CHAPTER - 5

PERFORMANCE OF BOTTOMHOLE CHOKE

CHAPTER - V

5.1 INTRODUCTION

An analysis of the performance of bottomhole chokes with special reference to Gandhar field is presented. A brief discussion of the applicability of bottomhole chokes for different reservoirs and well condition is also given. The surface choke model presented in Chapter-III has been extended for predicting the flow through bottomhole chokes at critical flow conditions. The predictions of flow rate through bottomhole chokes by the other existing empirical and theoretical models have been compared with that of the present model. A method of choke size selection based on system analysis approach is also presented. The advantages of using bottomhole choke in oil production in terms of energy spent and static bottomhole pressure change per ton of oil production is brought out.

5.2 THEORETICAL CONSIDERATIONS

Surging production and natural intermittent production are relatively inefficient ways of using formation gas energy to drive a well. The methods by which the available formation gas energy can be more efficiently used can be classified into three types:

i. Methods reducing the liquid throughput capacity of the well
ii. Methods preventing abrupt entrance of large volume of gas from the annulus (casing-tubing) and
iii. The methods that, by periodical shut-in and unloading of the well will prevent the production of gas without liquid.

The throughput capacity of the well can be reduced by replacing the wellhead choke by that with smaller bore. While this will assure a steady flow, it results in a higher tubinghead pressure. Consequently it results in a lower work potential of

the gas and if GOR is small it may kill the well also. The risk of killing the well is considerably reduced if the choke is installed at the tubing shoe. The choke is then called as a bottomhole choke. While the installation of a bottomhole choke brings about the same damping effect on the surging and the work potential of the gas is retained at higher level. A furthet advantage of bottomhole choke is that it reduces the working pressure of the wellhead assembly. It also reduces the risk of formation of gas hydrates in a gas well because of the relatively higher temperatures existing at the well bottom. Gas hydrate, if formed, will obstruct the choke and may kill the well. If the cooling due to expansion is still high it is expeditious to install several bottomhole choke one above the other and distribute the required pressure drop.

Bottomhole chokes can be classified as (i) non-removable type and (ii) removable type. The non-removable type is nothing but a pressure reducing insert in the tubing that can be removed by the removal of the tubing only. These types of chokes are employed in high pressure gas wells only. There are a variety of removable chokes that can be installed and retrieved by means of wireline tools. Some have to be seated in a special landing device while others can be seated at any point of tubing. The latter types of retrievable bottomhole chokes are not recommended for a pressure differential over 120 bars. For higher pressure drops, removable bottomhole chokes with mechanical locking device are used.

5.2.1 BOTTOMHOLE CHOKE SIZE SELECTION

An optimum choke is one that gives the required tubinghead pressure for a given static bottomhole pressure and Productivity Index. Brown [37] employed a system analysis approach for choke size selection. The procedure adopted is as follows :

a) Flow rate through a particular choke is calculated using known choke performance equation.

c) Using the flowrate determined in step (a) and the Productivity Index (PI) data obtained from the well test data, the flowing bottomhole pressure (P_{wf}) is determined using the equation:

$$P_{wf} = P_r - q_o/PI$$

(P_{wf})

d) Using FBHP calculated in step (c) and assuming critical pressure ratio, the choke downstream pressure is calculated.

e) Pressure gradient in the tubing downstream of the choke is determined from the known twophase correlations.

f) For a given tubinghead pressure and the knowledge of the depth of the choke the downstream pressure of the choke is calculated.

g) The calculation of choke downstream pressure starting from bottom (steps (a) to (d)) and starting from the surface (steps (e) and (f)) is repeated for different choke diameter.

h) Optimum choke diameter is that one for which the choke downstream pressure determined in step (d) and that obtained in step (f) are equal.

5.2.2 THE WORK POTENTIAL OF GAS

In a flowing well, fluid from the well is brought to the surface at the expense of the work potential of the fluid in the reservoir. Considering the well as a system at steady state, the overall mechanical energy balance can be written as follows :

Energy Input per ton of liquid produced =	Energy lost in lifting one ton of oil
	+ Energy Lost by the expansion from P_r to P_o by the gas .

.....................(5.1)

If P_r is the reservoir pressure and P_o is the atmospheric pressure, the energy input along with one cubic meter of gas entering the well is equal to the work potential of one cubic meter of gas.

Energy input per cubic meter of gas = $\frac{RT}{V_o} \ln\left(P_r/P_o\right) = W_{fg}$.

.....................(5.2)

Energy is lost

1. **In lifting the fluid from the reservoir to the wellhead through well bore.**
2. **By flow of fluids through the wellhead equipment**
3. **By energy carried away by the fluids beyond wellhead.**

While comparing the performance of bottomhole choke with that of surface choke in lifting one ton of liquid from the reservoir all other energy losses can be assumed to be same except the work done by the pressure energy that will be different for bottomhole choke and surface chokes. For this purpose, the energy spent by change in pressure on the liquid by accompanying gas are only considered. Energy potential lost in lifting one ton of liquid from pressure of P_r to P_{wh} and P_r to P_o are given as:

$$W_{liq} = \frac{(P_r - Pwh)}{\rho}$$

$$W_{liq} = 98.1\frac{(P_r - Po)}{\rho} \quad \textbf{J/Ton} \qquad \textbf{.....................(5.3)}$$

Where P_r = **Static Bottomhole Pressure , Kgf/cm2**

P_{wh} = **Wellhead pressure, Kgf/cm2.**

P_o = **Atmospheric pressure, Kgf/cm2.**

ρ = **Density of liquid, Kg/ Cu. M**

Gas energy potential lost in expansion of the free gas accompanying one ton of liquid in expansion from a pressure P_r to P_o assuming isothermal expansion is given as :

$$W_{fg} = RT\ln\left(\frac{P_r}{P_o}\right)(G_o / V_o) \qquad \text{......................(5.4)}$$

Where G_o = **Quantity of gas in standard cubic meters produced along with one ton of liquid.**

R = **Gas constant in Joule/Kg.mole °K.**

V_o = **Volume of one mole of gas accompanying at NTP.**

The energy potential lost in lifting one ton of liquid and by expansion of accompanying gas

$$\boxed{W_n = W_{liq} + W_{fg}} \qquad \text{......................(5.5)}$$

In this equation energy of gas evolved during pressure decline from P_r to P_o has been neglected as its contribution is very small compared to the total energy loss. Therefore,

$$W_n = 98.1\left(\frac{P_r - P_o}{\rho}\right) + \left\{\left(RT\,G_o / V_o\right)\ln\left(\frac{P_r}{P_o}\right)\right\} \ \text{J/Ton} \text{......................(5.6)}$$

5.3 EXPERIMENTAL

Field trial tests have been conducted for predicting the performance of bottomhole choke in Gandhar field. Flowing oil wells having provision to install bottomhole chokes with mechanical locking device were selected for the field trial tests. The details of a typical field trial set up is presented in Figure 5.1. The well was completed with 5 1/2" 17 ppf production casing and 2 7/8" 6.4 ppf tubing.

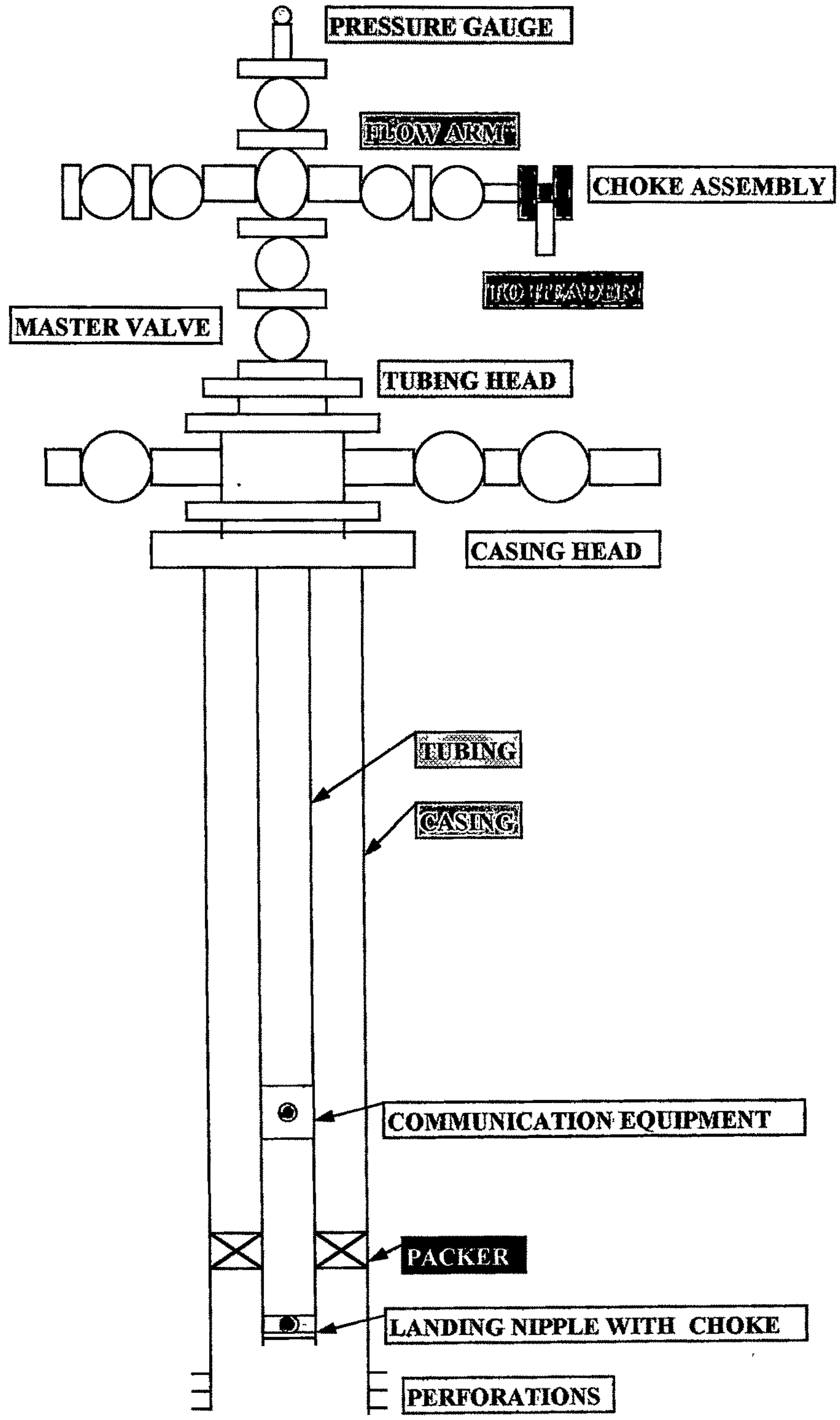


FIGURE - 5.1 DETAILS OF TYPICAL FIELD TRIAL SETUP (BOTTOMHOLE CHOKE)

The possibility of surging of gas from the annulus is removed by the use of a hydraulic packer at 2827 meters as the packer seals the communication between the tubing and the casing-tubing annulus. The well was producing from a zone perforated among 2913 and 2918 meters.

Field trial tests were designed specifically for the following :-

i. To measure the oil and gas flowrates through surface chokes

ii. To measure the oil and gas flowrate through bottomhole choke

iii. To measure the tubing head pressures for both surface choke and bottomhole choke.

iv. To analyse the productivity indices for both surface and bottomhole chokes

v. To measure the change in static bottomhole pressure per ton of oil production.

5.3.1 TEST PROCEDURE

1) Initially the well was allowed to flow through a surface choke for considerable amount of time in order to stabilize the flow.

2) At stabilized flow conditions, the tubinghead pressure, oil and gas flowrate, and tubing head pressures have been measured.

3) Flowing bottomhole fluid sample has been collected and PVT analysis has been done.

4) Then the well was closed for measuring the pressure buildup for evaluating the reservoir parameters.

5) Then a bottomhole choke was installed in the landing device by wireline.

6) The well was allowed to become stabilized. For stabilization it took more than 8 days.

7) At stabilized conditions the flowrates of oil and gas and tubinghead pressure have been measured.

In order to compare the performance of bottomhole production system with that of surface choke system another field trial test was designed to measure the productivity index for both bottomhole and surface chokes production systems. The following procedure was followed :

1) Initially the well was allowed to flow through 6 mm surface choke.

2) At stabilized flow conditions, the tubinghead pressure, oil and gas flowrate, flowing bottomhole pressure and tubing head pressure have been measured

3) All the above measurements have been made for 8 and 10 mm surface chokes at stabilized conditions.

4) Then the well was closed for measuring the pressure buildup for evaluating the reservoir parameters.

5) Then the well was allowed to flow through a 6 mm surface choke for considerable amount of time in order to stabilize the flow.

6) A pressure bomb was installed in the landing nipple to record the upstream pressure of the choke.

7) Then a 10/64" choke was installed in the upper landing device.

8) The well was allowed to get stabilized through 8 mm surface choke with 10/64" bottomhole choke in position. For stabilization it took more than 8 days.

