GL07356-1

RRGE-2 TO RRG1-6

INITIAL ATTEMPT

RRG1-6 RESPONSE

RRGE2 & RRG1-6 TEST March, 1979.

WELL RRG1-6 Response (BUILDUP & FALLOFF)
& initial attempt at test, (duration 11.3 hrs.)

RRG1-6 RESPONSE BUILDUP

Initial Attempt. Discussion of results. Test duration 680 mins. Initial displacement of borehole. 19 mins. Temperature not in equilibrium until 350 elapsed minutes.

Accepting the interval 350 – 680 mins as representative of quasi-equilibrium, apparent characteristics are:

S_{10} = 17.2 psi/log cycle, Q = 600 gpm

Q/S_{10} = 34.88 gpm/psi/cycle.

$Kh = 5759 \; Q/S_{10} \; \mu$ = 5579 × 34.88 × 0.2 = 38,919 md ft.

$T = \frac{Kh}{1000} \times .3284 \frac{\gamma}{\mu} = \frac{38,919}{1000} \times .3284 \times \frac{57.93}{.2}$

= 38.92 × .3284 × 289.65

T = 3702 gpd/ft.

RRG1-6 RESPONSE FALLOFF

Initial Attempt. Recovery (falloff) permitted to ratio elapsed times of 17. undisturbed. Wellhead flow altered after this period and not reliable. Apparent characteristics are:

S_{10} = 21.5 psi/log cycle., Q = 600 gpm.

Q/S_{10} = 27.91 gpm/psi/log cycle.

RLG1-6 Response Falloff (initial attempt) control.

$$Kh = 5759 \frac{Q}{S_o} \mu = 5579 \times 27.91 \times 0.2 = \underline{31,142 \text{ md ft.}}$$

$$T = \frac{Kh}{1000} \times .3284 \frac{\rho}{\mu} = \frac{31,142}{1000} \times .3284 \times \frac{57.93}{.2}$$

$$T = \underline{2962 \text{ gpd/ft.}}$$

RRG1-6 - INITIAL PULSE TEST RECOVERY

TIME	t	t'	Ratio t/t'	WHP	
	645			201.9	pumps off.
	645.25	.25	2580	112.98	
	645.5	.50	1291	139.04	
	645.75	.75	861	135.1	
	646	1.0	646	132.2	
	646.25	1.25	517	130.02	
	646.50	1.50	431	128.22	
	646.75	1.75	370	126.72	
	647	2.0	323.5	125.42	
	647.5	2.5	259	123.3	
	648	3.0	216	121.6	
	649	4	162	118.9	
	650	5	130	116.8	
	651	6	109	115.7	
	652	7	93	114.4	
	653	8	82	113.3	
	654	9	73	112.2	
	655	10	65.5	111.3	
	657	12	55	109.6	
	659	14	47	108.2	
	660	15	44	107.5	
	665	20	33	104.8	
	670	25	27	102.7	
	675	30	22.5	101	
	680	35	19.4	99.4	
	685	40	17	87	

Flow diverted thru wellhead (69 gpm) this is not clear what is being done but evidently influences recovery data significantly. Only the initial 40 minutes used.

Note wellhead temperature fell from 270°F to 240°F during this 40 minute period. How significant is this in influencing interpretation? This does not reflect the rate of change of temperature in the borehole. Was temperature profile obtained?

ISIP = 48.64 psia

RRI-6 - INITIAL PULSE, 600 gpm.

	TIME	ELAPSED TIME (mins)	WELLHEAD PRESSURE (psia)	REMARKS
Mar 19th	13:14:50	0	48.64	INITIAL SHUT IN
	13:15:00	.17	63.13	
	:10	.33	81.30	
	:20	.50	82.60	
	:30	.67	88.73	
	:40	.83	106.34	
	:50	1.0	113.75	
	16:00	1.17	121.16	
	:10	1.33	124.64	
	:20	1.50	124.43	Q stabilized at 600 usgpm
	:30	1.67	127.46	
	:40	1.83	129.40	
	:50	2.0	130.32	
	17:00	2.5	132.00	
		3	134.85	
		3.5	137.16	
		4	138.63	
		4.5	140.12	
		5	140.14	
		6	141.97	
		7	143.64	
		8	144.97	
		9	146.20	
		10	147.30	
		12	149.15	
		14	150.81	
		16	151.92	
		18	153.14	
		20	154.56	
		25	157.47	
	13:45:00	30	159.97	
		35	162.13	
		40	163.8	
		45	165.48	
		50	166.82	
		60	169.42	
		65	170.65	
		75	172.97	
		85	174.92	
		95	176.78	
		105	178.49	
		125	181.76	
		145	185.50	
Mar 19th	16:00:00	165	188.73	

