GTL07352

CONTENTS

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1. OBJECTIVES

The objectives in testing included:

1. Assessment of Well RRGI-6 and receiving zone responses to injection.

2. Investigation of aquifer inhomogenities in the regions of Wells RRGE-2 and RRGI-6.

3. Investigation of potential mutual interferences within the Raft River KGRA aquifer system.

4. Prediction of behavior of Well RRGI-6 to extended periods of injection and to other temperature fluids.

2. SUMMARY STATEMENT

3. TEST ORGANIZATION

Geothermal fluid was withdrawn from RRGE-2 and injected into RRGI-6 for a period of 21 days in March-April, 1979. The test was organized to permit constant-rate, variable head conditions both for withdrawal and injection. The test rate was 37.8 lps. Testing initially commenced March 19, 1979, however, after approximately 11 hours had elapsed, equipment failure forced abandonment. After approximately 12 hours recovery, the test was re-commenced March 20th and continued until April 10, 1979. Following the 21 days of testing, recovery observations were recorded for a futher 21 day period. Figure 1 shows the location of wells and observation points.

At well RRGE-2 fluids were withdrawn by a vertical turbine pump with intake set at 802 ft. below ground level. Injection into well RRGI-6 was by means of 300 hp Johnson pump at ground level.

Drawdown was measured in well RRGE-2 by ~~means of~~ bubbler tube, exiting immediately above the pump impeller. Bubbler pressure was monitored through either a Heise gauge or digiquartz pressure transducer. Leaks in the bubbler tube introduced difficulties during testing.

Injection pressure at the RRGI-6 wellhead was monitored by digiquartz pressure transducers.

Flow rates at wells RRGE-2 and RRGI-6 were monitored on continuous strip chart recorders.

Fluid temperatures at the wellheads of RRGE-2 and RRGI-6 were monitored by Soltec strip chart recorders. A temperature profile was recorded in well RRGI-6 2 days after commencing the test and two additional profiles were obtained 10 and 20 days after ~~testing~~ injection ceased.

No bottom hole pressure instrumentation was available for the test.

Observations of head were recorded at wells RRGP-4, RRGE-3, MW1 & MW2 using digiquartz pressure transducers. Water levels were recorded at Monitor wells 3, 4, 5, 6 and 7 by Stevens Type F instruments.

4. TEST RESULTS

4.1 Test Rates, Duration and Interruptions

Well RRGE-2 was pumped at ~~600 gpm~~ 37.8 lps and well RRGI-6 was injected at ~~600 gpm.~~ 37.8 lps

The test was initially commenced on March 19, 1979. On March 20th after 665 elapsed minutes of pumping, mechanical failure caused the test to be aborted. The wells were permitted to recover for 610 minutes and the test re-commenced at 11:34 on March 20, 1979. The test continued for 21 days until April 10, 1980. One interruption occured for a period of 7 minutes on March 27th after approximately 10,000 elapsed minutes in the test. The interruption was caused by electrical overloading by lightning, after 14 elapsed minutes the pumping rates of 600 gpm were re-established at both wells.

4.2 RRGI-6 Response

Although the initial test attempt, March 19th was only 665 minutes in duration, the information has been included for comparative purposes in both buildup and falloff responses.

4.2 RRGI-6 RESPONSE

4.2.1 BUILDUP RESPONSE RRGI-6 (lower case)

The initial test attempt on March 13th included 680 minutes of buildup data and 610 minutes of recovery data. Pertinent information is summarized:

a. Initial Condition:

Warmup flow into the well at ~~100 gpm~~ 6.3 lps; initial wellhead temperature ~~200^{o}F~~ 93°C; initial wellhead pressure ~~48.6 psia~~ 335 Kpa.

b. Injection rate:

~~600 gpm~~ 37.8 lps stabilized rate after three minutes maintained for a duration of 680 minutes.

c. Maximum buildup:

~~202 psia~~ 1393 Kpa after 680 minutes.

d. Final wellhead temperature:

~~274^{o}F~~ 135°C maintained in quasi equilibrium for the final 300 minutes of buildup.

Buildup response and wellhead temperature are shown on the semilog plot in Figure ~~1~~ 2. It is evident in this figure that wellhead temperature did not stabilize until approximately 350 minutes had elapsed. Wellhead pressure reflects temperature-induced density changes during this initial period resulting in a non-linear shape for the early buildup curve. Late buildup data describes a straight line with slope of ~~17.2 psi/log cycle~~ 119 Kpa/log cycle.

