# RRGE-3 WELL PERFORMANCE DURING TESTS BEGINNING OCTOBER 31, 1981

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# RRGE-3 WELL PERFORMANCE DURING TESTS BEGINNING 10/31/81

## PURPOSE

The purpose of this very brief report is to provide Raft River operations with equations that can be used to predict the drawdown in RRGE-3 during power plant operations. This evaluation is not intended to define hydraulic reservoir parameters.

## PREVIOUS TEST DATA

Numerous previous tests have been conducted at discharge rates ranging from ~135 to 788 gpm. Since the primary intention of this report is to predict drawdown under pumping conditions, data collected for well discharge rates less than 350 gpm have not been included. No particularly obvious abnormal data trends were noted for pump test data within a 550 to 788 gpm discharge range.

Previous test reports have been included in the Raft River Resource Data Book, Volume 2, Section III. A previous (perhaps it was issued, reference unknown at present) report by the author included data up to 1/31/78. This report data will be used to define well drawdown. A brief review of the data included in the latter report will be included. Figure 1 is a semilogarithmic plot of bubbler pressure versus time for a 788 gpm test of 1440 min. duration beginning 6/29/77. Pertinent test data are listed in Tables 1 and 2. For the data in Tables 1 and 2, a shut-in bubbler pressure of 420 psig and a shut-in wellhead pressure of 126 psig were assumed. The data in Figure 1 plot as a linear trend having a $Q/\Delta s_1$ of 4.237 gpm/psi/log cycle after pumping approximately 400 min. The Q is the discharge rate in gpm and the $\Delta s_1$ is the slope of the data in psi/log cycle. Figure 2 is a semilogarithmic graph of bubbler pressure versus time for a 592 gpm test beginning 7/6/77. An apparent recharge boundary affects the data after 3325 min. of pumping. The ratio of $\Delta s_2$ of the second linear segment to $\Delta s_1$ of the first linear segment is 0.714 (Table 1). Figure 3 depicts the bubbler pressure for a one day test at a rate of 603 gpm. Figure 4 depicts the bubbler pressure for a 603 gpm test beginning 11/28/77. An apparent boundary affects the data after 3899 min. of pumping. Figure 5 is a semilogarithmic graph of bubbler pressure

versus time for a 650 gpm test beginning 1/31/78. An apparent recharge boundary affects the data after 3375 min. of pumping.

Based on the preceeding pump test data, three equations can be used to predict well drawdown. The drawdown after 3533 min. of pumping is defined by the following equation:

$$s_{t = 3533} = Q/2.420 \qquad (1)$$

where $s_{t = 3533}$ = drawdown after 3533 min. of constant rate pumping in psi

$Q$ = constant pumping rate in gpm

The drawdown from approximately 500 min. to 3533 min. of pumping is defined by the following equation:

$$s_{500 < t < 3533} = Q/2.420 - (Q/4.119)\ (\log 3533 - \log t) \qquad (2)$$

where $s_{500 < t < 3533}$ = drawdown between 500 and 3533 min. after constant rate pumping began in psi

$Q$ = constant pumping rate in gpm

$t$ = time since pumping began in minutes

The drawdown between 3533 and approximately 40,000 min. ($\sim$28 days) after pumping begins can be estimated by the folliwng equation:

$$s_{3533 < t < 40{,}000} = Q/2.420 + (Q/5.485)\ (\log t - \log 3533) \qquad (3)$$

$s_{3533 < t < 40{,}000}$ = drawndown between 3533 and 40,000 min. after constant rate pumping began in psi

$Q$ = constant pumping rate in gpm

$t$ = time since pumping began in minutes

Equation 3 can be used to estimate drawdown after 40,000 min. of pumping. However, additional boundary effects could cause significant deviation from the estimated drawdowns.

Two additional pump tests were conducted prior to 10/28/81 but after 1/31/78. The data for the May 14, 1980 test is not available at present.

A 700 gpm 15,000 min. pump test began on 3/19/81. Figure 6 is a semilogarithmic graph of bubbler pressure versus time (Raft River Geoscience Case Study, M. R. Dolenc et al, Figure 49, p 70). Numerous pump outages and a discharge rate charge at t = 13,000 min. obscure apparent boundary effects and result in data of little value in defining well drawdown responses.

10/28/81 TEST

The pump at RRGE-3 was used to supply water to the power plant beginning 10/28/81. The primary purpose of the test was to produce power and not to conduct a reservoir test. It was necessary to vary the discharge rate to suit plant requirements. Figure 7 is a semilogarithmic graph of bubbler pressure, wellhead temperature and discharge rate versus time. The well discharge rate as measured at the wellhead with an orifice plate was 510 gpm between 10 to 15 min. and then increased to approximately 565 gpm between 16 to 65 min. The discharge rate then gradually decreased to approximately 500 gpm at 120 min. The rate remained at approximately 500 gpm until 290 min. when the rate was increased to approximately 550 gpm and was then held constant until 1250 min. The rate then increased to 610 gpm and remained approximately constant until 1550 min. The rate then increased to 655 gpm and gradually decreased to 645 gpm at well shut-in after 3367 min. of pumping.

The wellhead temperature was measured using a continuous recording platinum resistance thermometer device (RTD) and a mercury thermometer. The wellhead temperature was approximately 280$^{o}$F at well start-up. The temperature gradually increased until it reached 291$^{o}$F at t = 115 min. The temperature remained at approximately 291$^{o}$F until t = 1135 min. The temperature gradually declined to 290.7$^{o}$F at approximately t = 1300 min. The temperature began to increase from $\sim$290.7$^{o}$F at t = 1323 min. and then increased to $\sim$291.2$^{o}$F at t = 1600 min. The temperature gradually decreased to 291$^{o}$F at t =3300 min. The significance of the small temperature fluctuations is not known. The examination of additional data may permit a meaningful interpretation of the temperature fluctuations. However, based on these data, the wellhead temperature during production can be expected to be approximately 291$^{o}$F.

