6

Distribution of Permeable Sand:

Permeability Range Millidarcys	Feet	Cum. Ft.
0 - 5	11.1	11.1
5 - 10	3.0	14.1
10 - 50	17.3	31.4
50 - 100	8.4	39.8
100 & above	7.0	46.8

Average Permeability Millidarcys - - - - - 44.3

Average Percent Porosity - - - - - 19.4

Average Percent Oil Saturation - - - - - 35.0

Average Percent Water Saturation - - - - - 40.9

Average Oil Content, Bbls./A. Ft. - - - - - 522.

Total Oil Content, Bbls./Acre - - - - - 24,931.

Average Percent Oil Recovery by Laboratory Flooding Tests - - - - - 11.0

Average Oil Recovery by Laboratory Flooding Tests, Bbls./A. Ft. - - - - - 174.

Total Oil Recovery by Laboratory Flooding Tests, Bbls./Acre - - - - - 3,764.

Total Calculated Oil Recovery, Bbls./Acre (Primary & Secondary) - - - - - 7,590.

Packer Setting, Feet - - - - -

Viscosity, Centipoises @ - - - - -

A. P. I. Gravity, degrees @ 60 °F - - - - -

Elevation, Feet - - - - - 1031.0

OILFIELD RESEARCH LABORATORIES

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Fresh water mud was used as the circulating fluid while taking this core. The core was sampled and the samples sealed in plastic bags by a representative of Oilfield Research Laboratories. The well was drilled in virgin territory.

FORMATION CORED

The detailed log of the formation cored is as follows:

Depth Interval, Feet	Description
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609.0 - 619.0	- Alternate layers sandstone and shale.
619.0 - 630.0	- Light brown, slightly shaly sandstone.
630.0 - 631.0	- Shale.
631.0 - 633.0	- Brown, slightly shaly sandstone.
633.0 - 633.6	- Light brown, laminated, shaly sandstone.
633.6 - 636.0	- Brown, slightly shaly sandstone.
636.0 - 636.6	- Light brown mudstone.
636.6 - 642.6	- Brown, slightly shaly sandstone.
642.6 - 645.0	- Brown to dark, slightly carbonaceous sandstone.
645.0 - 645.2	- Shale.
645.2 - 667.0	- Brown to dark, laminated, shaly, slightly carbonaceous sandstone.
667.0 - 668.0	- Dark, carbonaceous, calcareous sandstone.

Coring was started at a depth of 609.0 feet in alternate layers of sandstone and shale and completed at 668.0 feet in carbonaceous sandstone. For the most part, the pay is made up of brown, slightly shaly sandstone.

PERMEABILITY

For the sake of distribution, the core was divided into three sec-

tions. The weighted average permeability of the upper, middle and lower sections is 69.3, 63.6 and 23.4 millidarcys respectively; the overall average being 44.3 (See Table III). By observing the data given on the coregraph, it is noticeable that the sand has an irregular permeability profile. The permeability of the sand varies from impermeable to a maximum of 145. millidarcys.

PERCENT SATURATION & OIL CONTENT

The sand in this core shows a good weighted average percent oil saturation, namely, 35.0. The weighted average percent oil saturation of the upper, middle and lower sections is 17.0, 39.2 and 40.7 respectively. The weighted average percent water saturation of the upper, middle and lower sections is 53.7, 40.0 and 36.8 respectively; the overall average being 40.9 (See Table III). This gives an overall average total fluid saturation of 75.9 percent. This low total fluid saturation indicates considerable fluid was lost during coring most of which was probably oil.

The weighted average oil content of the upper, middle and lower sections is 264, 626 and 585 barrels per acre foot respectively; the overall average being 522. The total oil content, as shown by this core, is 24,931 barrels per acre of which 13,909 barrels are in the pay sand section (See Table III).

LABORATORY FLOODING TESTS

The sand in this core responded to laboratory flooding tests, as a total recovery of 3,764 barrels of oil per acre was obtained from 21.6 feet of sand. The weighted average percent oil saturation was reduced

from 41.2 to 30.2, or represents an average recovery of 11.0 percent. The weighted average effective permeability of the samples is 4.92 millidarcys, while the average initial fluid production pressure is 24.8 pounds per square inch (See Table V).

By observing the data given in Table IV, you will note that of the 47 samples tested, 33 produced water and 21 oil. This indicates that approximately 45 percent of the sand represented by these samples is floodable pay sand. The tests also show that the sand has a wide variation in effective permeability to water.