9) At stabilized conditions a second pressure bomb was lowered in a wireline and the downstream pressure of the choke was recorded.

10) The flowrates of oil and gas and tubinghead pressure have been measured through 8,10 and 12 mm surface chokes.

11) Then the well was closed for sufficient time to record the static bottomhole pressure.

12) The choke was removed from the landing device followed by the choke upstream pressure bomb with the help of the wireline.

13) The recorded choke upstream pressure and static bottomhole pressure from the bottom pressure recorder and the choke downstream pressure from the top pressure bomb has been read carefully.

Another field trial test was designed to measure the change in static bottomhole pressure per ton of oil production through surface as well as bottomhole choke systems. The following procedure was followed :-

1) Initially the static bottomhole pressure was recorded and the reservoir parameters were evaluated.

2) Then the well was put on production through an optimum choke.

3) After producing the well for a calculated amount of oil, static bottomhole pressure was measured again.

4) A bottomhole choke was installed.

5) The well was allowed to flow through bottomhole choke system almost for eight months.

6) During this period the flow has been closely monitored and the variation in the flowrate was found to be very small.

7) Then the bottomhole choke was removed and the static bottomhole pressure was measured.

5.4 RESULTS AND DISCUSSION

The oil flowrate, gas flowrate and tubinghead pressure measured through surface choke as well as through bottomhole choke from the field trial are presented in Table 5.1. In Table 5.2 the well test and PVT data for the test wells obtained from the field trials are given.

5.4.1 PERFORMANCE OF BOTTOMHOLE CHOKE

It has been brought by Perkins [16] that the empirical correlations generally are valid over the range where experimental data were available but may give poor results when extrapolated to new conditions. Hence, the co-efficient in the Gilbert form of equation has been modified to fit the bottomhole choke data given in Table 5.1. A co-efficient of 10.82 has been found to give minimum deviation. So, the equation for bottomhole choke becomes :

$$P_{tf} = \frac{10.82\ q_L^{'}\ R_p^{0.500}}{d_c^{2.000}} \qquad \text{..................(5.7)}$$

It can be noted that the value of coefficient is different for bottomhole choke when compared to the values of surface choke. This is because of the fact that the upstream pressure, the temperature and solution gas ratio are much higher for bottomhole choke. Further, these empirical correlations do not consider the physical properties of fluids.

The tubinghead pressure predictions by the equation 5.7 for bottomhole choke data are presented in Table 5.3. In order to compare the performance of other empirical correlations the bottomhole choke data collected from the field trial have been fitted in the empirical correlations of Gilbert, Ros, Baxendell, Achong, and Pilhevari. The tubinghead pressure predictions by these correlations are presented in Table 5.4. The statistical analyses of the tubinghead pressure predictions by the empirical models have been done and the results are given in Table 5.5. It can be seen from this table that the present empirical correlation , Equation 5.7 best predicts the field trial test data. The proposed empirical equation (Equation 5.7) for bottomhole chokes best predicts the bottomhole choke data with an average relative percentage error of -7.73 and standard deviation of 14.7 while Ros correlation predicts with a relative percentage error of 48.38 and standard deviation of 54.71.

CROSS PLOT

The cross plot of predicted versus experimental values for bottomhole choke tubinghead pressure prediction by the equation 5.7 is shown in Figure 5.2. The cross plots of predicted versus experimental values for bottomhole choke tubinghead pressure prediction by various other empirical correlations are presented in Figures 5.3 through 5.8 In figure 5.2 it can be seen that most of the plotted points fall very close to the perfect correlation of 45° line. The other empirical correlations reveal their overestimation.

5.4.1.1 EVALUATION OF THE THEORETICAL MODEL

A theoretical model developed in the present work for predicting the flow through choke has been presented in Chapter - III and is given below :-

$$Q = (184648.26)\frac{C_d\,A_c\left[k\left(\frac{2}{k+1}\right)^{\left(\frac{k+1}{k-1}\right)} g_c\,P_{tf}\,A\,B(1+C)\right]^{0.5}}{A(B+C)} \qquad \text{.....................(3.29)}$$

where

$$A = \rho_o + \frac{\rho_g R_s}{5.615} + F_{wo}\rho_w \qquad \text{.....................(3.25)}$$

$$B = B_o + F_{wo} \qquad \text{.....................(3.26)}$$

$$C = \frac{(R_p - R_s)}{5.615} + \frac{P_{sc}}{T_{sc}}\frac{T_1 Z_1}{144 P_{tf}} \qquad \text{.....................(3.30)}$$

The above equation includes a discharge coefficient C_d to accommodate the deficiencies of the model. Theoretical models developed by previous investigators have included such a discharge coefficient. It is necessary to evaluate this coefficient so that the correlation can be used for the prediction of the performance of the bottomhole choke.

5.4.1.2 DETERMINATION OF DISCHARGE COEFFICIENT, C_d

The field trial test data presented in Table 5.1 have been used to determine the value of C_d, using regression analysis. For this purpose, a program developed in QBASIC and is presented in Appendix-II. A value of 1.574 for discharge coefficient, C_d , was found to give minimum deviation for the flowrate through bottomhole choke. With the value of 1.574 for C_d, equation 3.29 can be written as follows :

$$Q = (1.574)(184648.26)\frac{A_c\left[k\left(\frac{2}{k+1}\right)^{\left(\frac{k+1}{k-1}\right)} g_c\, P_{tf}\, A\, B(1+C)\right]^{0.5}}{A(B+C)} \quad \text{..........(5.8)}$$

The discharge coefficient for the bottomhole choke is twice higher than that of surface chokes system. This is due to the fact that the model assumes mist flow through choke. In case of surface choke this assumption is valid whereas in case of bottomhole choke the flow through the choke may be either single phase of bubble flow. Further, the properties of the fluid are measured at upstream conditions of the choke. The upstream solution gas oil ratio and pressure are more in case of bottomhole choke making the fluid compressible unlike the surface choke system.

5.4.1.3 STATISTICAL ANALYSIS

In Table 5.6 values of flowrate calculated using equation 5.8 are presented along with the corresponding test data. Statistical analyses of the data have been carried out using EXCEL. Equation 5.8 predicts the flowrate with an average relative percentage error of -4.17, minimum relative percentage error 0.03, a maximum absolute relative percentage error of 29.57, a standard deviation of 14.04 and a correlation coefficient of 0.9984.

5.4.1.4 EVALUATION OF OTHER MODELS

Flowrates have been calculated using the theoretical models developed by Poettmann and Beck, Omana, Ashford, Ashford and Pierce, Sachdeva and Perkins. Measured values of flowrate are presented along with the values predicted by these models in Tables 5.7 through 5.12. These tables also include the calculated values of relative percentage error.

Statistical parameters like average percentage relative error, average absolute percentage relative error, standard deviation and correlation coefficient have also

Statistical parameters like average percentage relative error, average absolute percentage relative error, standard deviation and correlation coefficient have also been estimated from these data and are in Table 5.13. Among the theoretical models, Omana's model performs better than the other models. It gives a correlation coefficient of 0.9871 and a standard deviation of 42.34 that is comparable to the model proposed in the present investigation. Ashford and Pierce's model gives the highest standard deviation of 79.93.

CROSS PLOT

The cross plots of measured flowrate against the flowrate predicted by equation 5.8 is shown in Figure 5.8. It shows that equation 5.8 predicts the flow rate with a good accuracy. Cross plots prepared for the correlations developed by previous investigators are shown in Figures 5.10 through 5.15. Here also it can be seen that the equation proposed by Omana predicts the data with a good accuracy. The overprediction of flowrates by other correlations is due to the fact that the tubinghead pressure , solution gas oil ratio and the temperature for bottomhole choke are much higher when compared to surface choke.

5.4.2. COMPARISON OF BOTTOMHOLE CHOKE PRODUCTION SYSTEM WITH THAT OF SURFACE CHOKE.

In order to evaluate the performance of bottomhole choke production system, the performance of bottomhole choke has been compared with that of surface choke system in terms of the following :

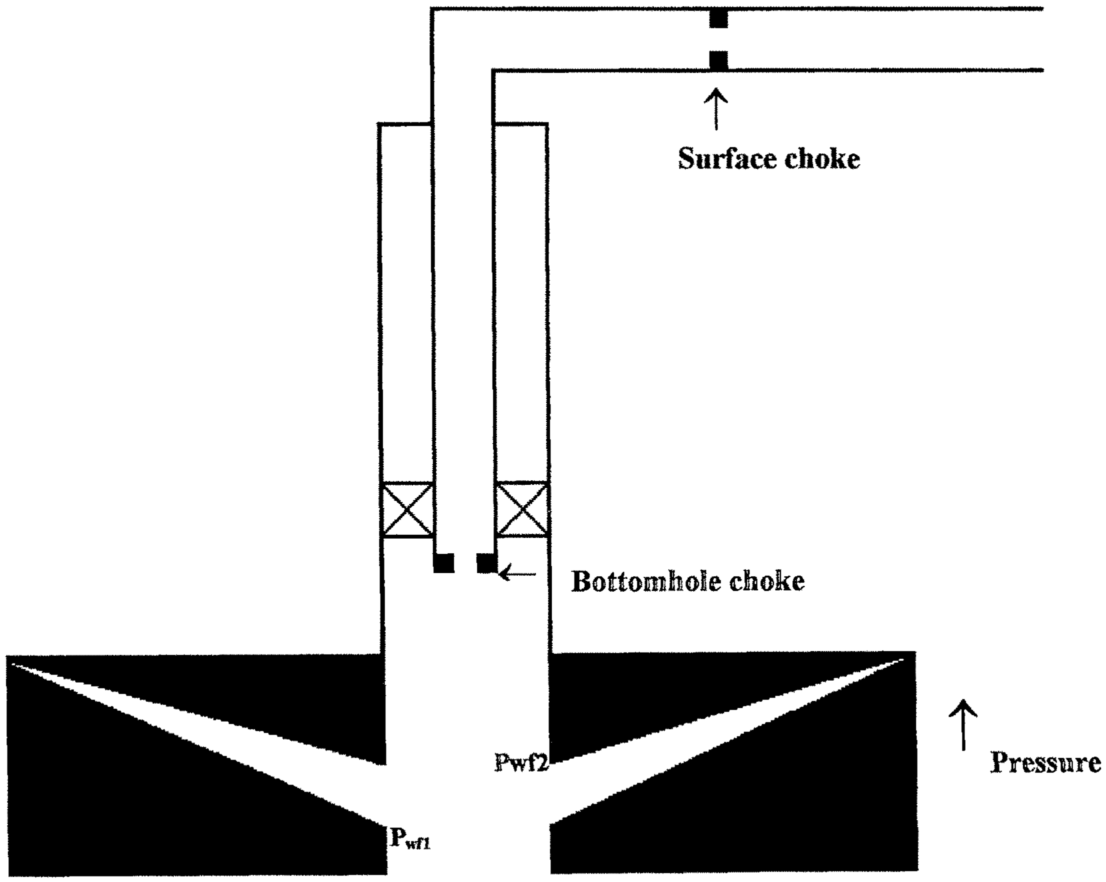
- **PRODUCTIVITY INDEX**
- **PRESSURE DROP PER TON OF OIL PRODUCTION**
- **CONSUMPTION OF ENERGY POTENTIAL IN LIFTING UNIT MASS OF OIL**

5.4.2.1 PRODUCTIVITY INDEX

The oil flowrate, gas oil ratio, flowing bottomhole pressure, static bottomhole pressure and tubinghead pressure obtained from the productivity index field trial test through 6,8 and 10 mm surface chokes are tabulated in Table 5.14. The oil flowrate and gas flowrate measured through 10/64" size bottomhole choke with 8,10 and 12 mm surface chokes are presented in Table 5.15. The recorded choke upstream pressure, choke downstream pressure and the shut in pressure for the 10/64" bottomhole choke are tabulated in Table 5.16. For the purpose of comparing the bottomhole choke performance with that of the surface choke, flowrate has been taken as the basis. The flowing bottomhole pressure corresponding to the measured flowrates through 10/64" bottomhole choke with 8 an 10 mm surface chokes have been obtained from the surface choke inflow performance curve.

The drawdown corresponding to these flowrates and the respective productivity indices are calculated and presented in Table 5.17. It is evident from this table that the use of bottomhole choke increased the flow efficiency by 4.5 times with respect to surface choke system.

It has been observed during the experiments that when the well is changed from surface choke system to bottomhole choke system the well requires minimum of 8 days to get fully stabilized. During this period, the gas flowrate observed is more than the gas flowrate at stabilized conditions. This may be due to the fact that once bottomhole choke is installed, the drawdown given to the reservoir is less than that of the surface choke system. This has already been confirmed from Table 5.17. This can be explained using Figure 5.16. When a surface choke is installed the flowing bottomhole pressure at the wellbore is denoted as P_{wf1} for a reservoir pressure of P_r whereas for the same liquid flowrate through a bottomhole choke the flowing bottomhole pressure is P_{wf2}. Since the flowing bottomhole pressure in case of bottomhole choke is higher than that of the surface chokes system, when the well is changed from surface choke to bottomhole choke



P_{wf1} - Surface choke flowing bottomhole pressure

P_{wf2} - Bottomhole choke flowing bottomhole pressure

Fig. 5.16 Flowing bottomhole pressures

system the already liberated gas occupies the pores around the well bore at a pressure of P_{wfl}. This area has been shown in dark shade in Figure 5.16. These gas starts entering the wellbore till it attains the equilibrium condition with the flow through bottomhole choke system.