The bubbler pressures are a dampened response to well discharge and to wellbore temperature and thus, wellbore fluid density. Significant short-term fluctuations occurred in well discharge up to t = 290 min. with wellhead temperature essentially stabilizing after t = 115 min. Thus, bubbler pressure data collected prior to t =290 min. cannot be expected to plot as linear segments on a semilogarithmic graph as in Figure 7. The bubbler pressure data appear to form a straight line segment having a $\Delta s_1$ value of 105 psi/log cycle that extends from t = 300 min. to t = 1100 min. The $Q/\Delta s_1$ value is 5.24 gpm/psi/log cycle for this segment. This value appears to be somewhat high compared to the values in Table 1. Figure 8 is a graph of Q versus $Q/\Delta s_1$. It appears that there is a possibility that the values for $Q/\Delta s_1$ may increase with decreasing discharge rates as is the case for RRGE-2 and RRGE-1.

Following the increase in discharge rate to 655 gpm at t = 1588 min., the bubbler pressure data in Figure 7 plot as a linear trend until well shut-in. However, the discharge rate was gradually decreasing during this period. Figure 9 is a graph of bubbler pressure divided by discharge rate versus time. From this graph $\Delta s_1$ = 144.4 psi/log cycle and $Q/\Delta s_1$ = 4.47 gpm/psi/log cycle. This $Q/\Delta s_1$ value is somewhat above the log mean of 4.12 gpm/psi/log cycle (Figure 8, Table 1). The value for $Q/\Delta s_1$ for the second linear segment (Figure 7) is only 0.85 as large as that for the first linear segment. This suggests that $Q/\Delta s_1$ is dependent on the pumping rate.

Drawdown values have been calculated using Equation 2. To convert drawdown to bubbler pressure, it is necessary to know the bubbler pressure with the well heated to equilibrium temperature with no previous well discharge. This condition cannot be attained in the field since the well must be flowed to heat the wellbore fluid. The highest bubbler pressure attained prior to this test was 526 psig with a corresponding annulus pressure of 133.1 psig. The previous discharge history prior to this pressure measurement is not known. For convenience,

a hot wellhead shut-in pressure of 530 psig will be assumed until additional data can be collected and past records scrutinized. The calculated bubbler pressures are plotted in Figure 7. Calculated values for $200 \leq t \leq 1200$ min. assumed that the well was continually producing at 550 gpm from t=0 min. Calculated values for $2000 \leq t \leq 3363$ assumed that the well continually discharged at 646 gpm from t=0 min. The observed and calculated bubbler pressures are surprisingly similar with a maximum error of 9 psi for t>500 min. Since the well discharge was generally increasing during the test, calculated bubbler pressures should be greater than those observed. This was not the case for t<900 min. Equation 2 probably slightly underestimates the drawdown. No recovery data were collected.

## CONCLUSIONS

1. Equations have been defined using pump test data collected prior to 10/28/81 that can be used to calculate the drawdown and bubbler pressures for constant discharge tests for $500<t<40{,}000$ min.

2. The calculated bubbler pressures for the 10/28/81 test are within 9 psi of the observed values for $500<t<3363$ min.

3. There is a tendency for the $Q/\Delta s_1$ values to be dependent on Q. This implies that a unique value cannot be used to define the apparent intrinsic transmissivity, and permeability.