	TIME	ELAPSED TIME min.	WELLHEAD P. psia	REMARKS
Mai 19	16:30:00	195	191.78	
		225	193.45	
		255	194.48	
		285	195.32	
		315	196.00	
		345	196.79	
		405	198.10	
		465	199.35	
		525	200.10	
		585	201.00	
		645	201.77	
Mai. 20	00:20	665	201.90	

RRG1-6 - INITIAL PULSE 600 gpm

	Time	Elapsed Time	Temp. °F (chart readout)
Mar 19th	13:15	0	196
		3	201
		6	204
		9	205.5
		12	207
		15	210
		18	211.5
		21	213
		24	214
		27	215
		30	216
		33	217
		36	218
		39	219
		42	220
		45	221
		48	222
		51	223
		54	224
		57	225
		60	226
		66	228
		72	230
		78	232
		84	234
		90	235.5
		96	237
		99	238
		105	240
		111	243
		117	246
		123	249
		129	252
		135	255
		141	258
		147	259
Total Elapsed Time is: 665 min		153	260.5
		159	262.5
		171	264
		183	265.5
		195	266.5
		207	267
		+42 249	268.5
		+40 289	268.5
		+35 324	271.5
		+24 348	274

Total Elapsed Time is:

approx stable for 5 hrs to end of run

RRGE-2 TO RRG1-6

SUSTAINED 21 DAY TEST

RRG1-6 RESPONSE

RRGI-6 RESPONSE (SUSTAINED TEST) BUILDUP.

Duration. 21 days. Data describe reasonably straight line (Horner) after 2000 min. Temperature quasi-stable at 270-273°F after 400 min. Temperature correction by density change-midpoint method (Dermith) not satisfactory because effective mid point is not clearly enough understood. Selection of mid point influences correction significantly. Using arbitrary mid-point centered in open-hole segment of bore-hole provides reasonable fit between early buildup and very late thermally stable build up data. The method is not effective in correcting data during rapid rate-of-change of temperature producing a non-linear plot.

Uncorrected wellhead pressure data and wellhead temperatures are shown vs time in Figure (x). Initial shut-in pressure prior to injection was

$T = 200°F$ $\quad Q/s_{10} = \frac{600}{27} = 22.2$ gpm/psi/cycle.

$\mu = 0.3$ cp

$\gamma = 60.06$ lb/ft^3 $\quad kh = 5759\ Q/s_{10}\ \mu = 5759 \times 22.2 \times .3 = \underline{38354}$ md.

$$T = \frac{kh}{1000} \times .3284\ \gamma/\mu = \frac{38,354}{1000} \times .3284 \times \frac{60.06}{.3}$$

$$= 38.354 \times .3284 \times 200.2$$

$$= \underline{2533\ gpd/ft}.$$

$T = 273°$

$\mu = 0.2$

$\gamma = 58.14$ lb/ft^3

$$Q/s_{10} = \frac{600}{13} = 46.15 \text{ gpm/psi/cycle}.$$

$$kh = 5759\ Q/s_{10}\ \mu = 5759 \times 46.15 \times .2 = 53,155 \text{ md}.$$

$$T = \frac{kh}{1000} \times .3284\ \gamma/\mu = 53.155 \times .3284 \times 290.7 = 5074 \text{ gpd/ft}.$$

Denniff Correction of buildup data for temperature influences:

Assume: Midpoint = 2778 ft.
Temperature at midpoint at end of test is 273°F.
Time required to reach midpoint at 60 B/pm is 30 min.