Pertinent buildup data for the sustained 21 day test is summarized.

a. Initial conditions.

- Warmup flow of 100 gpm [6.3 lps] into the well uninterrupted for 30 minutes prior to startup.

- Initial wellhead temperature 220°F [104 °C].

- Wellhead pressure was declining prior to testing at a rate of 0.3 psi/minute [2 kpa/minute]. A value of 67.5 psia [465 Kpa] is accepted as initial wellhead pressure.

b. Injection rate:

The rate of 600 gpm [37.8 lps] stabilized after approximately three minutes and remained constant thereafter with the exception of one interruption after approximately 10,000 elapsed minutes. Pumping ceased for a period of seven minutes and a total of 14 elapsed minutes were required to re-established rate of 600 gpm [37.8 lps].

c. Maximum buildup:

226 psia [1558 Kpa] after 21 days.

d. Wellhead temperature:

After approximately 500 minutes, wellhead temperature reached quasi-equilibrium at approximately 274°F [135 °C]. During the remainder of the test, wellhead temperature apparently deviated within a range of 4°F (272-274°F).

2°C (133 - 135°C)

Buildup response and wellhead temperature are shown on the semilog plot in Figure 3. Several linear segments are evident in this figure. In the initial 70 minutes of injection, wellhead temperature increased by 10^{0}F [6°C] and the time-buildup curve is linear with a slope of 27 psi/log cycle [186 Kpa/log cycle]. The time required to displace one casing volume in RRGI-6 is approximately 20 minutes and it might be argued that the initial twenty minute period represents useful data because the original casing volume was in quasi-stable thermal equilibrium and the injection zones had been "pre-heated" during the initial aborted 11-hour test.

Between 70 and 200 elapsed minutes, both the pressure and temperature at wellhead increased rapidly in non-linear form. Temperature rose abruptly after 100 elapsed minutes, reflecting transmission time through the pipeline from RRGE-2 to RRGI-6. The greatest thermal change occurred between 100 and 200 elapsed minutes; during this period, wellhead pressure rose correlatively in response to the decreased density of the hotter borehole volume.

Between 200 and 1000 elapsed minutes, fluid temperature fluctuated by approximately 10^{0}F. [6°C] At extant densities, this order of fluctuation could result in a range of 5.8 psi [40 Kpa] at wellhead. For this reason, the apparent straight line segment between 200 and 1000 elapsed minutes is not considered to be representative for analysis.

Between 1,000 minutes and the terminating of test, fluid temperature was reasonably constant within the range 272 to 274^{0}F [133 to 135°C]. After 10,360 minutes, the test was interrupted, approximately 14 minutes elapsed before the injection rate of 600 gpm was re-established. Two linear segments are evident in the time-building curve during the late test period. A change in slope is recognized after approximately 8,000 minutes. This inflection point occurs only 2,000 minutes before the interruption in the test introducing some uncertainty as to whether the inflection represents hydrologic boundary influence or deviation in response to the interruption. The deviated data maintains a linear trend for the final 14 days of the test; in view of the length of this period versus the relatively short 14 minute interruption, it is considered more likely that the late deviated data represents hydrologic boundary influence rather than response to interruption.

4.2.2 RRGI-6 RESPONSE (SUSTAINED TEST) FALLOFF (lower case)

Wellhead pressure recovered to apparent initial shit-in pressure of approximately 68 psia after a recovery period of 5,000 minutes (3.5 days). This represents a ratio of elapsed times of 7.

The apparent wellhead pressure of 68 psia does not represent full recovery because the initial shut-in pressure was measuered with 100 pgm warm-up flow entering RRGI-6.

Falloff data plotted against ratio elapsed times is shown in Figure 4. It is evident in this figure that only 16 late fallof data approaches straight line configuration after a ratio of elapsed times of 100 (284 elapsed minutes of falloff).

Early falloff data is non-linear. This is interpreted as reflecting the effects of slowly decreasing temperature. As the fluid in the borehole slowly cools, it's density increases marginally tending to reduce pressure measured at the wellhead. Fluid in the reservoir will experience a reduction in temperature during falloff as a result of heat exchange between fluid and reservoir matrix at the lower velocities which prevail during falloff. The resulting marginally higher fluid viscosities and the resistance to flow will be reflected in higher wellhead pressure measureemnts and delayed recovery time.