4. The wellhead discharge temperature for RRGE-3 is approximately 291$^{o}$F.

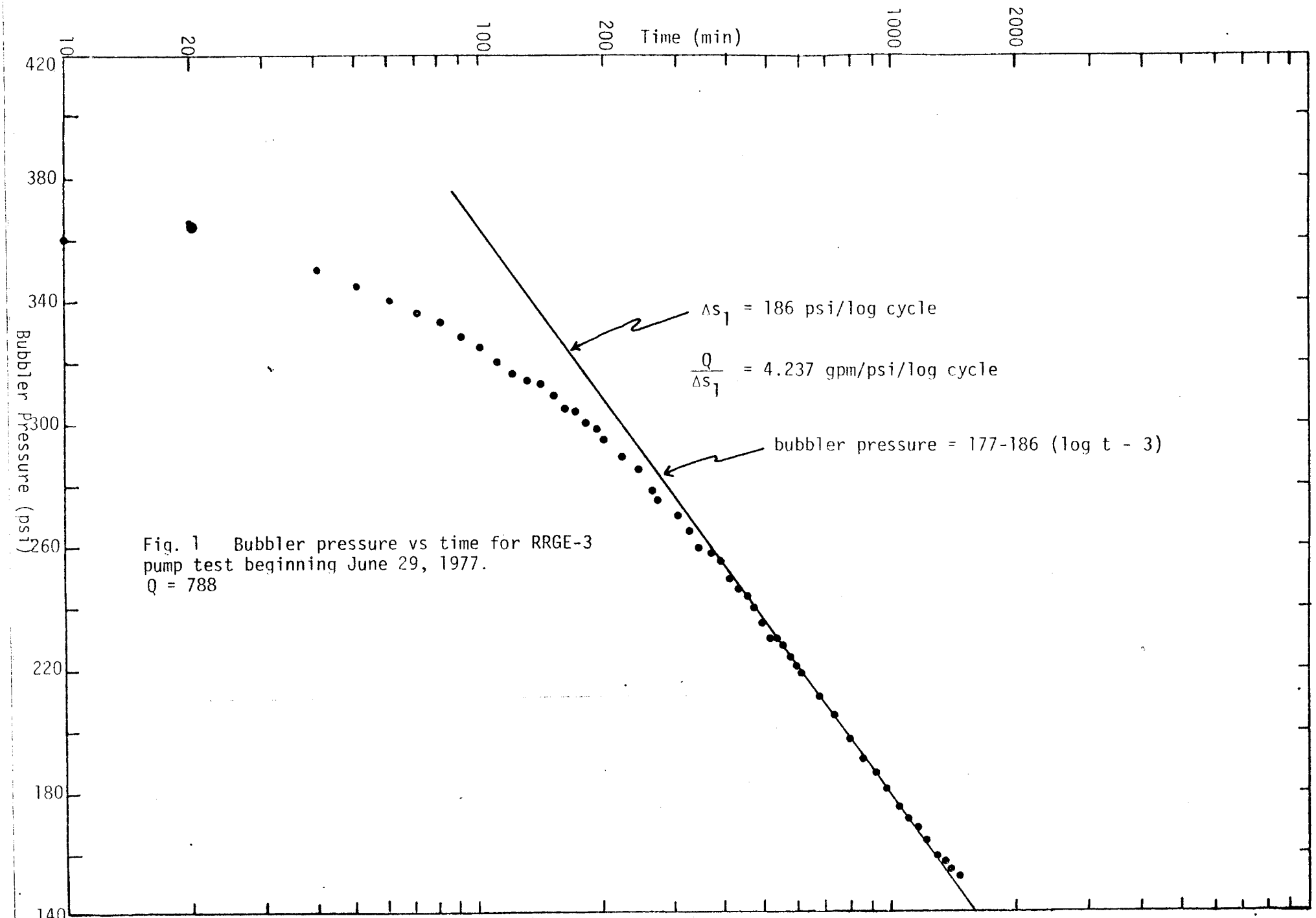



Fig. 1 Bubbler pressure vs time for RRGE-3 pump test beginning June 29, 1977.
Q = 788

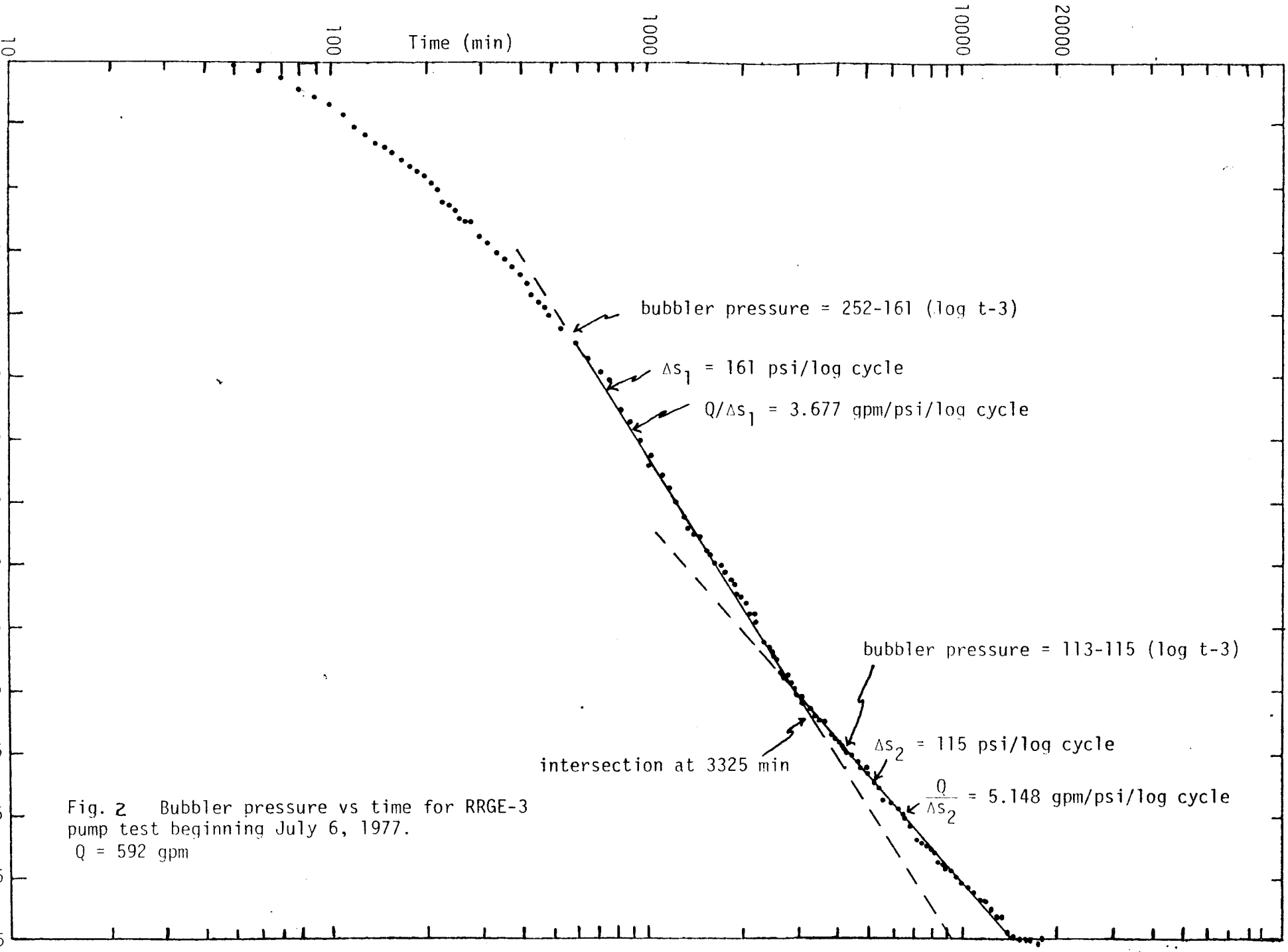



Fig. 2 Bubbler pressure vs time for RRGE-3 pump test beginning July 6, 1977.
Q = 592 gpm