$\bar{\omega}$ at end of test at middepth is 58.14 lb/ft³ at 273°F

	150°	61.16	3.02			58.26	
	200°	60.06	1.92	$\Delta\bar{\omega}$ lb/ft³		37.04 ΔP_{WH} (psi)	
$\bar{\omega}$	at 220°F	59.61	1929	1.47	19.3	28.36 ✓	21.43
$\bar{\omega}$	at 225°	59.48		1.34	17.59	25.86 ✓	19.54
$\bar{\omega}$	at 230°	59.35		1.21	15.89	23.34 ✓	17.64
ω	at 236°	59.19		1.05	13.79	20.25 ✓	
$\Delta\bar{\omega}$	at 240°	59.08		0.94	12.34	18.13 ✓	
	246°	58.91		0.77	10.11	14.85 ✓	11.23
	250°	58.80		0.66	8.67	12.73 ✓	
	256°	58.63		0.49	6.43	9.45 ✓	
	260°	58.54		0.40	5.25	7.72 ✓	
	266°	58.34		0.20	2.63	3.86 ✓	
	270°	58.22		0.08	1.05	1.54	1.17

midpoint 1900'
$\Delta P_{wh} \times 13.13$

$$\Delta P_{WH} = \Delta\bar{\omega} \frac{2778}{144} \text{ psi} \qquad \text{(constant is 19.29)}$$

REMARKS

During late buildup. Temperature varied between 273° – 279°
This represents a difference in specific weight of 58.16 & 57.92 lb/ft³
= 0.24 lb/ft³ or a pressure difference of 4.63 psi

Examining this qualitatively for the period following 1000 min: This exercise is not worth it.

Correction becomes non linear with middepth accomplished of 2100'.

Time to inject borehole & introduce hotter water.

a) assume all water enters within 100' of casing foot.

V_{casing} = 11,024 gal.
V_{open} = 612 gal
V_{total} = 11,636 gal. at 600gpm this is: 19.39 say <u>20 min</u>

b) assume all water enters the entire open section.

V_{casing} = 11,024 gal.
V_{open} = 13,219 gal
V_{total} = 24,243 gal. at 600gpm this is: 40.41 say <u>40 min</u>

Temperature influences identified at time segments.

a. at wellhead initial 100 min. temp raised 13°F. (.13°F/min)
from 219°-232° (13°F)

Water V_f (at 219°F) 0.016768 / 59.64 lb/cuft
V_f (at 232°F) .016864 59.30 lb/cf

b) Mid point assumed to be 1698 (cased) plus ½(2160) = 2778 ft.

At t= 40 min. one borehole volume will have been displaced at 600gpm between t=40 mn and t=100 min. (see figure x) the wellhead temperature remained reasonably stable at 232°F. Time to reach wellhead through transite pipe from RRGE-2. $T_{initial}$ = 267°F. Temperature at RRGE-2 dropped to about 255 and rose again in first day of pumping.

2-1	3865	18" dia		
1-3	8861	10"	22,707	
3-6	3155	10"	36152	
			12872	

Route for injection was RRGE-2 & RRGE-1 & RRGE-3 & RRG1-6
total line volume: 71731 gals Time to flush at 600gpm is 119 min.
See temperature rise after approx 100 min (figure x)