From this reasoning it is interpreted that the early falloff data will be least influenced by either density of viscosity changes and may, therefore, be most representative of reservoir matrix characteristics underpseud0-stable conditions of density and viscosity. The falloff data shown in Figure 4 is for the above reasons analyzed as comprising three segments.

The initial segment between pump shut-off and ratio elapsed times of approsimately 1,000 (elapsed falloff time of 30 minutes) is accpeted as pseudo-stable fluid conditions. During this period wellhead temperature cooled by approximately 8°F (261-253°F). The wellhead temperature reduction toward ambient wellhead conditions will be much more rpaid than temperature changes in the borehole at the injection zones.

An intermediate segment is recognized between ratio elapsed times 1,000 and 100 (elapsed falloff time 30 minutes to 284 minutes). During this interval wellhead temperature cooled by approximately 53°F (253°-200°F). In this time interval both the density and viscosity of the fluid are changing significantly but the changes cannot be satisfactorily indentified without bottom hole pressure and temperature information. This segment of the fall data is considered not analyzable.

Late falloff data after ratio elapsed times of 100 (elapsed falloff time of 284 minutes) describes a reasonable straight line in Figure 4 with markedly increased slope. During this period of time (approximately 3 days) wellhead temperature cooled by approximately 100°F (200°-100°F). The residual buildip remaining at the beginning of this segment was approximately 40 psia. Increasing density in the borehole fluid is probably a significant influence on wellhead pressure during this segment of the falloff data rendering it difficult to analyze.

4.3 RRGE-2 RESPONSE

4.3.1 The initial attempt to test on March 19 provided 646 minutes of drawdown data and 460 minutes of recovery data. Pertinent data is summarized:

Initial Conditions:

Well RRGE-2 was free-flowing artesian at 100 gom for 7 hours prior to testing to provide preheating. Under these conditions initial wellhead pressure was 450 psia (bibbles pressure).

Maximum Drawdown:

Bubbles pressure reduced to 257 psia after 646 minutes pumping representing 193 psia drawdown.

Temperature Fluctuation:

Before testing, wellhead temperature was 272°F, it rose to 283°F at the end of the test attempt.

Time-drawdown data for the initial attempt is summarized on the semilog plot in Figure 5. Wellhead temperature before testing was 272°F; it reached quasi-stability at 282-283°F after approximately 100 elapsed minutes. The early data up to 100 minutes on Figure 5 is probably influenced by unstable temperature. Drawdown data between 100 and 646 minutes describes a straight line and appears to represent useful data for analysis.

Measurement difficulties with both temperature and pressure instrumentation introduce questionable reliability to drawdown data in RRGE-2 during the sustained 21 day test. Wellhead temperature records on the Soltec strip chart are eratic for the first three days of the test; during the remainder of the test, wellhead temperatures appeared to stablize at 282°F. Bubbles pressures measured by automated digiquartz records become erratic and unreliable after approximately 1,800 minutes. Manually recorded Heise guage bubbles pressures are less erratic during late drawdown but are less accurate. The erratic late drawdown pressures probably result from inadequate nitrogen purging or leakage in the bublerline.

Time-drawdown behavior is shown measured by automated digiquartz ~~in~~ and ~~Figure 6 and~~ by Heise guage in Figure 7. The marked inflection and change of slope occuring after 300 elapsed minutes is attributed to stablized temperature in the borehole, the data between 300 and 1,800 minutes describes a straight line and appears to represent useful data. Heise guage preesures in late drawdown (figure 7) provide a similar slope-rate-of-drawdown although displaced in absolute pressures.

4.3.2 RRGE-2 RECOVERY RESPONSE

Recovery measurements following the initial test attempt on March 19th are shown plotted against tario-of-elapsed times in Figure 8. Inadequate nitrogen purging of the bubbles line renders early recovery data unreliable. Late recovery data provides a relatively straight line segment, however, wellhead temperature cooled by 12^{0}F during this period and the wellhead pressures are probably influenced by density changes in the borehole.