Further, during flow through surface choke system the fluid entering the wellbore attains pressures below the bubble point pressure when the reservoir pressure is slightly higher than the bubble point pressure. In such cases the gas starts liberating inside the reservoir, forming two-phase flow causing higher pressure drop. On the other hand, while producing through a bottomhole choke system, single phase flow is maintained resulting in a lower pressure drop inside the reservoir. So, the uses of bottomhole choke results in an increase in oil production and decrease in gas production. It has been further confirmed that the increase in oil production is not only attributed to the retrograde gas condensation but also to the single phase flow inside the reservoir due to the less pressure drawdown.

5.4.2.2 PRESSURE DROP PER TON OF OIL PRODUCTION

The following static bottomhole pressure data collected from the pressure drop field trial test are tabulated in Table 5.18 :-

- Initial reservoir pressure (i.e. before starting production)
- Pressure after producing calculated amount of oil through surface choke system (i.e before installing bottomhole choke system) and
- After producing calculated amount of oil through bottomhole choke system.

From the static bottomhole pressure data, the pressure drop per ton of oil production has been calculated for both the cases of surface and bottomhole choke systems and are presented in Table 5.19 . It can be seen from this table that the static bottomhole pressure drop per ton of oil production in case of bottomhole choke is seventy (70) times lesser than that of the surface chokes system in one case and twenty-seven (27) times less in another case.

5.4.2.3 CONSUMPTION OF ENERGY POTENTIAL IN LIFTING UNIT MASS OF OIL

In order to analyse the benefits of using bottomhole choke, the energy spent in lifting unit mass of oil has been calculated using equation 5.6. This has been tabulated in Table 5.20. From this table it can be seen that the bottomhole choke system consumes only seventy percent (70%) of the energy consumed by the surface choke system. In other words the use of bottomhole choke conserves thirty percent (30%) of the total energy spent in case of surface choke system. This energy conservation is apparently due to the less free gas production. This free gas energy conservation will in turn result in higher over all recovery because the free gas energy is considered to be the main driving force in the process of oil production in a flowing well.

5.5. BOTTOMHOLE CHOKE SIZE SELECTION

A choke size selection procedure has been evaluated using system analysis approach. One of the main assumptions made in this procedure is the mist flow condition in the down stream side of the choke for calculating the pressure drop inside the tubing string. In the surface choke production system different flow pattern occurs at various depths starting from single phase flow, bubble flow, transition flow between slug and mist flow and finally mist flow. But in case of bottomhole choke only mist flow occurs at the downstream side of the choke due to the substantial pressure drop across the choke. Because of large pressure drop, the fluid is flashed liberating all the gas dissolved in the liquid forming liquid as mist in the continuous gas phase.

The following procedure was adopted for the choke size selection :-

i) The well is tested through a surface choke and flow measurements have been made at stabilized conditions.

ii) The well is closed for measurements of static bottomhole pressure and evaluation of reservoir parameters.

iii) PVT analysis of the bottomhole sample is done.

iv) The flow rate through various bottomhole chokes is calculated assuming static bottomhole pressure as choke upstream pressure and the test GOR as produced GOR using the model presented in Chapter - III with a dicharge co- efficient of 1.574

$$Q = (1.574)(184648.26)\frac{A_c\left[k\left(\frac{2}{k+1}\right)^{\left(\frac{k+1}{k-1}\right)} g_c\, P_{tf}\, A\, B\left(1+C\right)\right]^{0.5}}{A\left(B+C\right)} \qquad \text{......................(5.8)}$$

Where $$A = \rho_o + \frac{\rho_g R_s}{5.615} + F_{wo}\rho_w \qquad \text{. ....(3.25)}$$

$$B = B_o + F_{wo} \qquad \text{.....................(3.26)}$$

$$C = \frac{\left(R_p - R_s\right)}{5.615} + \frac{P_{sc}}{T_{sc}}\frac{T_1 Z_1}{144 P_{tf}} \qquad \text{.....................(3.30}$$

v) From the flowrates obtained from Step iv, the flowing bottomhole pressures (P_{wf}) are calculated using the productivity index estimated from the well test data.

$$\mathbf{PI} = \frac{Q}{P_1 - P_{wf}}$$

$$P_{wf} = P_1 - \frac{Q}{PI}$$

vi) From the flowing bottomhole pressure, the choke downstream pressure is calculated assuming a critical pressure ratio of 0.528 and flowing bottomhole pressure as choke upstream pressure.

$$P_{ds} = P_{wf} * 0.528$$

vii) From the given tubinghead pressure, the choke downstream pressure is calculated for a given flowrate assuming mist flow conditions.

viii) Plots of flowrate versus choke downstream pressure calculated in step vii and flowrate versus choke downstream pressure calculated in step vi are made.

ix) The inter section of these two plots gives the maximum possible choke size and flowrate for a given tubing head pressure.

x) The tubinghead pressure for a given choke is calculated by subtracting the pressure drop inside the tubing-string for the flowrate through the given choke from the choke downstream pressure, calculated in step vi.

The block diagram for the choke size selection for a given tubinghead pressure is shown in Figure 5.17. Chokes have been selected as above with the help of a personal computer and installed in different wells. The after choke pressure, calculated from top as well as from bottom of the well for various choke sizes for individual wells have been tabulated in Tables 5.21 through 5.30. The plots of choke size versus flowrate , choke downstream pressures calculated from the wellhead and from the bottom of the well for optimum choke size selection have

been shown in Figures 5.18 through 5.27. The predicted and measured tubinghead pressures of the field trial tests (10 wells) are tabulated in Table 5.31. It can be seen from this table and from Figure 5.28 (Cross plot for THP) that the predicted tubinghead pressures are in close match with the measured values.

5.6 CONCLUSIONS

1. **Field trial test results shows the uses of bottomhole choke in oil production resulted in increase in oil production and decrease in gas oil ratio.**

2. **During production through bottomhole choke system the static bottomhole pressure change per ton of oil production is much lesser than that of surface chokes system.**

3. **From the energy balance it has been observed that the use of bottomhole choke conserves the free gas energy which in turn will result in higher overall recovery.**

4. **The model proposed in Chapter-III has been extended for bottomhole choke.**

5. **A discharge co-efficient of 1.574 found to yield minimum deviation for the bottomhole choke.**

6. **A comparison of flowrate prediction by the present model with that of the other existing models has been made and proved that the present model predicts the flow through bottomhole choke better than any other existing models.**

7. A bottomhole choke size selection procedure has been evaluated and proved that mist flow occurs in the choke downstream section of the tubing string resulting increase in flow efficiency utilizing the maximum use of free gas energy.

8. The predicted tubinghead pressures . for different choice sizes are compared with that of measured values and found that the predicted values are very close to the measured ones.

TABLES OF CHAPTER-V

TABLE 5.1 SURFACE AND BOTTOMHOLE CHOKES DATA GATHERED FROM FIELD TRIAL TEST

A. SURFACE CHOKE FIELD TRIAL TEST-1 DATA

	CHOKE SIZE		LIQUID FLOW RATE		GOR		THP		
SL.NO	(mm)	(1/64 inch)	M^3/DAY	BBLS/DAY	M^3/M^3	SCF/BBL	Kg/Cm^2	PSI	OIL SPECIFIC GRAVITY
1	5.00	12.60	25.80	162.28	2430.00	13644.45	168.49	2395.93	0.83
2	6.00	15.12	84.40	530.88	681.00	3823.82	128.45	1826.56	0.84
3	6.00	15.12	46.00	289.34	2385.00	13391.78	180.69	2569.41	0.82
4	6.00	15.12	55.30	347.84	1109.00	6227.04	164.60	2340.61	0.84
5	6.00	15.12	50.60	318.27	2540.00	14262.10	210.00	2986.20	0.81
6	6.00	15.12	30.90	194.36	2944.00	16530.56	181.80	2585.20	0.81
7	6.00	15.12	65.00	408.85	1856.00	10421.44	178.47	2537.84	0.82
8	5.00	12.60	61.80	388.72	1680.00	9433.20	149.75	2129.45	0.81
9	8.00	20.16	80.86	508.61	1358.00	7625.17	166.62	2369.34	0.82
10	5.00	12.60	30.89	194.30	2944.00	16530.56	181.80	2585.20	0.82

B. BOTTOMHOLE CHOKE FIELD TRIAL TEST DATA

		LIQUID FLOW RATE		GOR		THP			
SL.NO	CHOKE SIZE (1/64 inch)	M^3/DAY	BBLS/DAY	M^3/M^3	SCF/BBL	Kg/Cm^2	PSI	BOTTOM HOLE TEMP. DEG.^{0} F	OIL SPECIFIC GRAVITY
1	12	140.06	880.98	571	3206.17	31.00	440.82	266	0.825
2	12	186.00	1169.94	476	2672.74	29.60	420.91	262	0.837
3	10	94.44	594.03	829	4654.84	82.40	1171.73	262	0.819
4	8	75.00	471.75	512	2874.88	68.00	966.96	270	0.837
5	12	58.00	364.82	1753	9843.10	42.00	597.24	280	0.809
6	8	40.85	256.95	1753	9843.10	79.00	1123.38	267	0.809
7	12	111.92	703.98	888	4986.12	84.50	1201.59	262	0.816
8	12	120.00	754.80	848	4761.52	50.00	711.00	262	0.809
9	12	113.20	712.03	829	4654.84	30.60	435.13	262	0.819
10.00	10.00	84.90	534.02	888	4986.12	91.90	1306.82	262.00	0.816

TABLE 5.2 WELL TEST AND PVT DATA OF TEST WELLS

		TEST WELL Nos.						
SL.NO	PROPERTIES	1	2	3	4	5	6	7
1	RESERVOIR PRESSURE	300.00	272.84	286.63	296.35	313.35	297.00	292.70
2	RESERVOIR TEMP. DEG. C	130.00	128.00	128.00	132.00	138.00	132.00	128.00
3	OIL SP.GR.	0.825	0.818	0.819	0.837	0.871	0.809	0.816
4	OIL FORMATION VOLUME FAC	2.472	2.559	2.616	1.957	2.862	1.806	2.479
5	OIL VISCOSITY (Cp)	0.775	0.627	0.880	1.325	0.775	0.749	0.627
6	OIL VISCOSITY AT Bp,(Cp)	0.069	0.082	0.280	0.213	0.069	0.191	0.082
7	GAS GRAVITY	0.944	0.805	0.838	0.825	0.833	0.829	0.824
8	SOLUTION GOR (v/v)	393	400	403	246	497	212	391

TABLE 5.3 TUBINGHEAD PRESSURE PREDICTIONS BY THE PRESENT EMPIRICAL CORRELATION FOR BOTTOMHOLE CHOKE

SL.NO.	MEASURED TUBINGHEAD PRESSURE psi	PREDICTED TUBING HEAD PRESSURE psi	PERCENT RELATIVE ERROR
1	4266	3748.20	-12.14
2	4133	4544.72	9.96
3	4076	4385.17	7.59
4	4214	4276.31	1.48
5	1971	2719.63	37.98
6	4233	4309.79	1.81
7	4162	3735.12	-10.26
8	4233	3913.54	-7.55
9	4076	3650.18	-10.45
10	4162	4080.06	-1.97

TABLE 5.4 TUBINGHEAD PRESSURE PREDICTIONS BY VARIOUS EMPIRICAL CORRELATIONS FOR BOTTOMHOLE CHOKE

SL.NO.	MEASURED	GILBERT	ROS	BAXENDELL	ACHONG	MACH	PILEHVARI	PRESENT
1	4266	6600.56	6027.60	5713.09	5984.92	5476.80	2718.34	3748.20
2	4133	7936.51	7308.51	6869.42	7061.36	6640.66	3410.09	4544.72
3	4076	7699.85	7051.93	6713.36	7244.49	6407.53	3026.21	4385.17
4	4214	7166.02	6876.87	6303.95	6398.36	6248.47	3309.62	4276.31
5	1971	5042.85	4373.52	4364.82	5138.27	3973.87	1599.17	2719.63
6	4233	7642.80	6930.71	6723.37	7755.91	6297.39	2649.79	4309.79
7	4162	6712.50	6006.57	5809.98	6372.45	5457.69	2494.16	3735.12
8	4233	7018.24	6293.49	6074.62	6630.85	5718.39	2635.92	3913.54
9	4076	6539.13	5869.97	5659.93	6163.64	5333.58	2468.97	3650.18
10	4162	7186.82	6561.29	6266.06	6810.32	5961.72	2779.69	4080.06