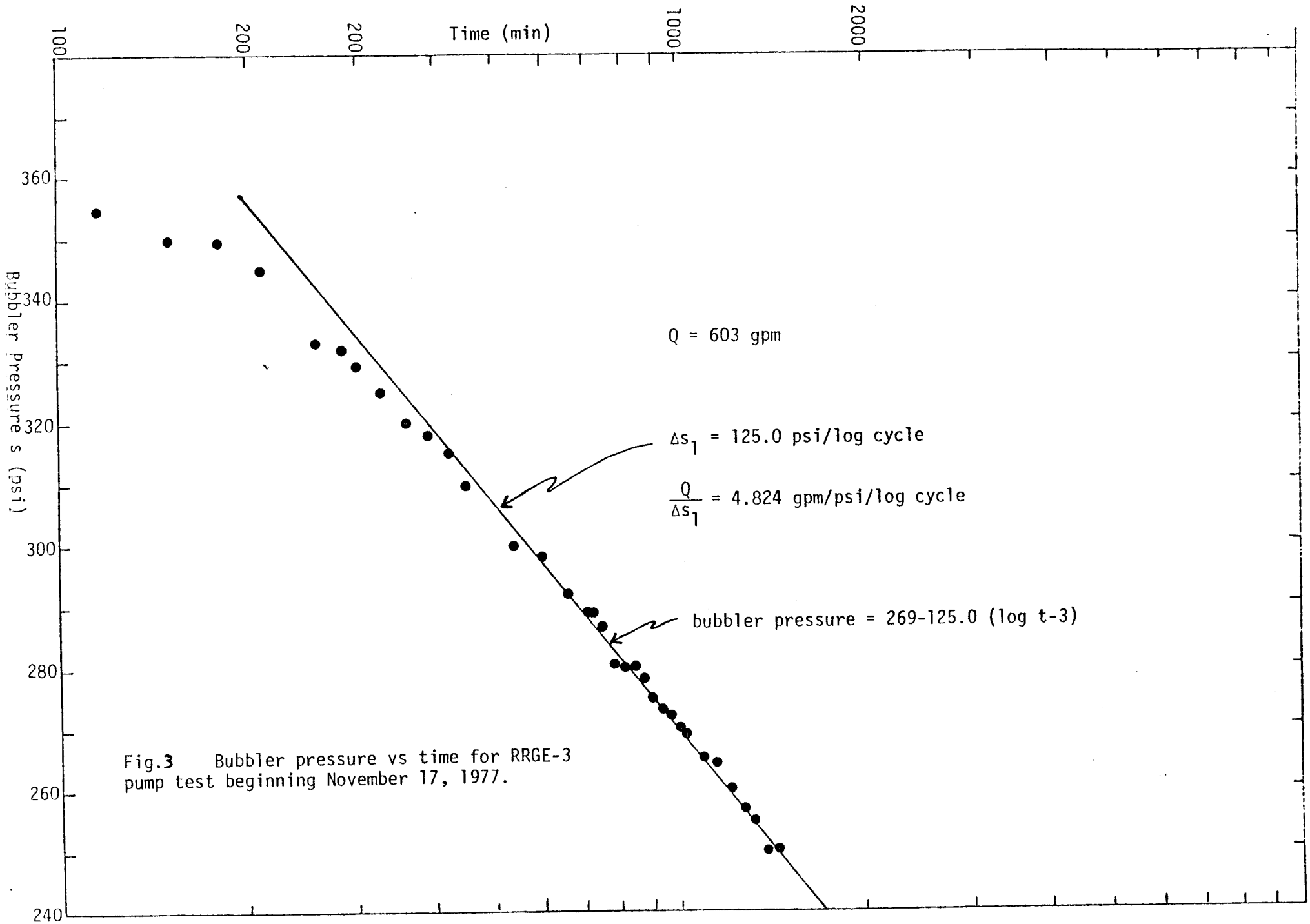



Fig.3 Bubbler pressure vs time for RRGE-3 pump test beginning November 17, 1977.