Measured bubbles recovery versus ratio elapsed times for the sustained test are shown in Figure 9. Fluids reached surface after 15 minutes (ratio elapsed times 2000). This segment of the data is non-linear and Figure 9, it may be influenced by frequency of nitrogen purging of the bubbles line and vapor compressibility in the wellhead occurring when the venting ports were shut in. This segment of data is not considered reliable for analysis. The data segment between ratio elapsed times 2000 and 50 (initial 10 elapsed hours of recovery) describes a relatively straight line on Figure 9. During this period wellhead temperatur cooled from 282^{0}F to approximately 200^{0}F. The measured wellhead pressure during this period can be expected to be influenced by changing density in the wellbore. The interval of the borehole open to significiant temperature variation during early recovery is that portion deviated during pumping or a depth of approximately 400 feet, below this depth the fluid column is presume to be in the relatively stable temperature equilibrium at approximately 282^{0}F.

The relatively short (440') column of fluid anticipated to undergo greatest temperature change in the initial 10 hours of recovery will introduce relatively small density-induced pressure correction. The order of correction is approximately 2 to 2.5 psia. The recovery data between ratio elapsed times 2000 and 50 usy, therefore, be representative for analysis.

Late recovery data, after ratio elapsed times 50, provides non-linear plot on Figure 0. Significant time has elapsed after pumping stopped in this segment of the data and wellhead prssure may be influenced by temperature-induced density changes throughout the entire borehole. These influences cannot be satisfactorily corrected without accurate downhole temperature information. For this reason, the very late recovery data is not representative for analysis.

4.4 OBSERVATION WELL RESPONSES

4.4.1 RRGI-7 RESPONSE

RRGI-7 exhibited anomalous behavior during and following the test period, evidently in response to injection to RRGI-6. During the initial week of the test, wellhead pressure at RRGI-7 oscillated by approximately ~~0.1 psi~~ in response to unidentified external influences. During the final two weeks of the test, wellhead pressure at RRGI-7 increased steadily, reaching a buildup of 1.68 psi at the end of the injection period. Wellhead pressure continued to build for 12 hours after injection ceased at RRGI-6, reaching a maximum buildup of ~~1.77 psi~~. The well did not recover satisfactorily following the test; a residual buildup of ~~1.0 psi~~ remained. Wellhead pressures, measured for a further two-week period oscillated by approximately ~~0.15 psi~~, again evidently in response to unidentified external influences.

The residual unrecovered buildup cannot be attributed to barometric influences, possible explanations include as yet unidentified external loading or severely delayed recovery from low permeability ~~repairs~~ or aquifer deformation.

Uncorrected time-buildup data is shown on Figure 10. The Theis, non-leaky, non-equilibrium curve-fitting method is applied because the assumption is not satisfied, precluding application of the modified Jacob method.

Late uncorrected buildup data provides a reasonable fit with the Theis non-leaky curve. Standard analysis by this method provides values of ~~7088 gpd/ft~~ for transmissivity and .0082 for storage coefficient. ~~These values indicate an interference buildup of 20 psi (46.2 ft) in RRGI-7 after five years injection to RRGI-6 of 600 gpm.~~

4.4.2 RRGP-4 RESPONSE

Two weeks prior to testing RRGP-4 remained stable at 139 psia. In the week immediately before testing, March 12-18th, wellhead pressure apparently fluctuated in a range from 134 to 149 psia. The pre-test wellhead behavior is shown in Figure 11. No explanation for the erratic wellhead pressure is available. For one hour before testing, shut-in wellhead pressure was stable at 148 psia.

During the initial eleven-hour attempt to test, RRGP-4 wellhead pressure declined by approximately 0.5 psi. It continued to decline during the 12-hour recovery period following this and during the sustained 21 day test reaching a maximum drawdown of 9.3 psia two days after pumping stopped. Wellhead pressure did not recover during the twenty day period after pumping stopped.

The lack of recovery raises some doubt as to whether the observed drawdown is in fact related to pumping-injection or to some unidentified influence. Uncorrected observed drawdown data has been analyzed by Theis non-leaky curve-fitting technique in Figure 12. Best-fit curve-matching assuming non-leaky conditions suggests the influence of a limiting boundary in the RRGP-4 response, effective after approximately four days pumping. The apparent bounday results in a doubling of the rate-fo-drawdown.

4.4.3 RRGE-3 Response

In the week prior to testing, wellhead pressure in RRGE-3 was increasing at an average ratio of 0.07 psia/day as shown in figure 13.

During the inital eleven hour test attempt, wellheard pressure declined by approximately 3 psia and continued to decline during both the twelve hour recovery period following this and during the sustained 21 day test reaching a maximum drawdown of 13.2 psia. Wellhead pressure at RRGE-3 recovered by only 1.3 psia during the twenty day period following pumping-injection.