TABLE 5.5 STATISTICAL ACCURACY OF EMPIRICAL CORRELATIONS FOR BOTTOMHOLE CHOKE

SL.NO	CORRELATION	AVERAGE PERCENT RELATIVE ERROR	AVERAGE ABSOLUTE PERCENT RELATIVE ERROR	MINIMUM ABSOLUTE PERCENT ERROR	MAXIMUM ABSOLUTE PERCENT ERROR	STANDARD DEVIATION	CORRELATION CO-EFFICIENT
1	GILBERT	63.01	63.01	18.21	86.04	69.18	0.976
2	ROS	48.38	48.38	2.52	71.32	54.71	0.964
3	BAXENDELL	41.82	41.82	2.31	61.02	47.31	0.953
4	ACHONG	53.68	53.68	20.45	81.80	59.11	0.969
5	MACH	34.82	34.82	6.85	55.67	40.88	0.939
6	PILEHVARI	-36.49	36.49	20.06	62.51	40.25	0.867
7	PRESENT	-7.73	9.85	0.24	36.25	14.77	0.9998

TABLE 5.6 FLOW RATE PREDICTION BY THE PRESENT THEORETICAL MODEL FOR BOTTOMHOLE CHOKE

SL.NO	MEASURED FLOW RATE BBLS/DAY	PREDICTED FLOW RATE BBLS/DAY	PERCENT RELATIVE ERROR
1	881.00	803.43	-8.80
2	1170.00	824.03	-29.57
3	594.00	527.40	-11.21
4	472.00	393.68	-16.59
5	365.00	379.75	4.04
6	257.00	313.52	21.99
7	704.00	752.90	6.95
8	755.00	706.18	-6.47
9	712.00	712.18	0.03
10	534.00	522.85	-2.09

TABLE 5.7 FLOW RATE PREDICTION BY POETTMANN AND BECK MODEL FOR BOTTOMHOLE CHOKE

SL.NO	MEASURED FLOW RATE BBLS/DAY	PREDICTED FLOW RATE BBLS/DAY	PERCENT RELATIVE ERROR
1	881.00	373.13	-57.65
2	1170.00	459.29	-60.74
3	594.00	148.52	-75.00
4	472.00	155.51	-67.05
5	365.00	92.62	-74.62
6	257.00	35.2	-86.30
7	704.00	198.33	-71.83
8	755.00	254.17	-66.34
9	712.00	247.57	-65.23
10	534.00	137.73	-74.21

TABLE 5.8 FLOW RATE PREDICTION BY ASHFORD MODEL FOR BOTTOMHOLE CHOKE

SL.NO	MEASURED FLOW RATE BBLS/DAY	PREDICTED FLOW RATE BBLS/DAY	PERCENT RELATIVE ERROR
1	881.00	460.05	-47.78
2	1170.00	487.77	-58.31
3	594.00	261.31	-56.01
4	472.00	216.91	-54.04
5	365.00	142.44	-60.98
6	257.00	107.73	-58.08
7	704.00	364.85	-48.17
8	755.00	376.64	-50.11
9	712.00	374.87	-47.35
10	534.00	253.37	-52.55

TABLE 5.9 FLOW RATE PREDICTION BY ASHFORD AND PIERCE MODEL FOR BOTTOMHOLE CHOKE

SL.NO	MEASURED FLOW RATE BBLS/DAY	PREDICTED FLOW RATE BBLS/DAY	PERCENT RELATIVE ERROR
1	881.00	43.24	-95.09
2	1170.00	31.75	-97.29
3	594.00	88.60	-85.08
4	472.00	43.96	-90.69
5	365.00	274.25	-24.86
6	257.00	157.70	-38.64
7	704.00	133.12	-81.09
8	755.00	59.68	-92.10
9	712.00	70.46	-90.10
10	534.00	92.44	-82.69

TABLE 5.10 FLOW RATE PREDICTION BY OMANA MODEL FOR BOTTOMHOLE CHOKE

SL.NO	MEASURED FLOW RATE BBLS/DAY	PREDICTED FLOW RATE BBLS/DAY	PERCENT RELATIVE ERROR
1	881.00	754.96	-14.31
2	1170.00	757.47	-35.26
3	594.00	368.20	-38.01
4	472.00	376.04	-20.33
5	365.00	30.79	-91.56
6	257.00	168.68	-34.37
7	704.00	522.18	-25.83
8	755.00	524.84	-30.48
9	712.00	511.22	-28.20
10	534.00	376.09	-29.57

TABLE 5.11 FLOW RATE PREDICTION BY SACHDEVA MODEL FOR BOTTOMHOLE CHOKE

SL.NO	MEASURED FLOW RATE BBLS/DAY	PREDICTED FLOW RATE BBLS/DAY	PERCENT RELATIVE ERROR
1	881.00	383.00	-56.53
2	1170.00	486.59	-58.41
3	594.00	132.07	-77.77
4	472.00	108.80	-76.95
5	365.00	105.76	-71.02
6	257.00	43.34	-83.14
7	704.00	182.68	-74.05
8	755.00	288.36	-61.81
9	712.00	262.23	-63.17
10	534.00	126.86	-76.24

TABLE 5.12 FLOW RATE PREDICTION BY PERKINS MODEL FOR BOTTOMHOLE CHOKE

SL.NO	MEASURED FLOW RATE BBLS/DAY	PREDICTED FLOW RATE BBLS/DAY	PERCENT RELATIVE ERROR
1	881.00	695.68	-21.04
2	1170.00	818.40	-30.05
3	594.00	335.31	-43.55
4	472.00	370.49	-21.51
5	365.00	218.66	-40.09
6	257.00	98.63	-61.62
7	704.00	448.29	-36.32
8	755.00	478.16	-36.67
9	712.00	479.15	-32.70
10	534.00	311.31	-41.70

TABLE 5.13 STATISTICAL ACCURACY OF THEORETICAL MODELS FOR BOTTOMHOLE CHOKE

SL.NO	MODEL	AVERAGE PERCENT RELATIVE ERROR	AVERAGE ABSOLUTE PERCENT RELATIVE ERROR	MINIMUM ABSOLUTE PERCENT ERROR	MAXIMUM ABSOLUTE PERCENT ERROR	STANDARD DEVIATION	CORRELATION CO-EFFICIENT
1	PRESENT	-4.17	10.77	0.03	29.57	14.04	0.9984
2	POETTMANN & BECK	69.90	69.90	57.65	86.30	68.93	0.9596
3	ASHFORD	53.34	53.34	47.30	60.98	54.01	0.9768
4	ASHFORD & PIERCE	-77.76	77.76	24.86	97.29	79.93	0.9457
5	OMANA	-34.79	34.79	14.31	91.56	42.34	0.9871
6	SACHDEVA	-69.90	69.90	56.53	83.14	68.87	0.9595
7	PERKINS	-36.52	36.52	21.04	61.62	34.69	0.9259

TABLE 5.14 SURFACE CHOKE TEST DATA OF TEST WELL NO.2

SL.NO	CHOKE SIZE (mm)	LIQUID FLOW RATE M^3/DAY	GOR (V/V)	THP Kg/Cm^2	FBHP Kg/Cm^2	DRAWDOWN (Kg/Cm^2)	PI
1	6	87.00	661.00	127.59	252.39	20.45	4.25
2	8	149.00	528.00	117.95	234.98	37.86	3.94
3	10	206.00	563.00	107.53	213.27	59.57	3.46
	SHUT IN			147.80			

TABLE 5.15 WELL TEST DATA THROUGH 10/64 INCH BOTTOMHOLE CHOKE (WELL NO.2)

SL.NO	SURFACE CHOKE SIZE (mm)	LIQUID FLOW RATE M^3/DAY	GOR (M^3/M^3)	GAS RATE M^3/DAY
1	8	163.00	574.00	93562.00
2	10	186.00	434.00	80724.00
3	12	185.00	382.00	70670.00

TABKE 5.16 RECORDED BOTTOMHOLE PRESSURE DATA WITH 10/64" BOTTOMHOLE CHOKE IN POSITION (TEST NO.2)

SURFACE CHOKE SIZE IN mm	SBHP IN Kg/Cm^2	FBHP IN Kg/Cm^2	DIFFERENTIAL PRESSURE IN Kg/Cm^2	CHOKE DOWN STREAM PRESSURE IN Kg/Cm^2
8	-	261.04	11.8	129.8
10	-	261.64	11.2	130.1
	272.84	-	-	-

TABLE 5.17 COMPARISION OF SURFACE CHOKE DATA WITH THAT OF BOTTOMHOLE CHOKE IN TERMS OF PRODUCTIVITY INDEX

STATIC BOTTOMHOLE PRESSURE = 272.84 Kg/Cm^2

SURFACE CHOKE SIZE IN mm	FBHP IN Kg/Cm^2	DIFFERENTIAL PRESSURE IN KG/CM^2 (SBHP-FBHP)	FLOW RATE M^3/DAY (Q_O)	PRODUCTIVITY INDEX (Q_O/(SBHP-FBHP))
BOTTOMHOLE CHOKE 10/64"				
8	265.54	11.8	163	13.81
10	266.14	11.2	186	16.6
SURFACE CHOKE				
	230*	42.84	168	3.8
	225.5*	50.34	186	3.69

* CALCULATED FROM SURFACE CHOKE IPR FOR THE FLOWRATES

TABKE 5.18 STATIC BOTTOMHOLE PRESSURE DATA

TEST NO	INITIAL SBHP IN Kg/Cm^2	FINAL SBHP IN Kg/Cm^2	CUMULATIVE OIL PRODUCTION METRIC TONS	REMARKS
1	292.8	278.79	824.39	SURFACE CHOKE
	278.79	272.84	24652.90	BOTTOMHOLE CHOKE
2	282.5	276.6	3736.10	SURFACE CHOKE
	276.6	275.45	20043.60	BOTTOMHOLE CHOKE

TABKE 5.19 CHANGE IN STATIC BOTTOMHOLE PREESURE PER TON OF OIL PRODUCTION

TEST NO	INITIAL SBHP IN Kg/Cm^2	FINAL SBHP IN Kg/Cm^2	CUMULATIVE OIL PRODUCTION METRIC TONS	CHANGE IN SBHP IN Kg/Cm^2	CHANGE IN SBHP IN Kg/Cm^2 PER TON OF OIL (10^5)
SURFACE CHOKE					
1	292.8	278.79	824.39	14.01	1699.44
2	282.5	276.6	3736.1	5.9	157.92
BOTTOMHOLE CHOKE					
1	278.79	272.84	20043.6	5.95	29.69
2	276.6	275.45	24652.9	1.15	4.66

TABLE 5.20 COMPARISON OF ENERGY SPENT IN LIFTING UNIT MASS OF OIL
(SURFACE CHOKE VS BOTTOMHOLE CHOKE)

ENERGY SPENT IN LIFTING UNIT MASS OF OIL IN 10^4 JOULES

TEST NO	SURFACE CHOKE	BOTTOMHOLE CHOKE	ENERGY CONSERVATION BY BOTTOMHOLE CHOKE
1	17166.90	4309.44	12857.46
2	4960.55	3571.83	1388.72
3	16824.17	6074.78	10749.39
4	7893.70	3838.21	4055.49
5	15653.71	10856.21	4797.50
6	21093.81	12708.58	8385.23
7	13273.85	6537.97	6735.88
8	12194.65	6336.97	5857.68
9	9730.51	6075.89	3654.62
10	20845.58	6537.20	14308.38

TABLE 5.21 BOTTOMHOLE CHOKE SIZE SELECTION TEST NO.1

RESERVOIR PRESSURE	= 4266	Psi
RESERVOIR TEMPERATURE	= 266	^{0}F
FORMATION VOLUME FACTOR	= 1.707	
TEST GAS OIL RATIO	= 3208	Scf/Bbl
SOLUTION GAS OIL RATIO	= 2472	Scf/Bbl
REQUIRED TUBINGHEAD PRESSURE	= 750	Psi

CHOKE SIZE 1/64 INCH	FLOW RATE BBLS/DAY	AFTER CHOKE PRESSURE FROM BOTTOM (Psi)	AFTER CHOKE PRESSURE FROM SURFACE (Psi)
6	206	1997	1808
8	366	1799	1745
10	573	1544	1664
12	825	1233	1555
14	1123	864	1428
16	1467	440	1347

TABLE 5.22 BOTTOMHOLE CHOKE SIZE SELECTION, TEST NO.2

RESERVOIR PRESSURE = 4133 Psi
RESERVOIR TEMPERATURE = 262 ^{0}F
FORMATION VOLUME FACTOR = 1.555
TEST GAS OIL RATIO = 2673 Scf/Bbl
SOLUTION GAS OIL RATIO = 2156 Scf/Bb
REQUIRED TUBINGHEAD PRESSURE = 750 Psi