K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
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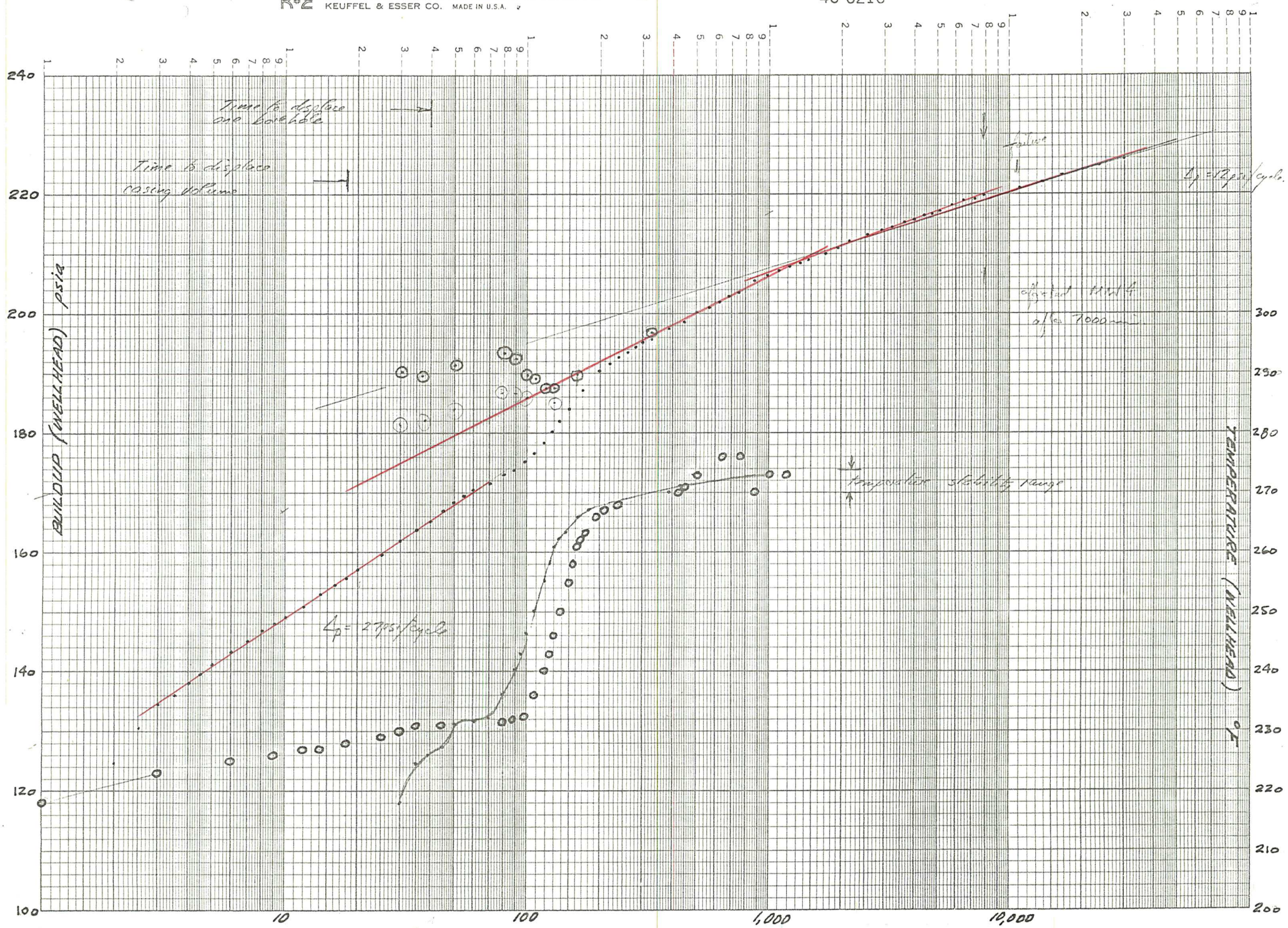
Sustained Test