CONCLUSION

The results of the laboratory tests indicate that efficient primary and secondary operations in the vicinity of this well should recover approximately 7,590 barrels of oil per acre or an average of 351 barrels per acre foot from the 21.6 feet of floodable pay sand analyzed in this core. These recovery values were calculated using the following data and assumptions:

Original formation volume factor	1.06
Reservoir water saturation, percent	22.0
Average porosity, percent	20.1
Oil saturation after flooding, percent	30.2
Performance factor, percent	50.0
Net floodable pay sand, feet	21.6

This core shows a pay sand section having a good oil saturation, a moderate water saturation and a wide variation in effective permeability to water.

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RESULTS OF SATURATION & PERMEABILITY TESTS

TABLE 1-B

Sample No.	Depth, Feet	Effective Porosity Percent	Percent Saturation			Oil Content Bbbls. / A Ft.	Perm., Mill.	Feet of Sand		Total Oil Content	Perm. Capacity Ft. X md.
			Oil	Water	Total			Ft.	Cum. Ft.		
1	619.1	20.7	10	60	70	161	101.	0.6	0.6	97	60.60
2	620.1	23.1	13	47	60	232	111.	1.0	1.6	232	111.00
3	621.1	20.9	13	64	77	210	47.	1.0	2.6	210	47.00
4	622.1	18.9	13	64	77	190	11.	1.0	3.6	190	11.00
5	623.1	18.8	12	54	66	175	29.	1.0	4.6	175	29.00
6	624.1	22.3	13	57	70	224	90.	1.0	5.6	224	90.00
7	625.1	19.5	14	56	70	212	48.	1.0	6.6	212	48.00
8	626.1	21.2	18	62	80	296	124.	1.0	7.6	296	124.00
9	627.1	18.5	24	47	71	344	22.	1.0	8.6	344	22.00
10	628.1	19.9	24	47	71	370	84.	1.0	9.6	370	84.00
11	629.1	19.7	26	41	67	397	97.	1.4	11.0	556	135.80
12	631.1	22.2	37	33	70	636	90.	0.6	11.6	382	54.00
13	632.1	19.8	35	38	73	539	75.	1.4	13.0	755	105.00
14	633.1	13.8	13	76	89	139	2.6	0.6	13.6	83	1.56
15	634.1	19.7	44	32	76	671	22.	1.0	14.6	671	22.00
16	635.1	25.8	50	31	81	1,000	118.	1.4	16.0	1,400	165.20
17	636.1	19.7	12	85	97	183	0.56	0.6	16.6	110	0.34
18	637.1	19.8	52	27	79	799	61.	1.0	17.6	799	61.00
19	638.1	20.2	31	35	66	485	9.7	1.0	18.6	485	9.70
20	639.1	17.5	40	56	96	543	39.	1.0	19.6	543	39.00
21	640.1	21.2	48	30	78	789	8.1	1.0	20.6	789	8.10
22	641.1	20.1	47	28	75	732	127.	1.0	21.6	732	127.00
23	642.1	18.1	37	43	80	519	145.	1.0	22.6	519	145.00
24	643.1	18.0	50	30	80	697	127.	1.0	23.6	697	127.00

Company CRA, Inc.

Lease Woodward

Well No. 21

Oilfield Research Laboratories

RESULTS OF SATURATION & PERMEABILITY TESTS

TABLE 1-B

Sample No.	Depth, Feet	Effective Porosity Percent	Percent Saturation			Oil Content Bbbls. / A Ft.	Perm., Mill.	Feet of Sand		Total Oil Content	Perm. Capacity Ft. X md.
			Oil	Water	Total			Ft.	Cum. Ft.		
25	644.1	19.3	45	32	77	673	38.	1.4	25.0	941	53.20
26	645.4	21.7	37	27	64	621	42.	0.4	25.4	248	16.80
27	646.1	19.0	35	32	67	516	58.	1.0	26.4	516	58.00
28	647.1	20.6	46	29	75	734	60.	1.0	27.4	734	60.00
29	648.1	20.0	41	27	68	636	24.	1.0	28.4	636	24.00
30	649.1	15.2	27	57	84	318	1.9	1.0	29.4	318	1.90
31	650.1	16.4	30	47	77	382	2.9	1.0	30.4	382	2.90
32	651.1	20.6	46	32	78	734	4.8	1.0	31.4	734	4.80
33	652.1	18.0	48	36	84	669	24.	1.0	32.4	669	24.00
34	653.1	19.6	32	32	64	486	25.	1.0	33.4	486	25.00
35	654.1	17.5	51	28	79	691	9.8	1.0	34.4	691	9.80
36	655.1	21.7	46	32	78	774	47.	1.0	35.4	774	47.00
37	656.1	20.4	38	29	67	601	29.	1.0	36.4	601	29.00
38	657.1	21.9	45	26	71	764	11.	1.0	37.4	764	11.00
39	658.1	18.0	26	37	63	362	21.	1.0	38.4	362	21.00
40	659.1	20.3	43	28	71	676	2.6	1.0	39.4	676	2.60
41	660.1	18.9	24	40	64	352	4.2	1.5	40.9	528	6.30
42	662.1	18.3	31	49	80	440	27.	1.5	42.4	660	40.50
43	663.1	14.5	39	59	98	438	0.23	1.0	43.4	438	0.23
44	664.1	18.4	31	45	76	422	1.4	1.0	44.4	422	1.40
45	665.1	17.7	45	47	92	616	0.84	1.0	45.4	616	0.84
46	666.1	18.1	66	31	97	926	0.49	1.4	46.8	1,298	0.69
47	667.1	12.8	57	15	72	566	Imp.	1.0	47.8	566	0.00
Total									-----	24,931	