CHOKE SIZE 1/64 INCH	FLOW RATE BBLS/DAY	AFTER CHOKE PRESSURE FROM BOTTOM (Psi)	AFTER CHOKE PRESSURE FROM SURFACE (Psi)
6	179	2131	2344
8	318	2092	2335
10	497	2041	2315
12	716	1980	2286
14	975	1907	2257
16	1274	1823	2228
18	1612	1727	2189
20	1990	1621	2140

TABLE 5.23 BOTTOMHOLE CHOKE SIZE SELECTION, TEST NO.3

RESERVOIR PRESSURE	= 4076 Psi
RESERVOIR TEMPERATURE	= 262 ^{0}F
FORMATION VOLUME FACTOR	= 2.616
TEST GAS OIL RATIO	= 4655 Scf/Bbl
SOLUTION GAS OIL RATIO	= 2300 Scf/Bbl
REQUIRED TUBINGHEAD PRESSURE	= 750 Psi

CHOKE SIZE 1/64 INCH	FLOW RATE BBLS/DAY	AFTER CHOKE PRESSURE FROM BOTTOM (Psi)	AFTER CHOKE PRESSURE FROM SURFACE (Psi)
6	169	2012	1410
8	301	1903	1390
10	470	1763	1371
12	677	1592	1351
14	922	1390	1332
16	1204	1156	1351
18	1524	892	1497
20	1882	597	2206

TABLE 5.24 BOTTOMHOLE CHOKE SIZE SELECTION TEST NO.4

RESERVOIR PRESSURE	= 4214Psi
RESERVOIR TEMPERATURE	= 270 ^{0}F
FORMATION VOLUME FACTOR	= 1.9568
TEST GAS OIL RATIO	= 2875 Scf/Bbl
SOLUTION GAS OIL RATIO	= 1344 Scf/Bbl
REQUIRED TUBINGHEAD PRESSURE	= 750 Psi

CHOKE SIZE 1/64 INCH	FLOW RATE BBLS/DAY	AFTER CHOKE PRESSURE FROM BOTTOM (Psi)	AFTER CHOKE PRESSURE FROM SURFACE (Psi)
6	200	1914	1459
8	356	1673	1410
10	557	1363	1341
12	803	983	1272
14	1092	535	1321
16	1427	18	2557

TABLE 5.25 BOTTOMHOLE CHOKE SIZE SELECTION, TEST NO. 5

RESERVOIR PRESSURE	= 1971 Psi
RESERVOIR TEMPERATURE	= 280 ^{0}F
FORMATION VOLUME FACTOR	= 2.8619
TEST GAS OIL RATIO	= 9844 Scf/Bbl
SOLUTION GAS OIL RATIO	= 3256 Scf/Bbl
REQUIRED TUBINGHEAD PRESSURE	= 750 Psi

CHOKE SIZE 1/64 INCH	FLOW RATE BBLS/DAY	AFTER CHOKE PRESSURE FROM BOTTOM (Psi)	AFTER CHOKE PRESSURE FROM SURFACE (Psi)
6	95	1008	977
8	169	983	977
10	264	950	998
12	380	911	1029
14	517	864	1101
16	675	810	1235
18	855	748	1473
20	1055	680	1927

TABLE 5.26 BOTTOMHOLE CHOKE SIZE SELECTION, TEST NO.6

RESERVOIR PRESSURE	= 4233 Psi
RESERVOIR TEMPERATURE	= 267 ^{0}F
FORMATION VOLUME FACTOR	= 1.805
TEST GAS OIL RATIO	= 9844 Scf/Bbl
SOLUTION GAS OIL RATIO	= 1630 Scf/Bbl
REQUIRED TUBINGHEAD PRESSURE	= 750 Psi

CHOKE SIZE 1/64 INCH	FLOW RATE BBLS/DAY	AFTER CHOKE PRESSURE FROM BOTTOM (Psi)	AFTER CHOKE PRESSURE FROM SURFACE (Psi)
6	178	1781	1068
8	317	1427	1106
10	495	972	1366
12	713	417	5096

TABLE 5.27 BOTTOMHOLE CHOKE SIZE SELECTION, TEST NO.7

RESERVOIR PRESSURE	= 4162 Psi
RESERVOIR TEMPERATURE	= 262 ^{0}F
FORMATION VOLUME FACTOR	= 2.4787
TEST GAS OIL RATIO	= 4988 Scf/Bbl
SOLUTION GAS OIL RATIO	= 2460 Scf/Bbl
REQUIRED TUBINGHEAD PRESSURE	= 750 Psi

CHOKE SIZE 1/64 INCH	FLOW RATE BBLS/DAY	AFTER CHOKE PRESSURE FROM BOTTOM (Psi)	AFTER CHOKE PRESSURE FROM SURFACE (Psi)
6	175	2113	1366
8	311	2048	1356
10	486	1964	1347
12	700	1862	1337
14	952	1740	1337
16	1244	1601	1356
18	1575	1442	1394
20	1944	1265	1508

TABLE 5.28 BOTTOMHOLE CHOKE SIZE SELECTION, TEST NO.8

RESERVOIR PRESSURE = 4233 Psi
RESERVOIR TEMPERATURE = 262 ^{0}F
FORMATION VOLUME FACTOR = 2.5588
TEST GAS OIL RATIO = 4673 Scf/Bbl
SOLUTION GAS OIL RATIO = 3516 Scf/Bbl
REQUIRED TUBINGHEAD PRESSURE = 750 Psi

CHOKE SIZE 1/64 INCH	FLOW RATE BBLS/DAY	AFTER CHOKE PRESSURE FROM BOTTOM (Psi)	AFTER CHOKE PRESSURE FROM SURFACE (Psi)
6	178	2063	1751
8	318	1930	1713
10	497	1758	1655
12	715	1548	1597
14	974	1301	1520
16	1272	1015	1443
18	1610	691	1424
20	1988	329	2079

TABLE 5.29 BOTTOMHOLE CHOKE SIZE SELECTION, TEST NO.9

RESERVOIR PRESSURE	= 4076 Psi
RESERVOIR TEMPERATURE	= 262 ^{0}F
FORMATION VOLUME FACTOR	= 2.6161
TEST GAS OIL RATIO	= 4655 Scf/Bbl
SOLUTION GAS OIL RATIO	= 3300 Scf/Bbl
REQUIRED TUBINGHEAD PRESSURE	= 750 Psi

CHOKE SIZE 1/64 INCH	FLOW RATE BBLS/DAY	AFTER CHOKE PRESSURE FROM BOTTOM (Psi)	AFTER CHOKE PRESSURE FROM SURFACE (Psi)
6	172	1875	1593
8	307	1661	1537
10	480	1385	1462
12	691	1047	1368
14	941	648	1284
16	1229	188	2550

TABLE 5.30 BOTTOMHOLE CHOKE SIZE SELECTION, TEST NO.10

RESERVOIR PRESSURE	= 4162	Psi
RESERVOIR TEMPERATURE	= 262	^{0}F
FORMATION VOLUME FACTOR	= 2.4787	
TEST GAS OIL RATIO	= 4988	Scf/Bbl
SOLUTION GAS OIL RATIO	= 2460	Scf/Bbl
REQUIRED TUBINGHEAD PRESSURE	= 750	Psi

CHOKE SIZE 1/64 INCH	FLOW RATE BBLS/DAY	AFTER CHOKE PRESSURE FROM BOTTOM (Psi)	AFTER CHOKE PRESSURE FROM SURFACE (Psi)
6	175	2091	1350
8	311	2009	1331
10	486	1903	1322
12	700	1774	1313
14	952	1621	1313
16	1244	1444	1322
18	1575	1244	1396
20	1944	1021	1590

TABLE 5.31 COMPARISION OF THP PREDICTION BY CHOKE SIZE SELECTION PROCEDURE WITH THAT OF MEASURED

Test No.	Measured THP in PSI	Predicted THP in PSI
1	441	428
2	421	452
3	1172	1174
4	967	1013
5	597	632
6	1138	1071
7	1123	1274
8	711	701
9	435	429
10	1306	1331