K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
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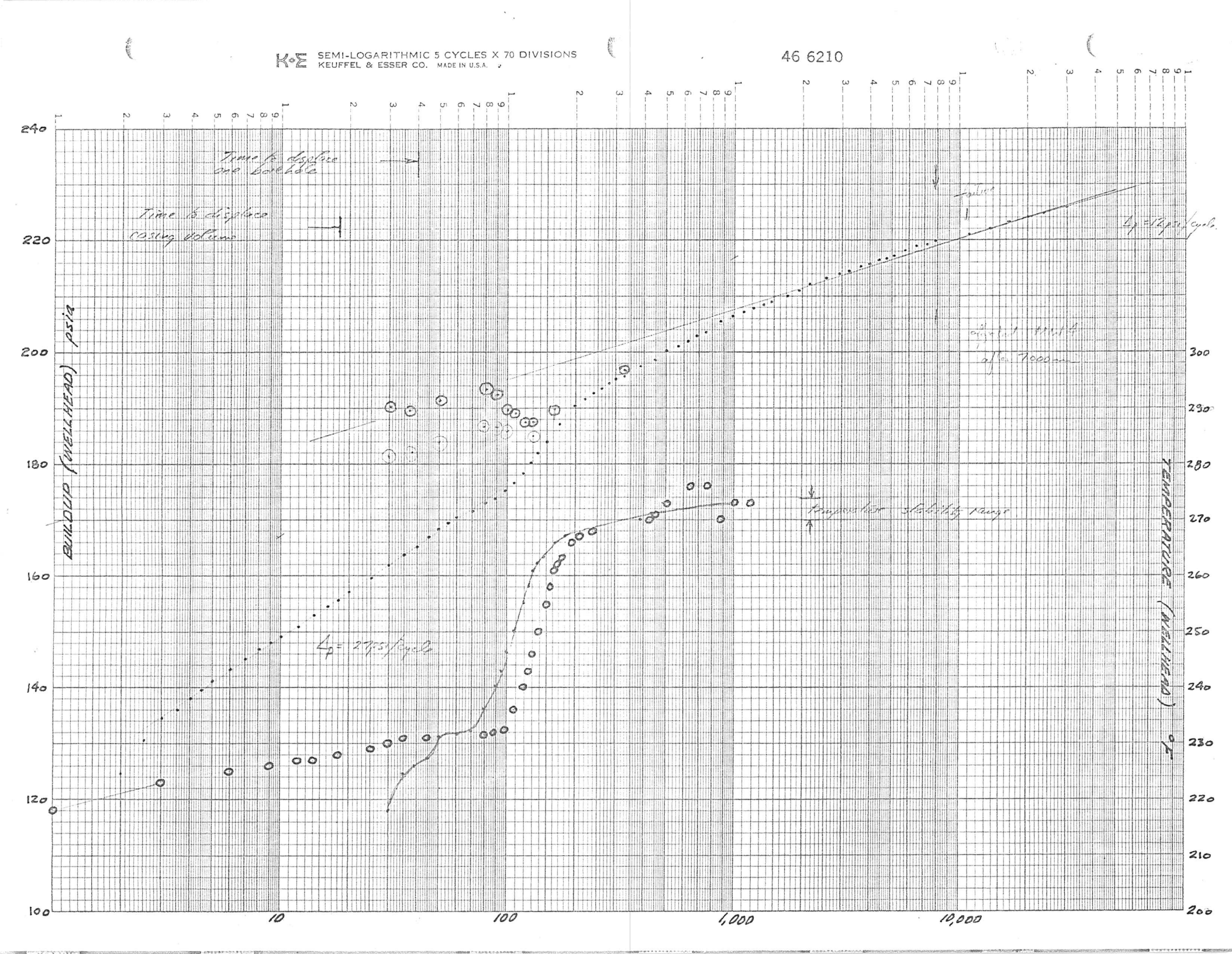

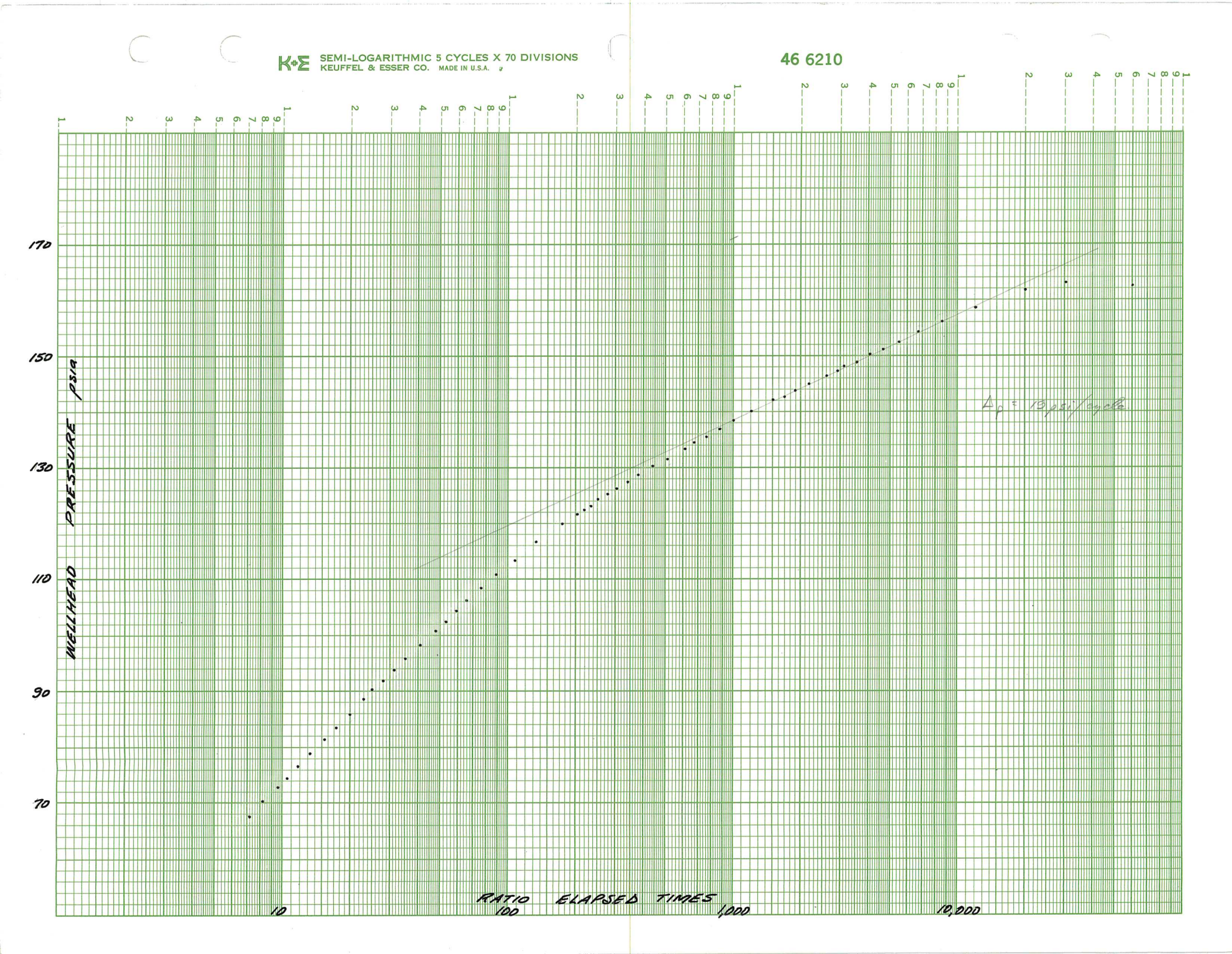
K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
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170
150
130
110
90
70
WELLHEAD PRESSURE psia
10
100
1,000
10,000
RATIO ELAPSED TIMES
Δp = 10 psi/cycle