Uncorrected time-drawdown data is shown in figure 14. This non-equilibrium curve-watching technique has been applied to this data as the most appropriate method of analysis. The response suggests multiple boundary influences.

4.4.4 MONITOR WELL RESPONSES (lower case)

Responses related to the injection at RRGI-6 are evident in monitor wells 4, 5, 6 and 7. Two types of response are identified: positive and negative water level changes. Prior to testing, monitor well water levels were rising at an average rate of 0.01 m/day in a defined trend. Monitor well 4 deviated positively from this trend by approximately 1.22 m. as shown in figure 15. Monitor wells 5, 6 and 7 deviated negatively from the pre-testing trend by approximately 0.15 m. or less as shown in figure 16. The amplitude of negative deviation in monitor wells 5, 6 and 7 reflects the degree of barometric efficiency of these wells, suggesting that the response is probably due to elastic deformation of aquifer matrix by dilation. Monitor wells 5, 6 and 7 recovered following injection.

The positive change in water level in Monitor well 4 indicates that more direct hydraulic communication exists between this well and RRGI-6. Monitor well 4 showed a delayed recovery following injection; the ~~degree~~ completeness of recovery cannot be satisfactorily assessed because irrigation withdrawals from the shallow ground water aquifers commenced about this time significantly influencing monitor well water levels.

5. Discussion of Test Results

5.1 Summarized Hydraulic Properties

Table 1 summarizes values for S_{10}, Q/S_{10} and apparent kh for Well RRGI-6. Late buildup data in the initial test attempt and intermediate-time buildup data in the sustained test provide the most reliable Q/S_{10} ratios to calculate apparent kh values. The average of these two is 0.34 lps/kPa/cycle representing a kh of 40,266 md-ft.

Late buildup data from the sustained test, interpreted to reflect a recharge influence, provides Q/S_{10} ratio of 0.46 lps/kPa/cycle or kh of 54,710 md-ft.

Table 2 summarizes S_{10}, Q/S_{10} and apparent kh values for Well RRGE-2. Late drawdown data in both the initial attempt and the sustained test show reasonable agreement in Q/S_{10} ratios, averaging 0.09 lps/kPa/cycle representing an apparent kh of 11,518 md-ft.

Table 3 summarizes transmissivity and storage coefficients calculated from apparent pressure responses at RRGE-3, RRGP-4 and RRGI-7. The values obtained for RRGI-7 are probably representative. Values obtained from RRGE-3 and RRGP-4 are probably not representative of aquifer properties, they reflect anisotropic behavior.

5.2 Analytical and Predictive Methods used:

In Wells RRGE-2 and RRGI-6 it has not been possiblt to calculate storage coefficient values. For this reason and because fluid characteristics influence apparent transmissivity values, predictions using standard Theis techniques are not practical.

Extrapolation of slope-rate-of-drawdown is the most reliable means of predicting drawdown in RRGE-2 at the 37.8 lps rate tested.

Prediction of drawdown and buildup at rates and fluid temperatures other than these tested is much less reliable. The ratio Q/S_{10} has been accepted, as a parameter of comparison of well performance at Raft River. It has been shown (Allman, 1979) that the ratio Q/S_{10} varies with Q and therefore, violates a primary assumption of the Theis solution. For this reason the Theis solution may not represent an accurate simulation of reservoir behavior, however, it is the most reasonable means available for predicting behavior.

The method used to predict at rates and temperature other than those tested is to initially calculate representative kh values (apparent permeability-thickness products) at the temperature (and viscosity) known during testing. The following relationship is used: (Allman et al, 1979)

$$kh = \frac{5759Qy}{S_{10}}$$

where: kh is in md-ft
Q/S_{10} is in gpm/psi/cycle
y is in centipoises

The apparent permeability-thickness product obtained is a sufficiently reasonable indication of the intrinsic transmissivity of the reservoir to use for predictive estimates.

Slope rates-of-drawdown (S_{10}) are calculated at the desired, cooler temperatures (higher viscosities) which are anticipated during operational injection to RRGI-6 and used to extrapolate long term buildup. This may be inaccurate if, as Mangold et al (1979) suggest, the characteristics of the in situ fluid govern behavior during late buildup time, however, the planned injection fluid temperatures are cooler than in situ fluids and the resulting buildup estimates will be conservative.