FIGURES OF CHAPTER-V

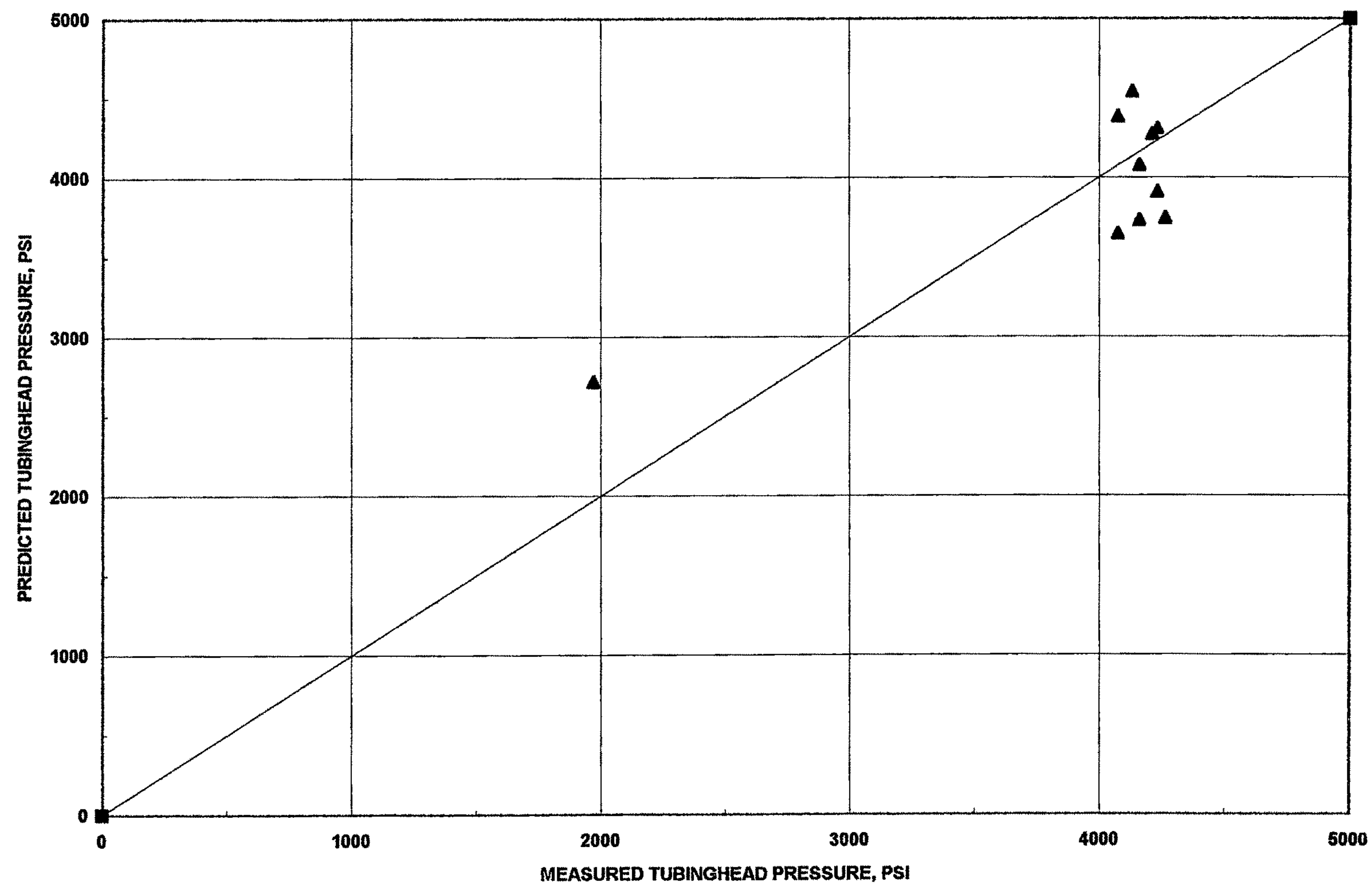


FIGURE 5.2 CROSS PLOT FOR BOTTOMHOLE CHOKE TUBINGHEAD PRESSURE - PRESENT EMPIRICAL CORRELATION

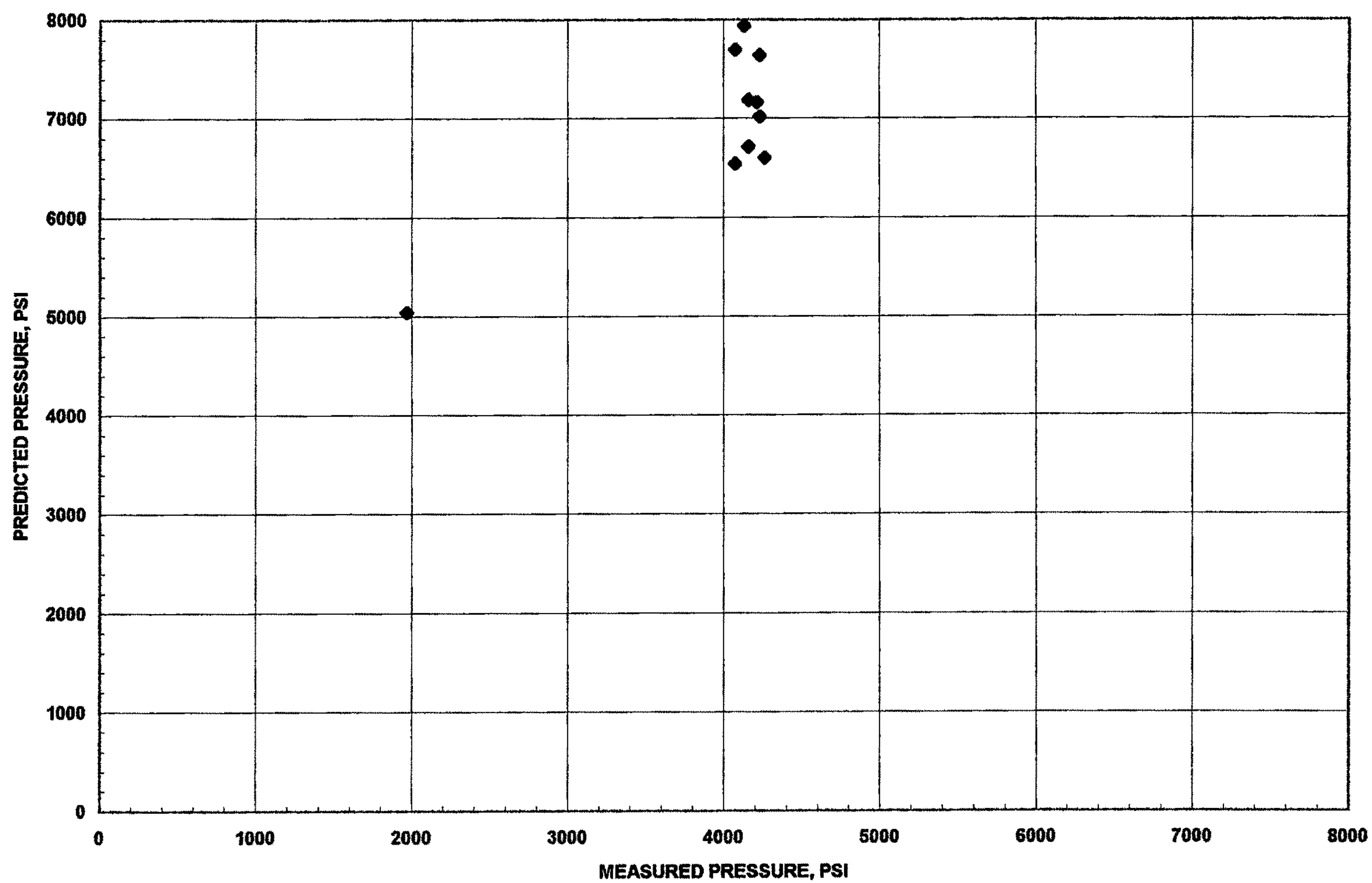


FIGURE 5.3 CROSS PLOT FOR BOTTOMHOLE CHOKE TUBINGHEAD PRESSURE - GILBERT'S CORRELATION

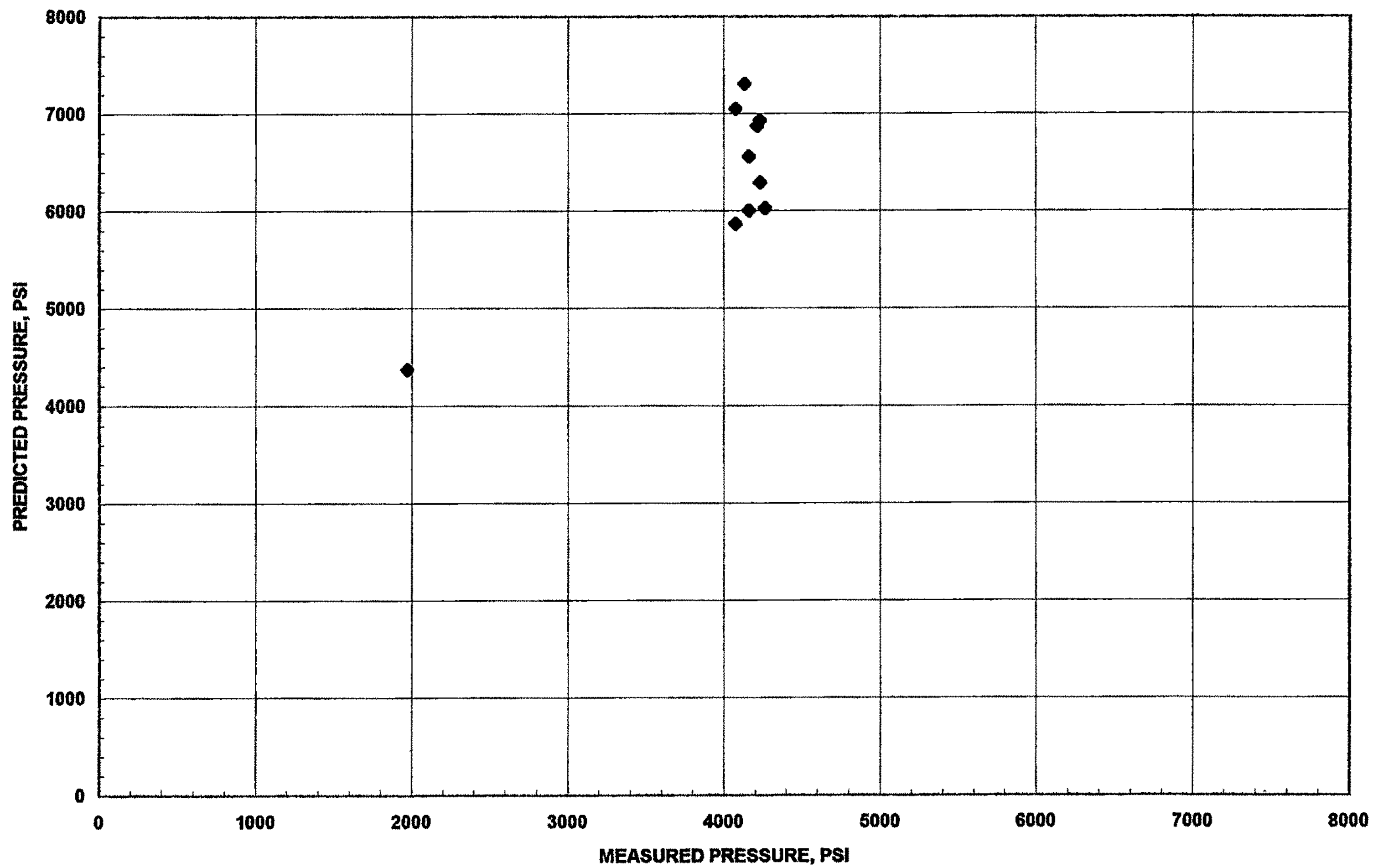


FIGURE 5.4 CROSS PLOT FOR BOTTOMHOLE CHOKE TUBINGHEAD PRESSURE - ROS'S CORRELATION

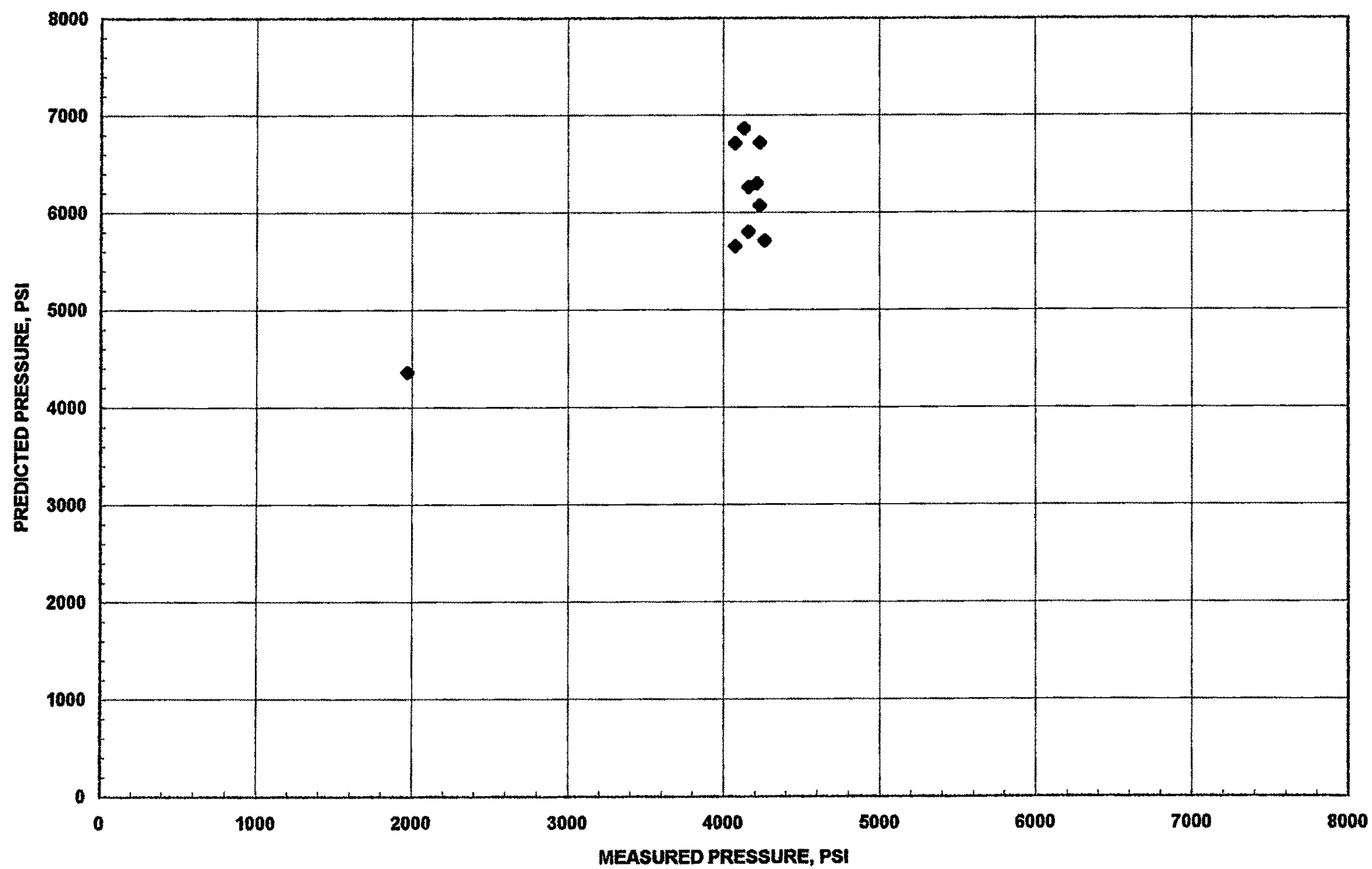