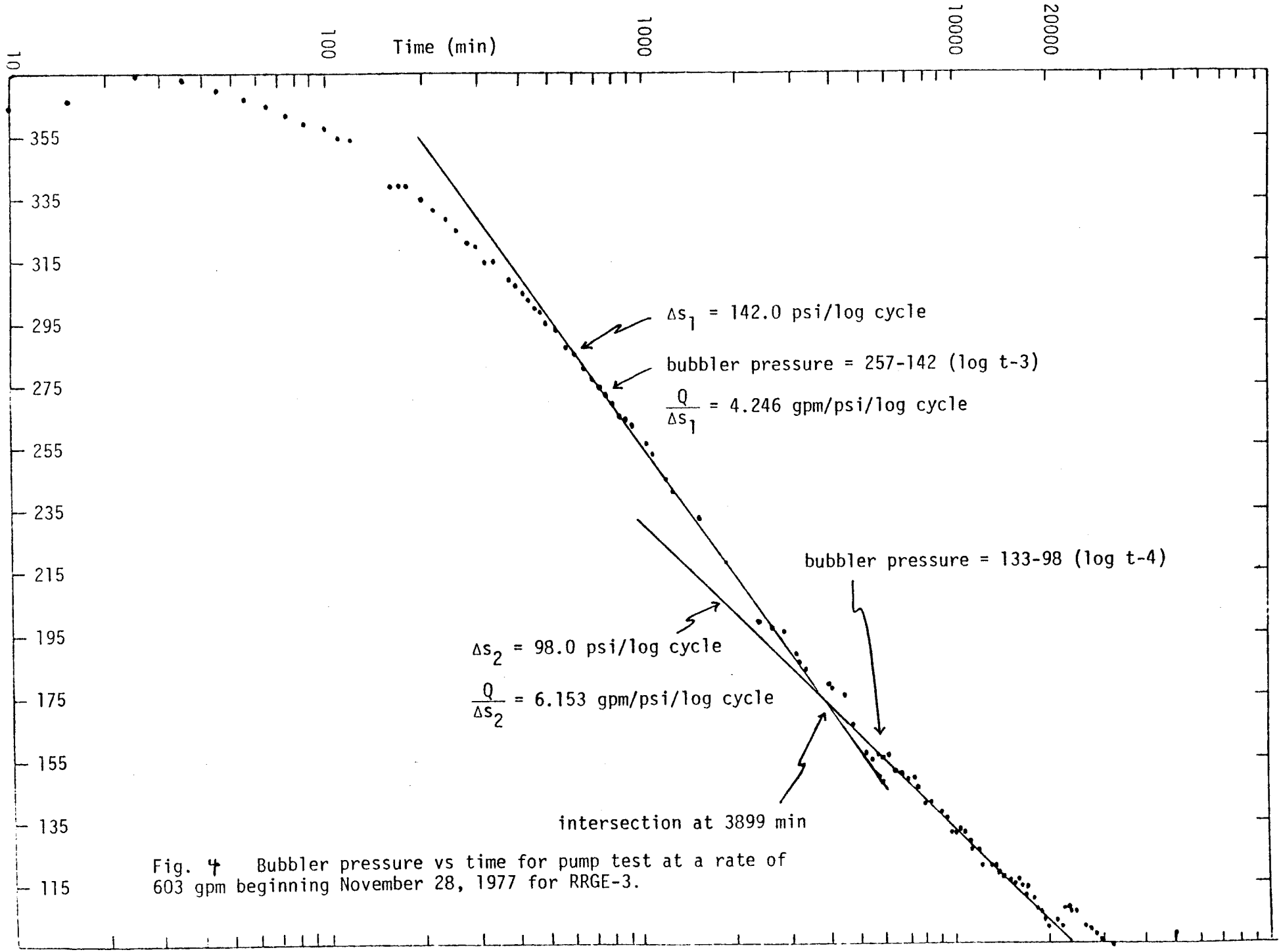



Fig. 4 Bubbler pressure vs time for pump test at a rate of 603 gpm beginning November 28, 1977 for RRGE-3.

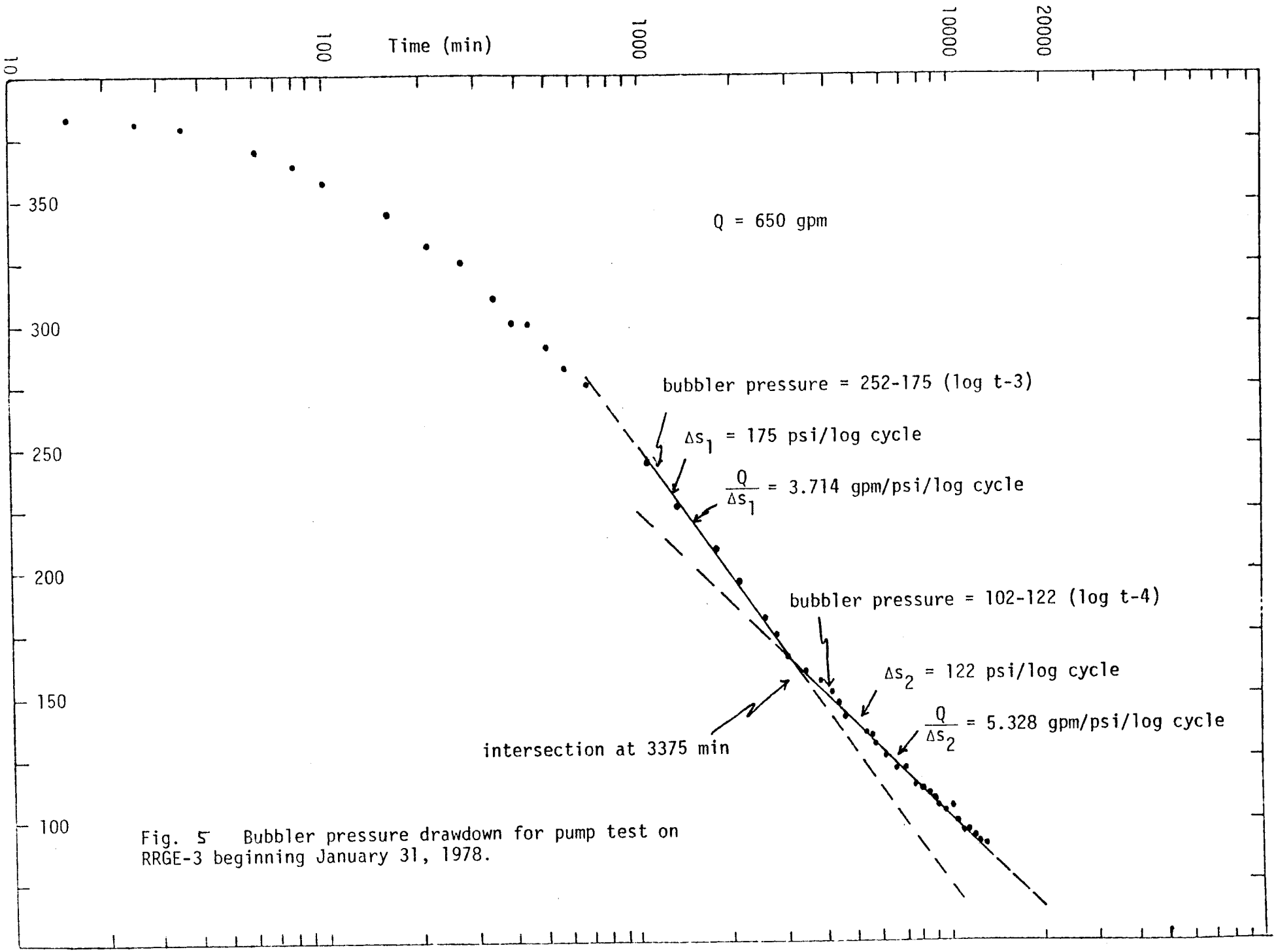



Fig. 5 Bubbler pressure drawdown for pump test on RRGE-3 beginning January 31, 1978.