Company CRA, Inc.

Lease

Woodward

Well No. 21

Oilfield Research Laboratories

SUMMARY OF PERMEABILITY & SATURATION TESTS

TABLE III

Company	CRA, Inc.	Lease	Woodward	Well No.	21	
	Depth Interval, Feet	Feet of Core Analyzed	Average Permeability, Millidarcys	Permeability Capacity Ft. x Md.		
	619.0 - 630.0	11.0	69.3	762.40		
	631.0 - 642.6	11.6	63.6	737.90		
	642.6 - 668.0	24.2	23.4	567.96		
	619.0 - 668.0	46.8	44.3	2,068.26		
	Depth Interval, Feet	Feet of Core Analyzed	Average Percent Oil Saturation	Average Percent Water Saturation	Average Oil Content Bbl./A. Ft.	Total Oil Content Bbls./Acre
	619.0 - 630.0	11.0	20.2	17.0	264	2,906
	631.0 - 642.6	11.6	20.1	39.2	626	7,268
	642.6 - 668.0	25.2	18.6	40.7	585	14,757
	619.0 - 668.0	47.8	19.4	35.0	522	24,931

Oilfield Research Laboratories

RESULTS OF LABORATORY FLOODING TESTS

TABLE IV

CRA, Inc.			Lease			Woodward			Well No.		21	
Sample No.	Depth, Feet	Effective Porosity Percent	Original Oil Saturation		Oil Recovery		Residual Saturation			Volume of Water Recovered cc*	Effective Permeability Millidarcys**	Initial Fluid Production Pressure Lbs./Sq./In.
			%	Bbls./A. Ft.	%	Bbls./A. Ft.	% Oil	% Water	Bbls./A. Ft.			
1	619.1	21.1	13	213	0	0	13	70	213	236	4.00	10
2	620.1	22.8	12	212	0	0	12	83	212	433	25.15	10
3	621.1	20.8	11	177	0	0	11	85	177	259	9.80	10
4	622.1	18.4	14	200	0	0	14	66	200	0	Imp.	-
5	623.1	18.6	12	173	0	0	12	78	173	97	3.20	20
6	624.1	22.0	15	256	0	0	15	80	256	355	17.45	10
7	625.1	19.0	14	206	0	0	14	79	206	161	5.40	10
8	626.1	21.6	17	285	0	0	17	71	285	332	14.00	10
9	627.1	18.1	25	351	0	0	25	61	351	47	0.900	20
10	628.1	20.4	24	380	2	32	22	72	348	336	9.00	10
11	629.1	20.0	26	403	2	31	24	74	372	231	20.00	10
12	631.1	21.8	37	625	14	236	23	71	389	252	12.45	20
13	632.1	20.3	35	551	9	142	26	72	409	226	10.30	20
14	633.1	13.4	15	156	0	0	15	77	156	0	Imp.	-
15	634.1	19.5	44	664	22	332	22	72	332	224	8.10	20
16	635.1	25.4	50	985	24	473	26	66	512	407	16.00	10
17	636.1	19.2	14	208	0	0	14	84	208	0	Imp.	-
18	637.1	19.6	52	790	27	410	25	74	380	118	3.80	20
19	638.1	19.8	31	476	2	31	29	68	445	34	0.900	20
20	639.1	18.0	40	558	16	223	24	71	335	37	0.900	20
21	640.1	20.9	48	777	23	373	25	66	404	15	0.400	20
22	641.1	20.5	47	746	19	302	28	71	444	154	4.70	10
23	642.1	17.9	37	513	10	139	27	70	374	9	0.300	30
24	643.1	18.4	50	713	8	114	42	49	599	28	0.800	30

Company

CRA, Inc.