FIGURE 5.5 CROSS PLOT FOR BOTTOMHOLE CHOKE TUBINGHEAD PRESSURE - BAXENDELL'S CORRELATION

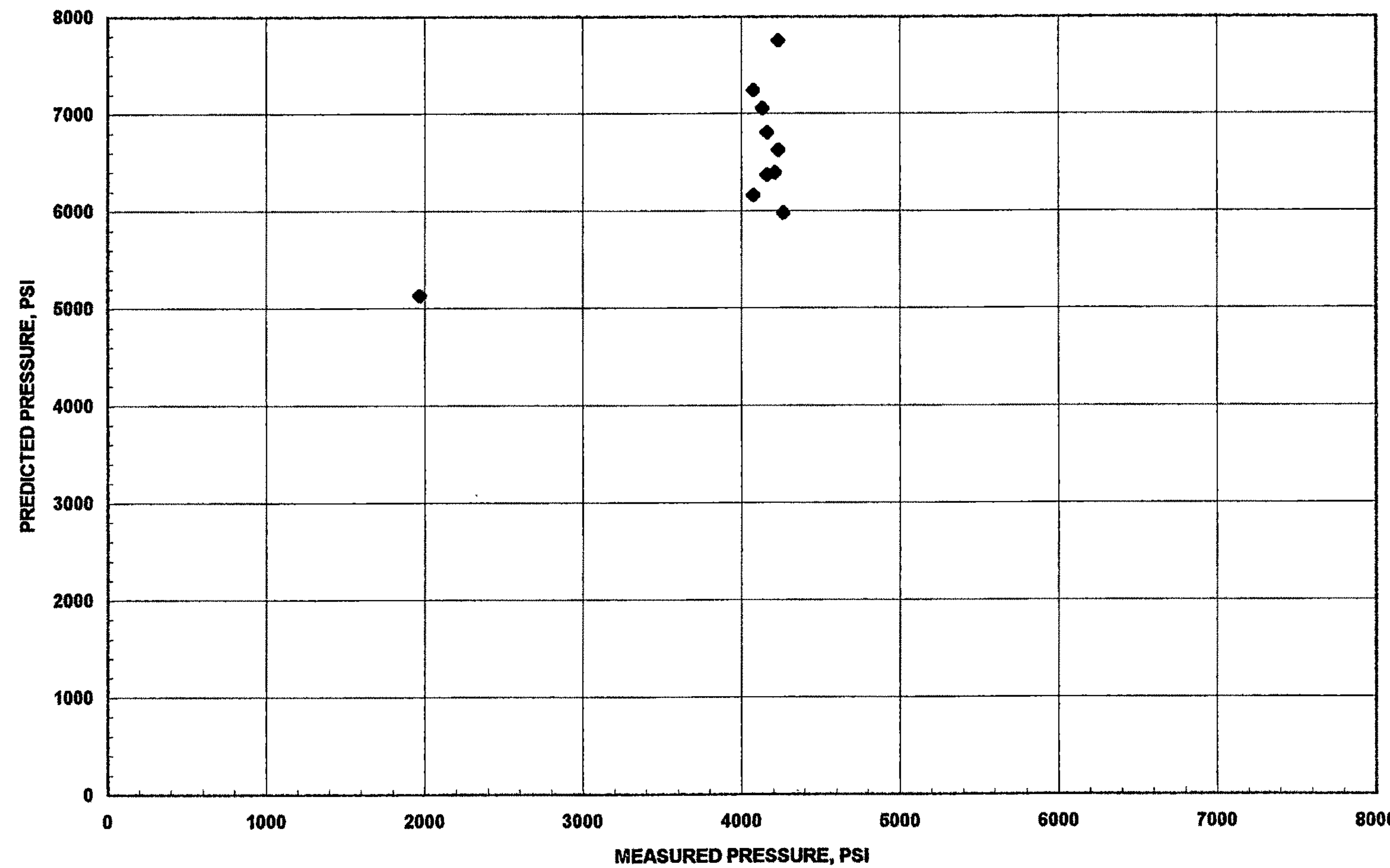


FIGURE 5.6 CROSS PLOT FOR BOTTOMHOLE CHOKE TUBINGHEAD PRESSURE - ACHONG'S CORRELATION

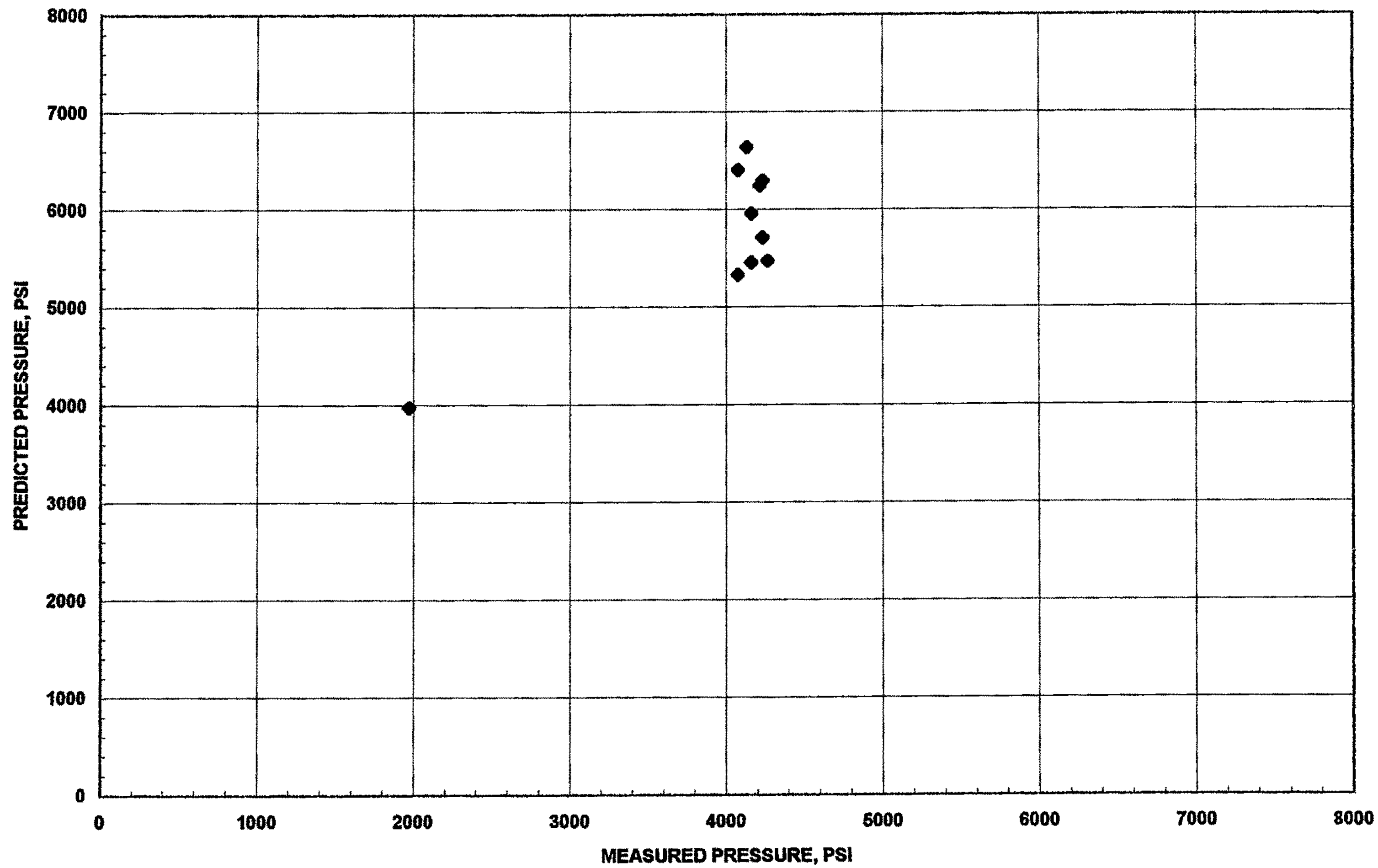


FIGURE 5.7 CROSS PLOT FOR BOTTOMHOLE CHOKE TUBINGHEAD PRESSURE - MACH'S CORRELATION

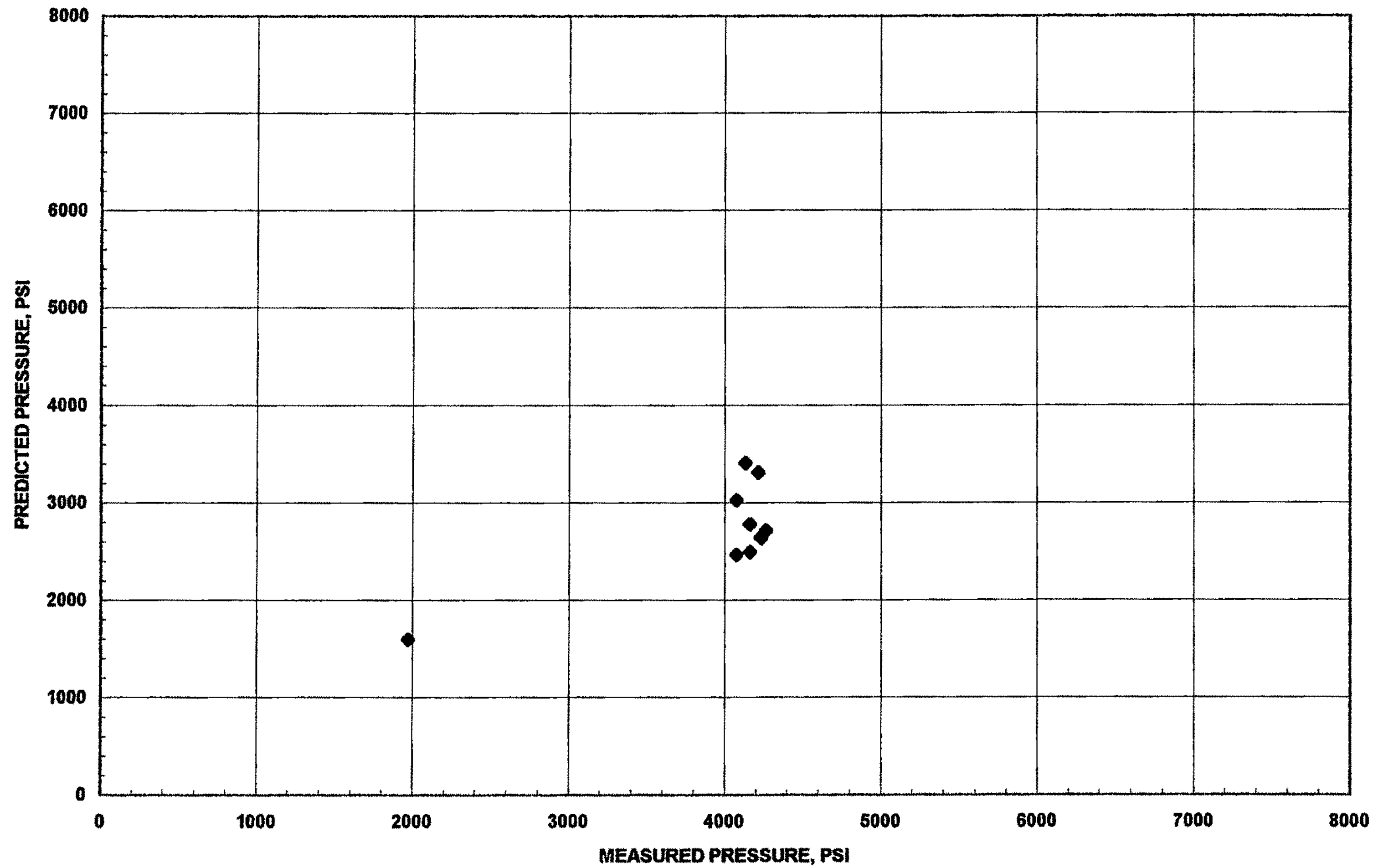


FIGURE 5.8 CROSS PLOT FOR BOTTOMHOLE CHOKE TUBINGHEAD PRESSURE - PILEHVARI'S CORRELATION

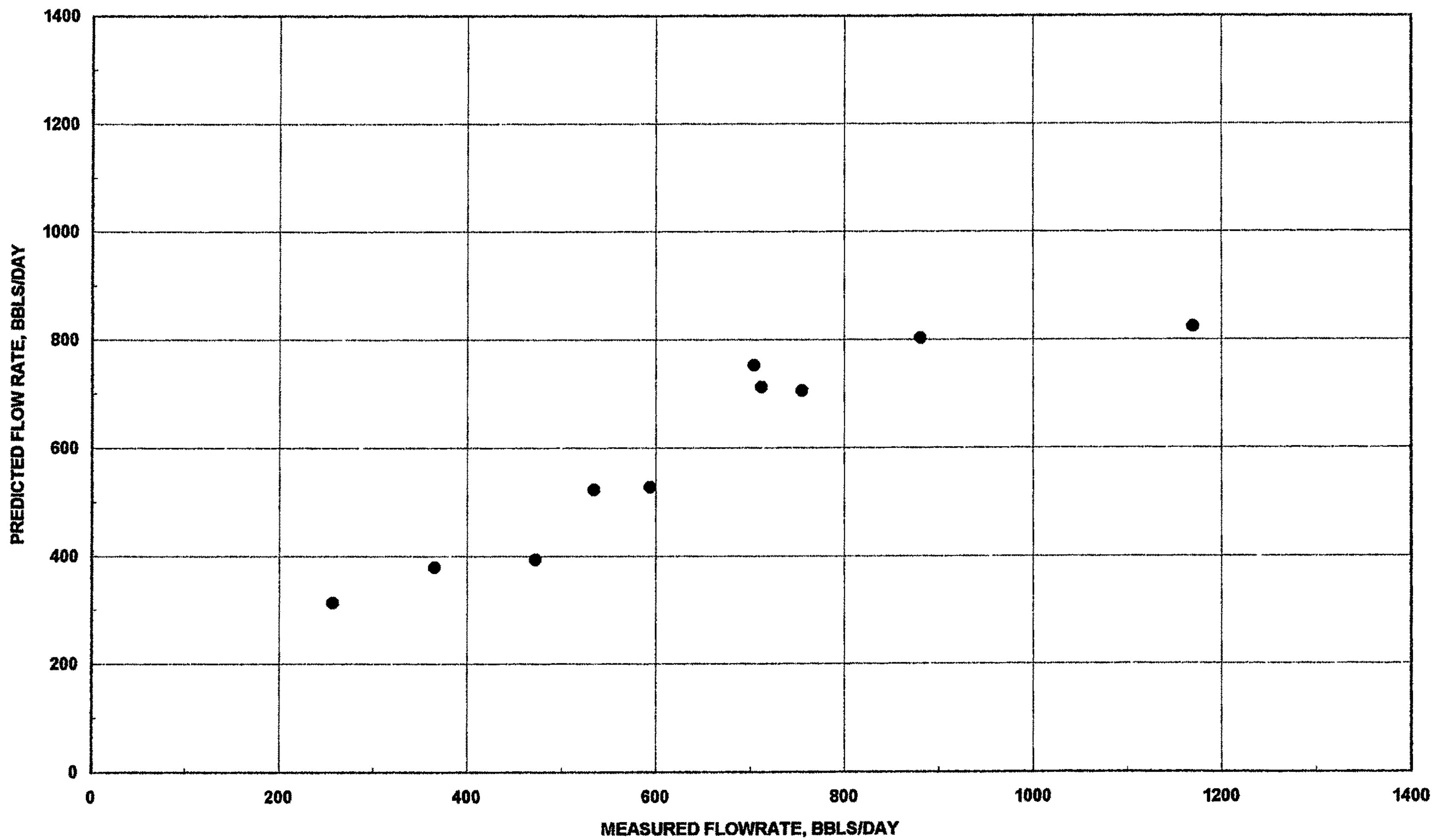