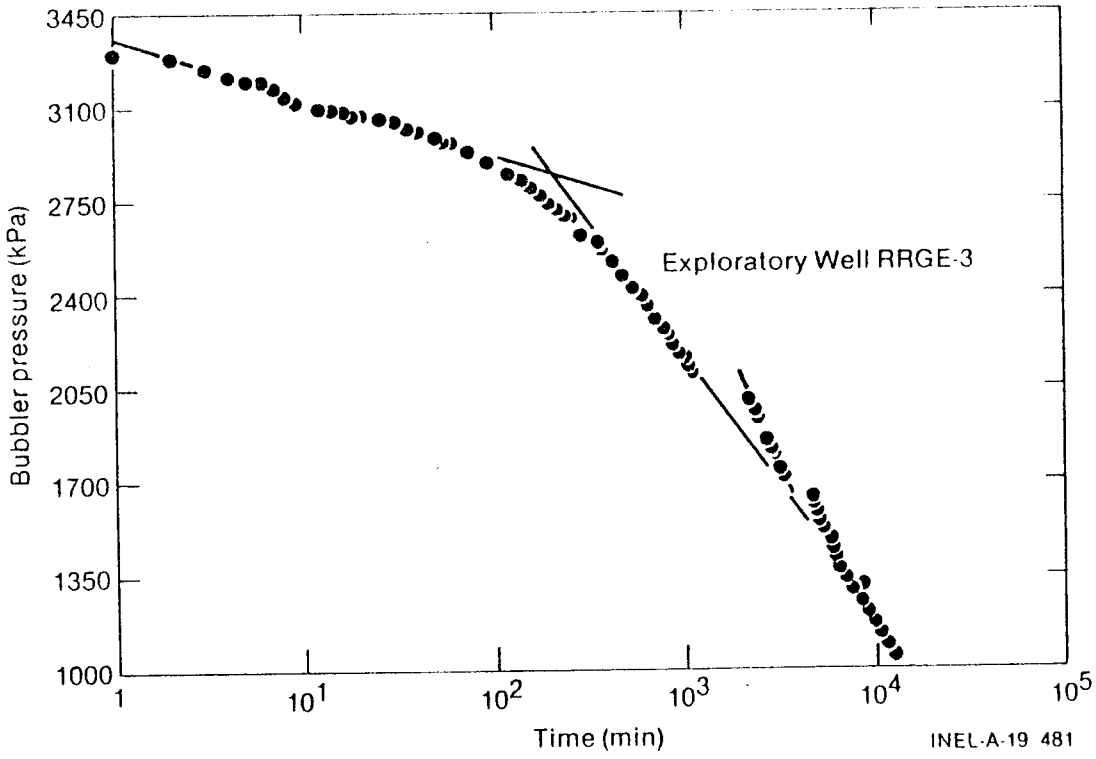



Figure 6 Drawdown during production test of well RRGE-3, March 19, 1981 at an average discharge