K+E LOGARITHMIC 3 x 5 CYCLES
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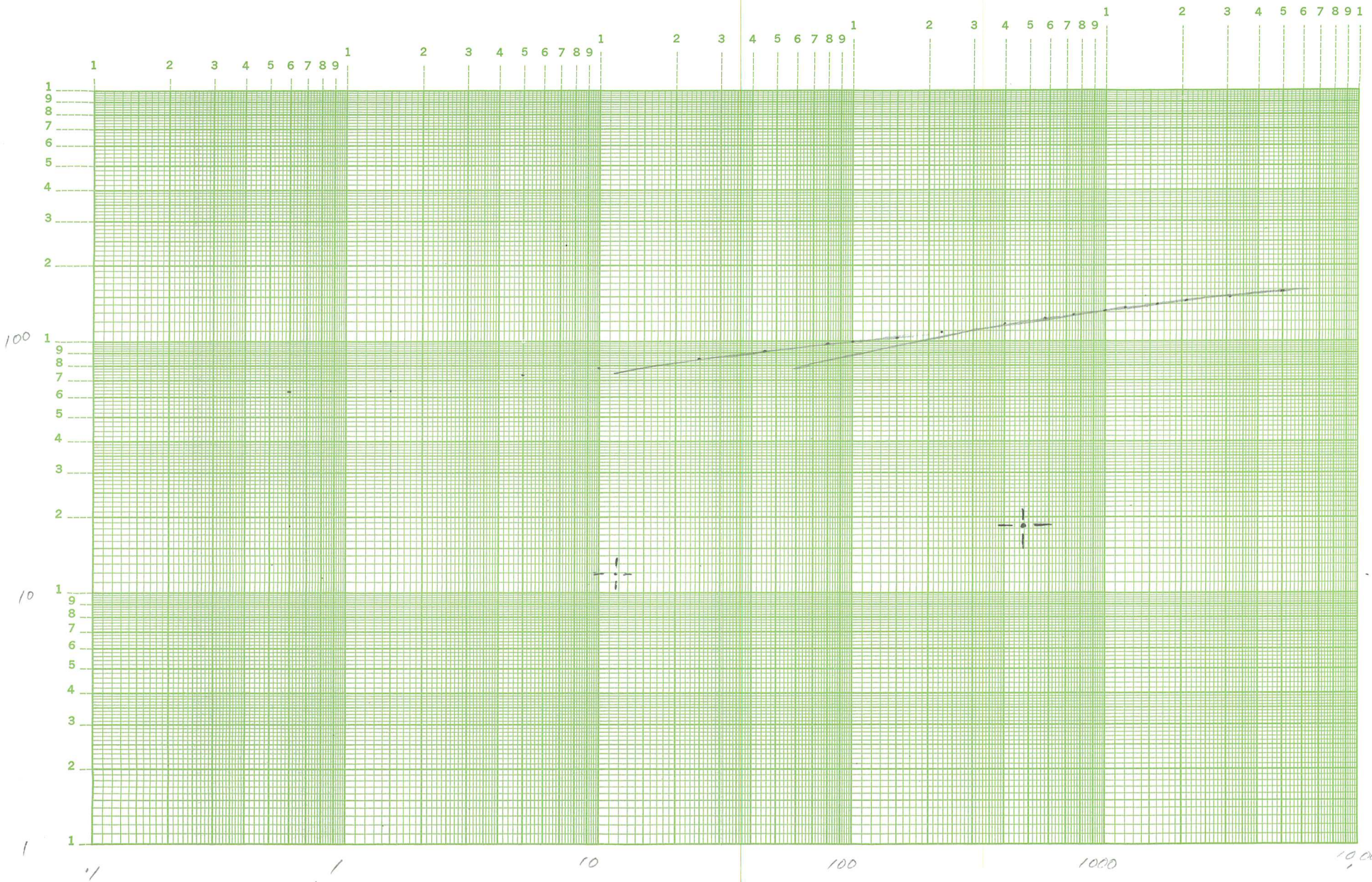