Early buildup behavior is significantly influenced by density changes in the borehole fluid column and inefficiencies of the flow at the well bore face.

The influence of cooler fluid density in the wellbore on wellhead pressure can be approximated by: $P_{tsc} = 6.895\ (P_{tsw} - (\gamma_c - \gamma_w)\frac{D}{144})$ kPa

where: P_{tsc} = wellhead pressure, cool water
P_{tsw} = wellhead pressure, warm water
γ_c = specific gravity, cool water
γ_w = specific gravity, warm water
D = depth to injection zone

The influence of restriction to flow at the wellbore face is more difficult to estimate. An approximation of this "skin" factor is derived from observed behavior during the present test and the following relationship: (Earlougher, 1977)

$$\Delta p_s = \frac{141.2qBu}{kh} \; s \text{ (psi)}$$

where: Δp_s = the pressure change dur to skin effect
q = the flow in ST B/D
B = the formation volume facts for water RB/STB
u = the viscosity in centiposites
kh = the permeability thickness product in md-ft
s = the "skin factor"

The information from the present test provides a value for the skin factor, s=3.42, this is used to derive initial pressure increases for other rates and temperatures.

The predictive equation to describe total buildup pressure is:

$$P_{tsc} + \Delta ps + S_{10} \log t.$$

5.3 Predicted Well Behavior

At a producing rate of 37.8 lps, the bubbler pressuer in Well RRGE-2 would be reduced to 240 kPa after five years sustained pumping. This assumes no further hydrologic boundaries will be encountered, no interference influences from other pumping/injection centers and relatively constant fluid temperature of approximately 140°C. With the present pump setting of 245 m; 37.8 lps represents the approximate maximum rate that the well can be pumped safely.

It is interpreted from the response of RRGI-6 to the present 21 day sustained test that a hydrologic boundary was intersected after appxoximately one week of injection. The boundary has an apparent recharge incluence and has the effect of increasing apparent injectability. The time of appearance of the recharge boundary effect coincides with the time at which Monitor well 4 responded with elevated water level and Monitor wells 5, 6 and 7 displayed probable elastic deformation. For these reasons it is suspected that sustained injection to RRGI-6 will result in leakage to the shallow aquifer system.

The interpreted recharge event occured when wellhead pressure at RRGI-6 reached approximately 1520 kPa. If this event represents escape to the shallow aquifer system, as interpreted, a wellhead pressure of about 1520 kPa may represent a limiting criterion to injectability in RRGI-6. This wellhead pressure wouldtheoretically be exceeded in one day's injection at 37.8 lps if the injection fluid were 65^{O}C.

By permitting leakage to the overlying shallow aquifers to occur, the injectability to RRGI-6 is significantly inproved. Under these circumstances, predicted wellhead pressure in RRGI-6 at selected times is summarized in Table 4 and presented graphically in figure 17. The predictions assume 65^{O}C fluid, no further hydrologic boundaries and no interference.

CALCULATIONS RRGI-6 INJECTION

1. ASSUMPTIONS

		μ	γ	B
T injection is	280°F	.19	57.93	1.06
T injection is	150°F	.427	61.13	1.02
T in situ is	220°F	.264	59.63	1.045
D (depth) is	2300 feet			

Q is 600 gpm, 800 gpm, 1000 gpm.
(20,571 STB/D) (27,428 STB/D) (34,286 STB/D)

Kh is 40,000 md ft.

2. $P_{tsc} = P_{tsw} - (61.13 - 59.63)\frac{2300}{144}$ psi

$P_{tsc} = 35 - 1.5 \times \frac{2300}{144}$ (24) psi = 11 psi. for 150°F water

$P_{tsc} = 35 - (57.93 - 59.63)\frac{2300}{144}$ psi

$= 35 + \left(1.7 \times \frac{2300}{144}\right)$ psi

27.

$P_{tsc} = 35 + 27 = 62$ psi for 280°F water.