Lease

Woodward

Well No.

21

Notes: cc—cubic centimeter.

*—Volume of water recovered at the time of maximum oil recovery.

**—Determined by passing water through sample which still contains residual oil.

Oilfield Research Laboratories

RESULTS OF LABORATORY FLOODING TESTS

TABLE IV

Company			CRA, Inc.			Lease			Woodward			Well No.		21	
Sample No.	Depth, Feet	Effective Porosity Percent	Original Oil Saturation		Oil Recovery		Residual Saturation		Volume of Water Recovered cc*	Effective Permeability Millidarcys**	Initial Fluid Production Pressure Lbs./Sq./In.				
			%	Bbls./A. Ft.	%	Bbls./A. Ft.	% Oil	% Water				Bbls./A. Ft.			
25	644.1	18.9	45	659	7	103	38	50	11	0.400	30				
26	645.4	21.4	37	614	2	33	35	63	16	0.500	30				
27	646.1	19.4	35	526	5	75	30	68	88	2.30	20				
28	647.1	20.5	46	731	6	95	40	39	6	0.200	50				
29	648.1	19.5	41	619	4	60	37	49	5	0.200	50				
30	649.1	15.2	28	330	0	0	28	58	0	Imp.	-				
31	650.1	16.5	29	371	0	0	29	50	0	Imp.	-				
32	651.1	20.1	46	717	10	156	36	57	40	0.800	40				
33	652.1	18.3	48	681	12	170	36	58	12	0.400	40				
34	653.1	19.5	34	514	0	0	34	58	9	0.200	40				
35	654.1	17.8	52	718	0	0	52	30	0	Imp.	-				
36	655.1	21.4	46	762	3	50	43	55	25	0.500	20				
37	656.1	20.0	40	620	0	0	40	48	4	0.100	50				
38	657.1	21.5	45	750	0	0	45	27	0	Imp.	-				
39	658.1	18.5	26	373	0	0	26	64	9	0.200	50				
40	659.1	20.0	45	697	0	0	45	29	0	Imp.	-				
41	660.1	19.0	24	354	0	0	24	42	0	Imp.	-				
42	662.1	18.7	33	479	0	0	33	55	7	0.200	50				
43	663.1	14.7	40	456	0	0	40	57	0	Imp.	-				
44	664.1	18.0	32	446	0	0	32	47	0	Imp.	-				
45	665.1	17.8	45	621	0	0	45	48	0	Imp.	-				
46	666.1	18.3	68	964	0	0	68	29	0	Imp.	-				
47	667.1	13.0	59	594	0	0	59	17	0	Imp.	-				

Company CRA, Inc.

Lease Woodward

Well No. 21

Notes: cc—cubic centimeter.

*—Volume of water recovered at the time of maximum oil recovery.

**—Determined by passing water through sample which still contains residual oil.

Oilfield Research Laboratories

SUMMARY OF LABORATORY FLOODING TESTS

TABLE V

Company	CRA, Inc.		Lease		Woodward		Well No.	
Depth Interval, Feet	619.0 - 630.0		631.0 - 642.6		642.6 - 668.0		619.0 - 668.0	
Feet of Core Analyzed	2.4		10.4		8.8		21.6	
Average Percent Porosity	20.2		20.5		19.6		20.1	
Average Percent Original Oil Saturation	25.2		42.3		44.3		41.2	
Average Percent Oil Recovery	2.0		16.7		6.7		11.0	
Average Percent Residual Oil Saturation	23.2		25.6		37.6		30.2	
Average Percent Residual Water Saturation	73.1		70.0		53.5		63.6	
Average Percent Total Residual Fluid Saturation	96.3		95.6		91.1		93.8	
Average Original Oil Content, Bbls./A. Ft.	393.		676.		671.		644.	
Average Oil Recovery, Bbls./A. Ft.	31.		270.		100.		174.	
Average Residual Oil Content, Bbls./A. Ft.	362.		406.		571.		470.	
Total Original Oil Content, Bbls./Acre	944.		7049.		5916.		13909.	
Total Oil Recovery, Bbls./Acre	75.		2812.		877.		3764.	
Total Residual Oil Content, Bbls./Acre	869.		4237.		5039.		10145.	
Average Effective Permeability, Millidarcys	15.40		6.09		0.677		4.92	
Average Initial Fluid Production Pressure, p.s.i.	10.0		19.0		34.5		24.8	

NOTE: Only those samples which recovered oil were used in calculating the above averages.