$T = \frac{114.6\ Q\ W(u)}{S} = 3716$

Theis Recovery Method RR61-6

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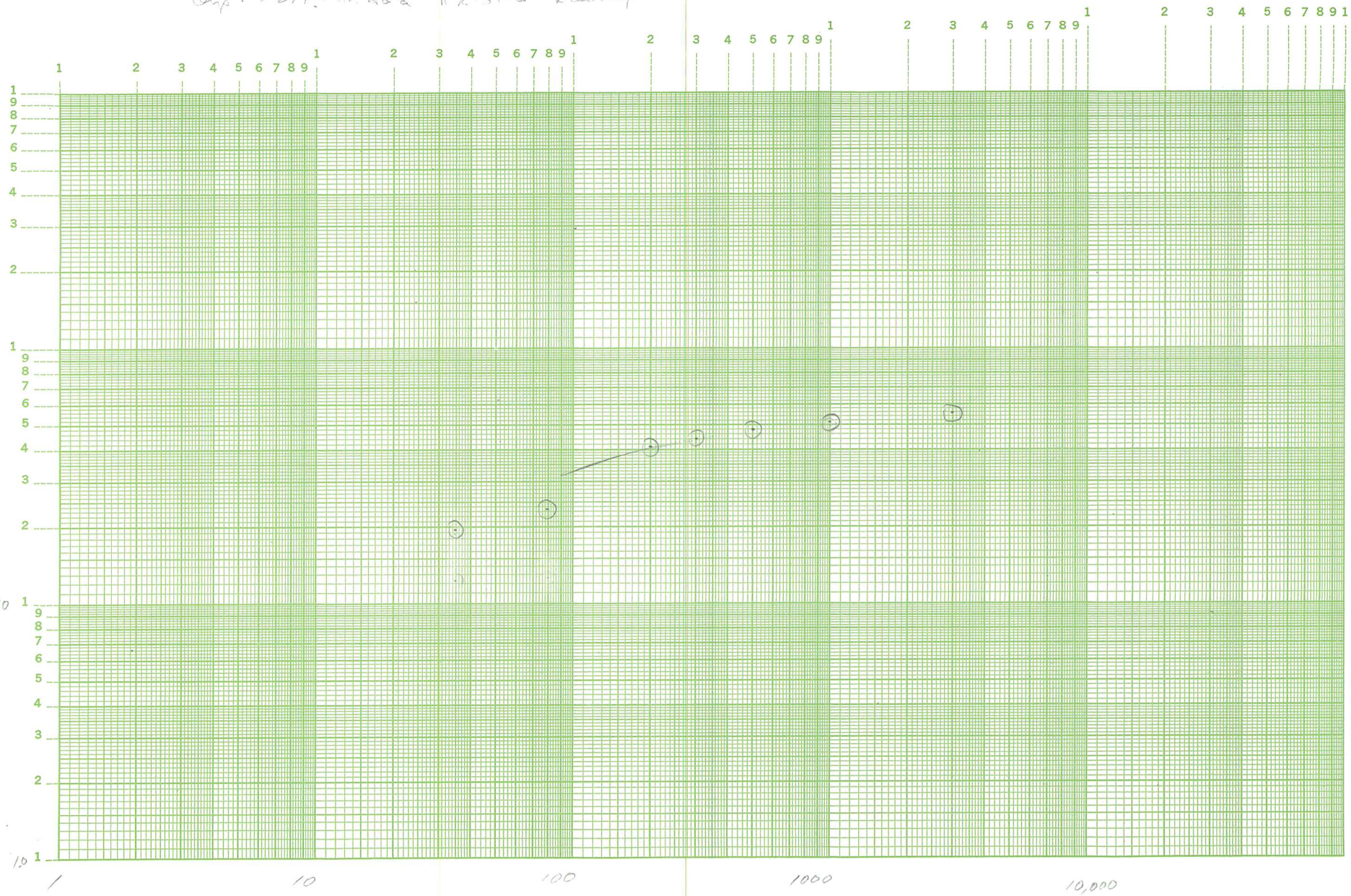
Comp. rollingfriction data KK51-6 Buildup