rate of 44.2 L/s for 250 hours with numerous pump outages.

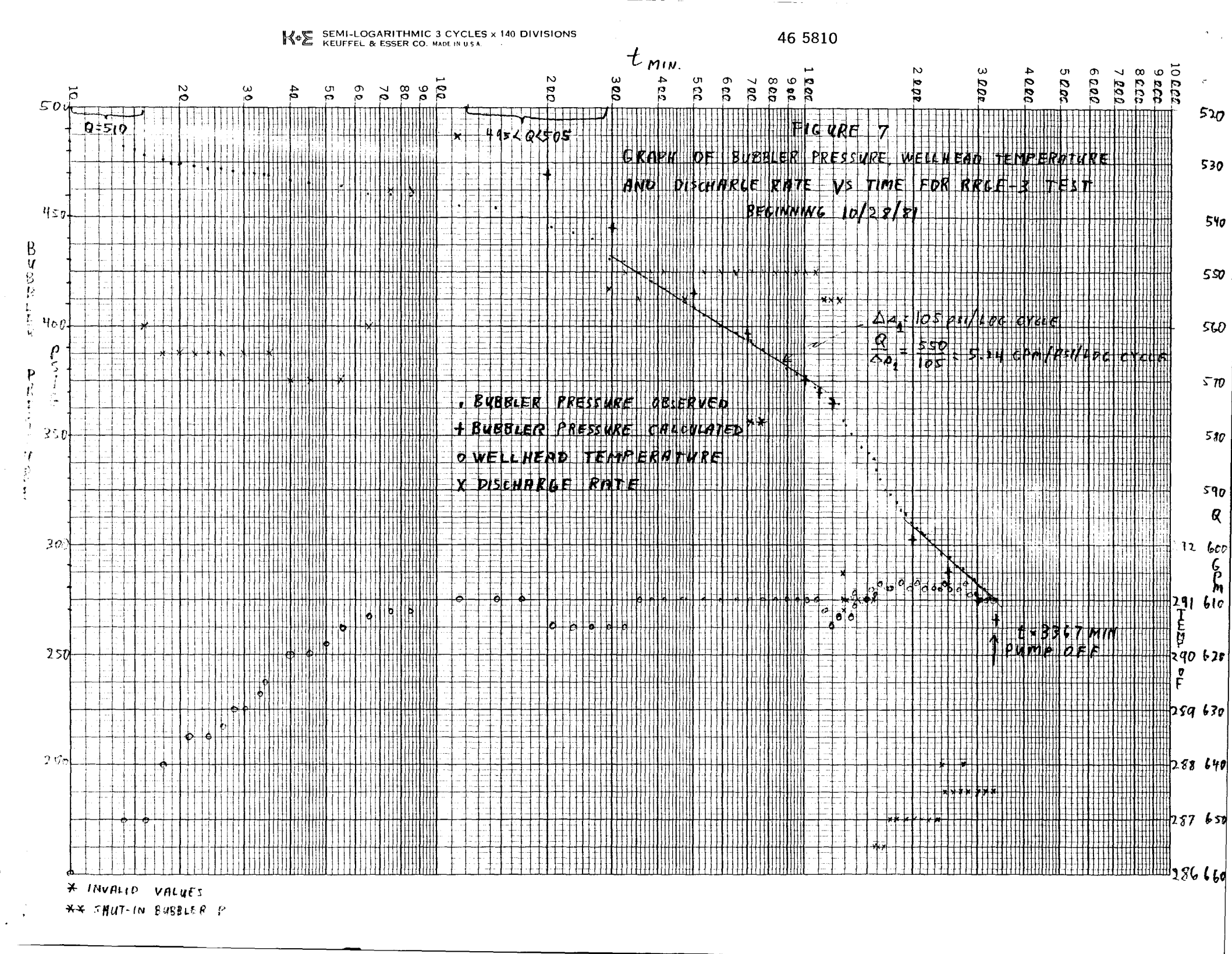
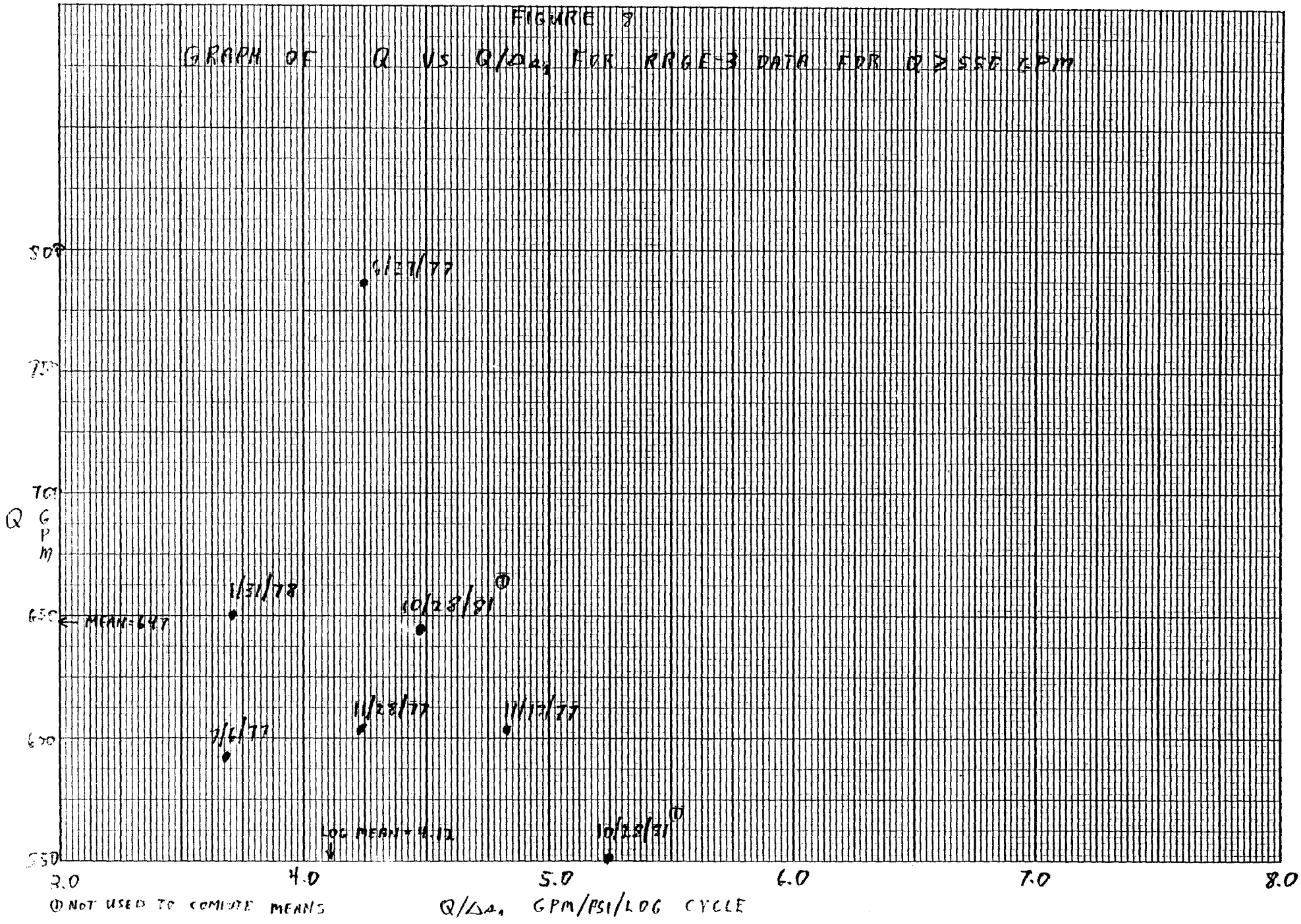