3. $\Delta p_s = 141.2\, q \frac{B\mu}{kh} \times 3.42$

REFINE THESE

$\Delta p_{s_{600h}} = \frac{141.2 \times 20,571 \times 1.06 \times .19}{40,000} \times 3.42 = 50.02$ psi

$\Delta p_{s_{600c}} = \frac{141.2 \times 20,571 \times 1.02 \times .427}{40,000} \times 3.42 = 108.16$ psi

$\Delta p_{s_{800c}} = \frac{141.2 \times 27,428 \times 1.02 \times .427}{40,000} \times 3.42 = 144.22$ psi

$\Delta p_{s_{1000}} = \frac{141.2 \times 34,286 \times 1.02 \times .427}{40,000} \times 3.42 = 180.28$ psi

131.8

CALCULATIONS RRGI-6 INJECTION

4. $S_{10} = \dfrac{5759\ Q\mu}{kh}$

$S_{10_{600h}} = \dfrac{5759 \times 600 \times .19}{40,266} = 16.3$ psi/cycle.

$S_{10_{600c}} = \dfrac{5759 \times 600 \times .427}{40,266} = 36.64$ psi/cycle.

$S_{10_{800c}} = \dfrac{5759 \times 800 \times .427}{40,266} = 48.86$ psi/cycle

$S_{10_{1000c}} = \dfrac{5759 \times 1000 \times .427}{40,266} = 61.07$ psi/cycle. (45)

INJECTION RATE (gpm)	TEMPERATURE (°F)	EQUATION FOR PRESSURE.
600	280	62 + 50 + 16.3 log t.
600	150	11 + 108 + 36.64 log t
800	150	11 + 144 + 48.86 log t.
1000	150	11 + 180 + 61.07 log t.

INJECTION RATE (gpm)	TEMPERATURE (°F)	ℓ(3.16) 1 DAY (1440 min)	ℓ(5.72) 1 YEAR (5.26×10^5)	6.2 3 YEAR (1.58×10^6)	6.42 5 YEAR (2.63×10^6)
600	280	163.5	205.24	213.06	216.65
600	150	234.72	328.6	346.17	354.23
800	150	309.4	434.48	457.93	468.68
1000	150	383.98	540.32	569.63	583.07

CALCULATIONS RRGI-6 INJECTION

Assume kh of the recharge boundary = 54,710 md ft.

INJECTION RATE (gpm)	TEMPERATURE (°F)	EQUATION FOR PRESSURE
600	280	62 + 36.57 + 12 log t.
600	150	11 + 79.08 + 26.97 log t
800	150	11 + 105.44 + 35.96 log t.
1000	150	11 + 131.81 + 44.95 log t.

INJECTION RATE (gpm)	TEMPERATURE (°F)	l 3.16 1 DAY	l 5.72 1 YR	l 6.2 3 YR	l 6.42 5 YR
600	280	136.49	167.21	172.97	175.61
600	150	175.31	244.35	257.29	263.23
800	150	230.07	322.13	339.39	347.3
1000	150	284.85	399.92	421.5	431.39

TABLE 1

SUMMARY OF HYDRAULIC PROPERTIES - WELL RRGI-6

S_{10} (kPa/cycle)	Q/S_{10} (lps/kPa/cycle)	Apparent kh (md-m)	Source
119	0.32	11.637	Late buildup data, initial attempt
148	0.26	9,303	Falloff data, initial attempt
107	0.35	12,904	Buildup data, imtermediate time, Sustained test
83	0.46	16,673	Buildup data, late time, Sustained test
131	0.29	10.537	Falloff data, early time, Sustained test
269	0.14	5.135	Falloff data, late time, Sustained test

TABLE 2

SUMMARY OF HYDRAULIC PROPERTIES - WELL RRGE-2

S_{10} (kPa/cycle)	Q/S_{10} (lps/kPa/cycle)	kh (md-m)	Source
407	0.09	3,391	Drawdown, initial attempt
441	0.09	3,128	Recovery data, initial attempt
290	0.13	4,765	Early drawdown, sustained test
421	0.09	3,281	Late drawdown, sustained test
331	0.11	4,168	Recovery data, sustained test

TABLE 3

SUMMARY OF HYDRAULIC PROPERTIES - OBSERVATION POINTS

WELL	APPARENT TRANSMISSIVITY m^2/day	STORATIVITY	SOURCE
RRGI-7	87.6	.0082	Rate buildup, non-leaky curve match
RRGE-3	131.3	.00001	Late drawdown, non-leaky curve match, hydrologic boundaries evident.
RRGP-4	160	.0012	Early drawdown, non-leaky curve match before interpreted hydrologic boundary
RRGP-4	83.6	.0002	Late drawdown, non-leaky curve match after interpreted hydrologic boundary