Temperature response in RRGI-6 borehole following the FET 2-injection Test.

Temperature logs were run in RRGI-6 eight, fifteen and twenty days after injection stopped. These logs show that the lower section of the RRGI-6 borehole cooled very slowly and, the borehole did not equilibrate within twenty days. Wellhead temperature cooled to 72°F after 20 days. Fluid in the borehole below 1400 ft remained reasonably constant at 258-260°F. The temperature gradient from 72° to 255°F is entirely accommodated within the upper 1400 ft of fluid column. The interface between quasi-stable temperature fluid and the more rapidly cooling fluid lying at 1400 ft is approximately 300 ft above the foot of casing in the well.

INSERT INTERPRETATION OF LITHOLOGICAL SIGNIFICANCE OF THIEF ZONE AND EXPLANATION OF COOLING.

The temperature influence on wellhead falloff pressures will be dominantly density changes within the upper 1400 ft. of borehole. In attempting to adjust well head pressures for this effect a mid-depth of 700 ft. is accepted to average the temperature throughout this interval. For an indication of the influence of density, the apparent wellhead pressures after eight and fifteen days of falloff have been corrected for a temperature of

Midpoint accepted at 700 ft

Temperature at midpoint at injection completion. 263°F

Temperature at midpoint after 8 days falloff

Temperature at midpoint after 15 days falloff

Reference $\bar{w}$ at end of injection. at middepth (263°F) is .01712 58.41 lb/ft³

$\bar{w}$ after 8 days falloff (160°F) is .01639 61.01 lb/ft³

$\bar{w}$ after 15 days falloff (150°F) is .01634 61.20 lb/ft³

$$\Delta P_{wh} = \Delta \bar{w} \frac{700}{144} (psi)$$

Rates - El. Times		$\bar{w}$	$\Delta \bar{w}$	× 4.86 =
	Reference temp (263°F)	58.41		
3.82	temp (160°F)	61.01	2.6	12.64
2.45	temp (150°F)	61.20	2.79	13.56

Those corrected values do not provide any analytical advantage. The procedure could be refined beyond a simple mid point approach to correct for density changes. Perhaps the most significant conclusion to be drawn from it is that the recovery was less complete that the uncorrected data suggests. Initial shut in pressure was reached after about eight days of falloff.

Accepting early recovery data as most representative provides the following estimates of Transmissivity

S_{10} = 19 psi/log cycle. Q = 600 gpm. Nearly

Q/S_{10} = 31.58 gpm/psi/log cycle. Fluid temp 273°F

Fluid viscosity @ 0.2 centipoise Fluid density 57.93

$$kh = 5759 \frac{Q}{s_{10}} \mu = 5759 \times 31.58 \times 0.2 = \underline{36,374 \text{ md ft}}$$

$$T = \frac{kh}{1000} \times .3284 \frac{\delta}{\mu} = \frac{36,374}{1000} \times .3284 \times \frac{57.93}{.2} = \underline{3460 \text{ gpd/ft}}$$