FIGURE 7
GRAPH OF BUBBLER PRESSURE, WELLHEAD TEMPERATURE AND DISCHARGE RATE VS TIME FOR RRGE-3 TEST BEGINNING 10/28/81

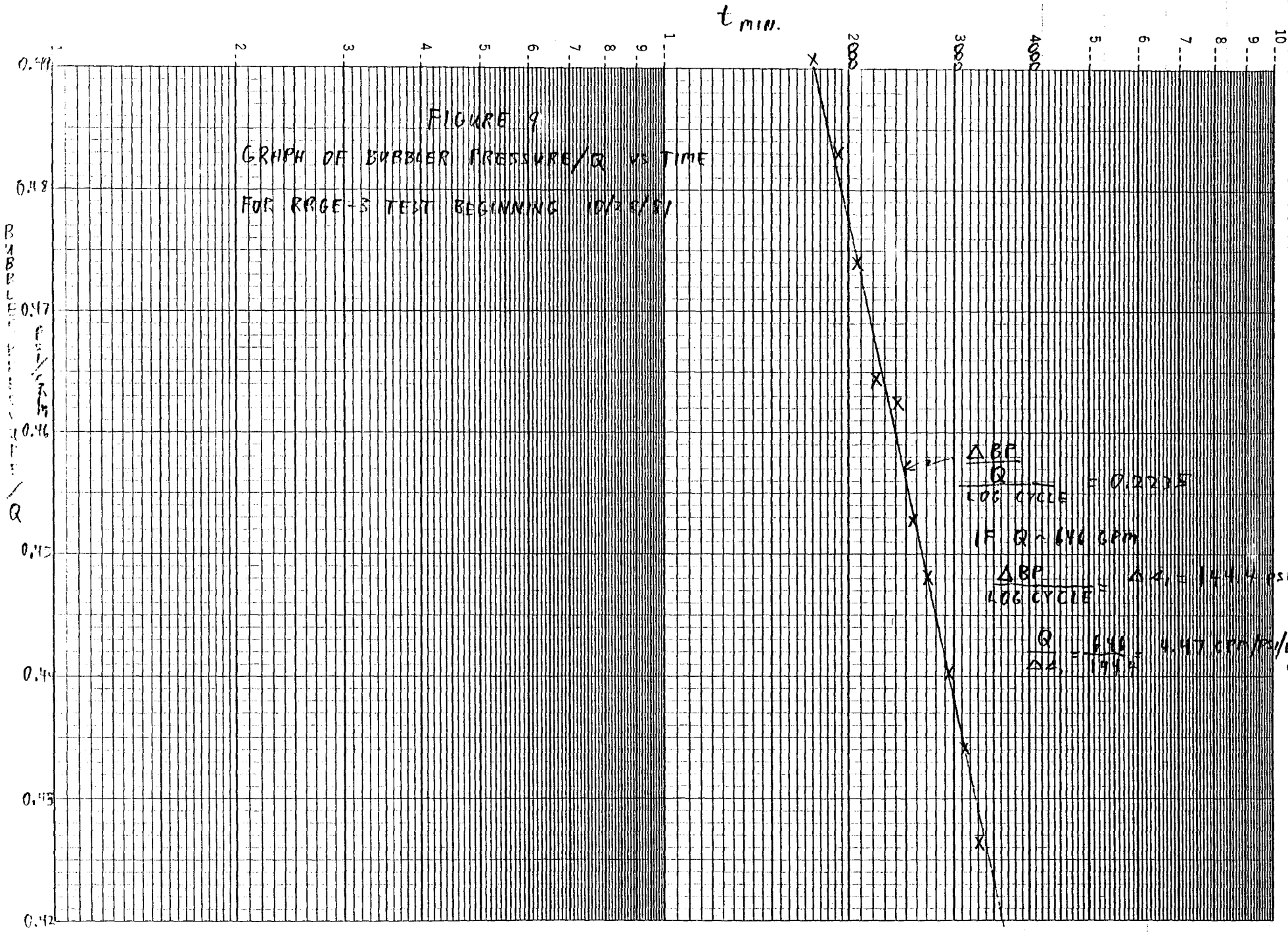
* INVALID VALUES
** SHUT-IN BUBBLER P

FIGURE 9

GRAPH OF Q VS $Q/\Delta s_1$ FOR RRGE-3 DATA FOR $Q \geq 550$ GPM




① NOT USED TO COMPUTE MEANS



# TABLE 1

## TEST DATA SUMMARY FOR PUMP TESTS ON RRGE-3

| Date at Beginning of Test | Duration (min) | Flow (gpm) | kh (md-ft) | $\frac{Q}{\Delta s_1}$(a) gpm / psi/log cycle | $\frac{Q}{\Delta s_2}$(b) gpm / psi/log cycle | Time for Intersection of 1st and 2nd Linear Segments (min) | $\frac{\Delta s_2}{\Delta s_1}$ |
|---|---|---|---|---|---|---|---|
| June 8, 1976 | 11,610 | ≈135 | 12,000(c) | 6.01(f) | | | |
| | | | 6,400(d) | 5.12(f) | | | |
| | | | 5,448(e) | | | | |
| June 29, 1977 | 1,440 | 788 | | 4.24 | | | |
| July 6, 1977 | 18,255 | 592 | | 3.68 | 5.15 | 3325 | 0.714 |
| | | | | | 5.36(e) | | |
| November 17, 1977 | 1,440 | 603 | | 4.82 | | | |
| November 28, 1977 | 34,185 | 603 | | 4.25 | 6.15 | 3899 | 0.691 |
| | | | | 4.71(e,f) | 7.18(e,f) | 1369(e,f) | 0.656(e,f) |
| January 31, 1978 | 13,085 | 650 | | 3.71 | 5.33 | 3375 | 0.697 |
| Logarithmic Mean | | | | 4.119 | 5.485 | | |
| Arithmetic Mean | | | | | | 3533 | 0.701 |

a - $\Delta s_1$ is the slope per log cycle time for the first linear data segment on a semilogarithmic plot of pressure versus time. Values for $\Delta s_1$ are also included.

b - $\Delta s_2$ is the slope per log cycle time for the second linear data segment on a semilogarithmic plot of pressure versus time. Values for $\Delta s_2$ are also included.

c - 1st case - 18 hrs
d - 2nd case - entire test
e - recovery test
f - omitted from calculations for means

# TABLE 1

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b - $\Delta s_2$ is the slope per log cycle time for the second linear data segment on a semilogarithmic plot of pressure versus time. Values for $\Delta s_2$ are also included.

c - 1st case - 18 hrs
d - 2nd case - entire test
e - recovery test
f - omitted from calculations for means

TABLE 2

# DATA USED TO GENERATE DRAWDOWN ESTIMATES AT RRGE-3 AFTER 5 YEARS OF CONTINUOUS PUMPING WITH NO WELL INTERFERENCE

| Date | Drawdown Equation for First Linear Segment (psi) | Drawdown at 3533 Min (psi) | $\frac{Q}{\text{Drawdown at 3533 Min}}$ (gpm/psi) | Drawdown Equation for Second Linear Segment (psi) | Drawdown at 5 Yrs (psi) | Increase in Drawdown from 3533 Min to 5 Yrs (psi) | $\frac{Q}{\text{Increase in Drawdown from 3533 Min to 5 Yrs}}$ (gpm/psi) | Pumping Rate Q (gpm) |
|---|---|---|---|---|---|---|---|---|
| 6/29/77 | 243+186(log t-3) | 345.0 | 2.284 | | | | | 788 |
| 7/06/77 | 168+161(log t-3) | 256.3 | 2.310 | 307+115(log t-4) | 585.3 | 329.0 | 1.800 | 592 |
| 11/17/77 | 151+125(log t-3) | 219.5 | 2.747 | | | | | 603 |
| 11/28/77 | 163+142(log t-3) | 240.8 | 2.504 | 287+98(log t-4) | 524.2 | 283.4 | 2.128 | 603 |
| 11/28/77 | 198+128(log t'-3) | 268.2 | 2.249 | 288+84(log t'-4) | 491.3 | 223.1 | 2.703[a] | 603 |
| 1/31/78 | 168+175(log t-3) | 263.9 | 2.463 | 318+122(log t-4) | 613.2 | 349.3 | 1.861 | 650 |
| Logarithmic Mean | | | 2.420 | | | | 1.925 | |

a - Omitted from calculations for mean