FIGURE 5.9 CROSS PLOT FOR BOTTOMHOLE CHOKE FLOW RATE - PRESENT THEORETICAL MODEL

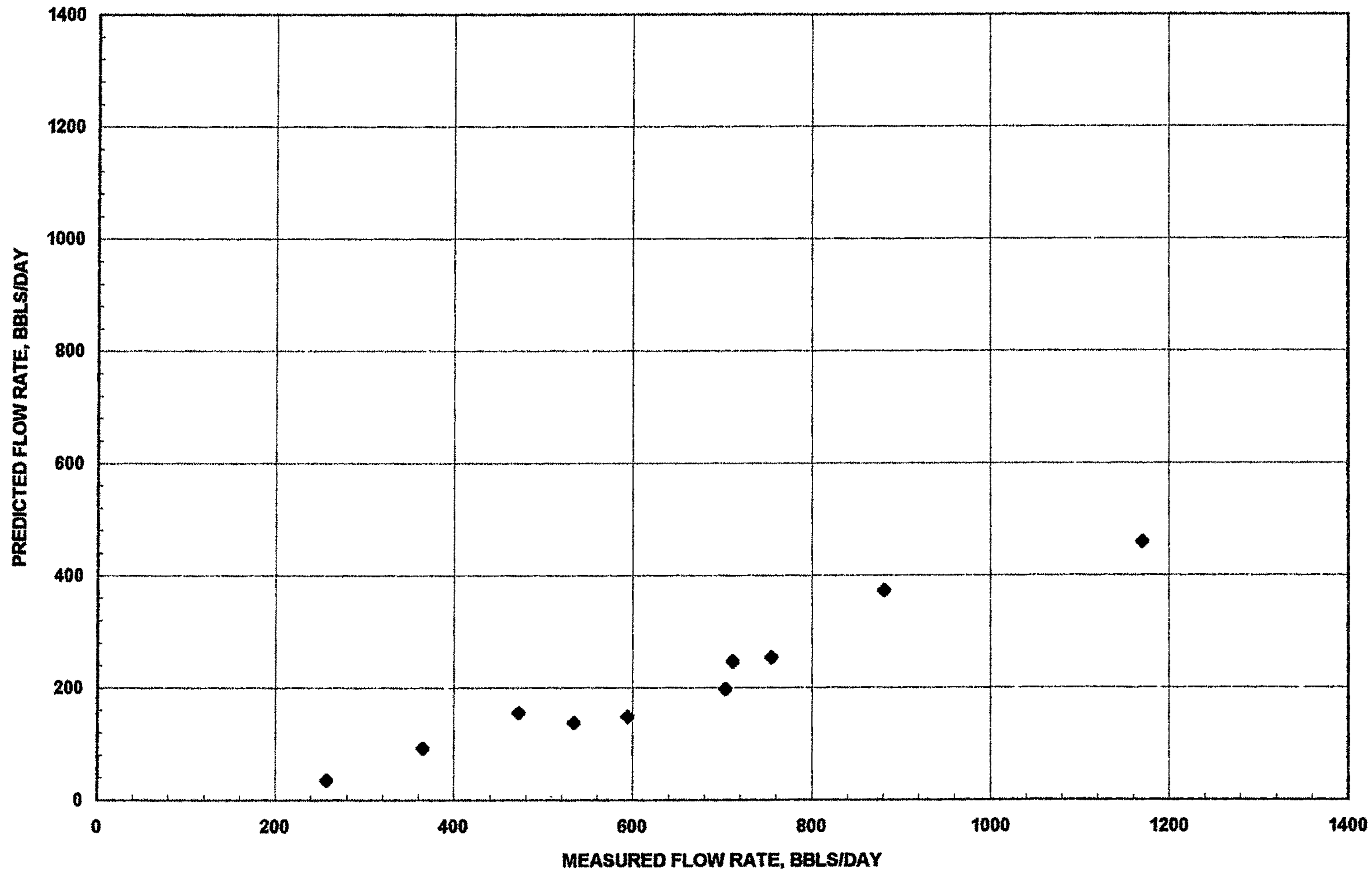


FIGURE 5.10 CROSS PLOT FOR BOTTOMHOLE CHOKE FLOW RATE - POETTMANN AND BECK CORRELATION

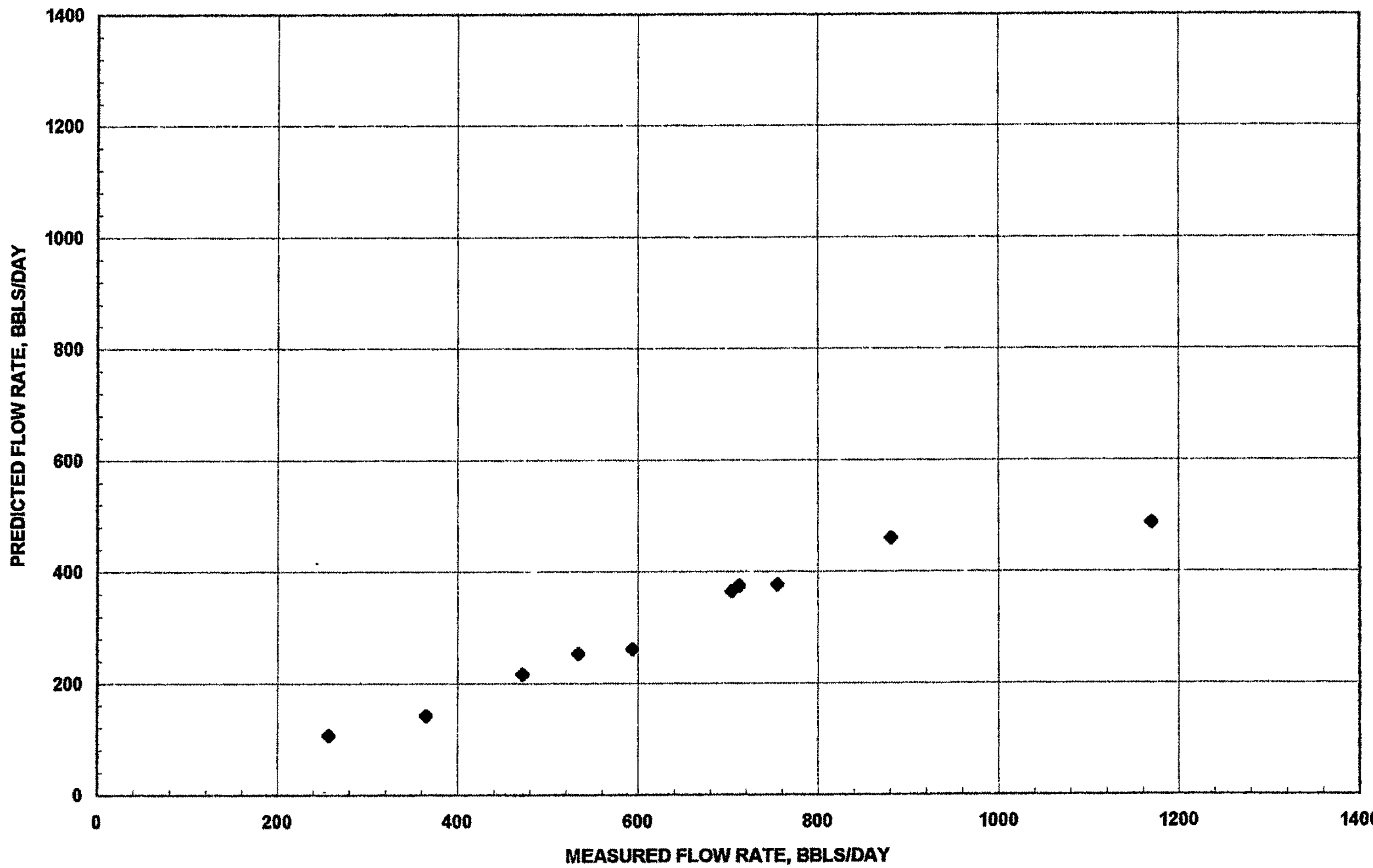


FIGURE 5.11 CROSS PLOT FOR BOTTOMHOLE CHOKE FLOW RATE - ASHFORD'S CORRELATION

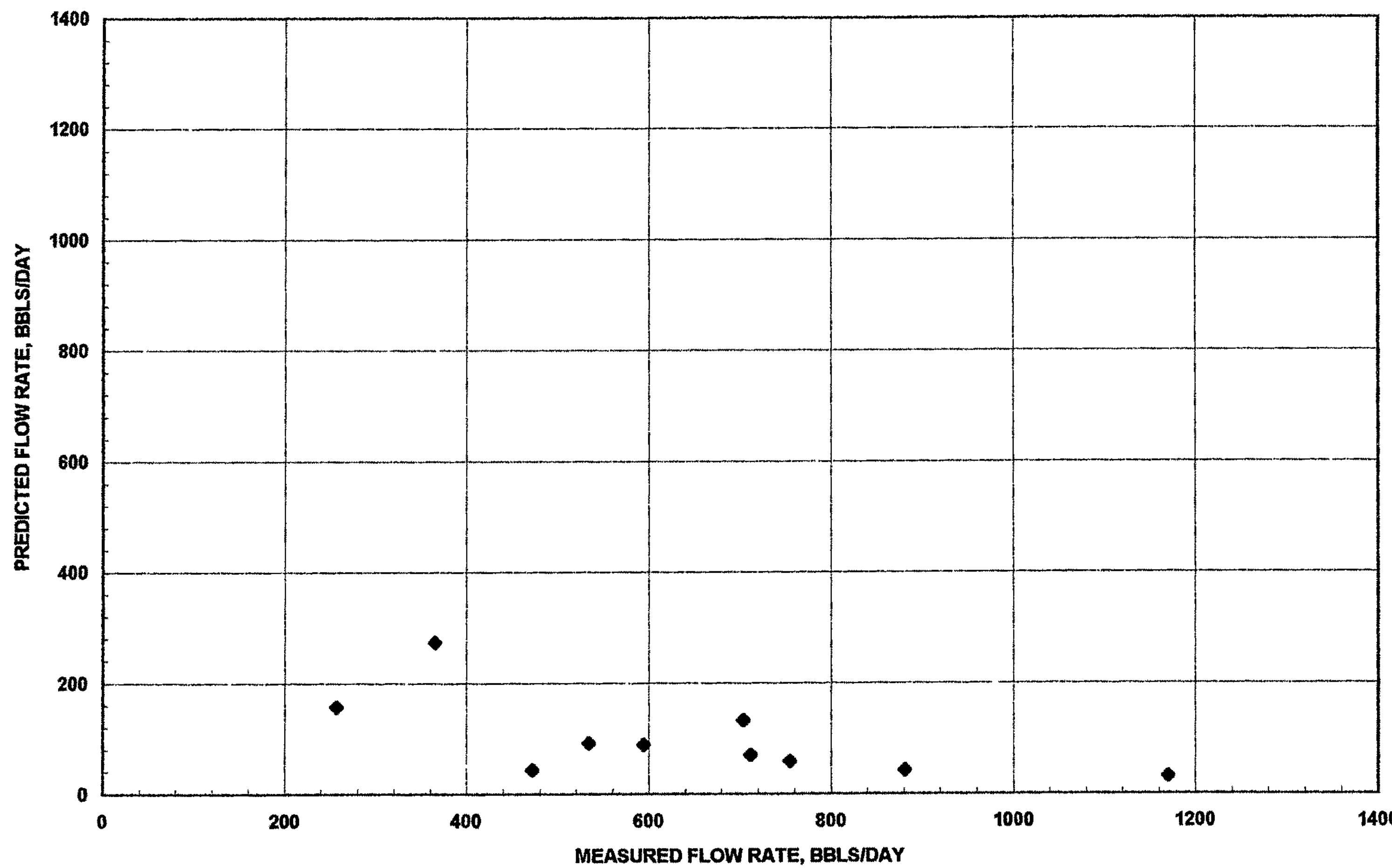


FIGURE 5.12 CROSS PLOT FOR BOTTOMHOLE CHOKE FLOW RATE - ASHFORD AND PIERCE CORRELATION

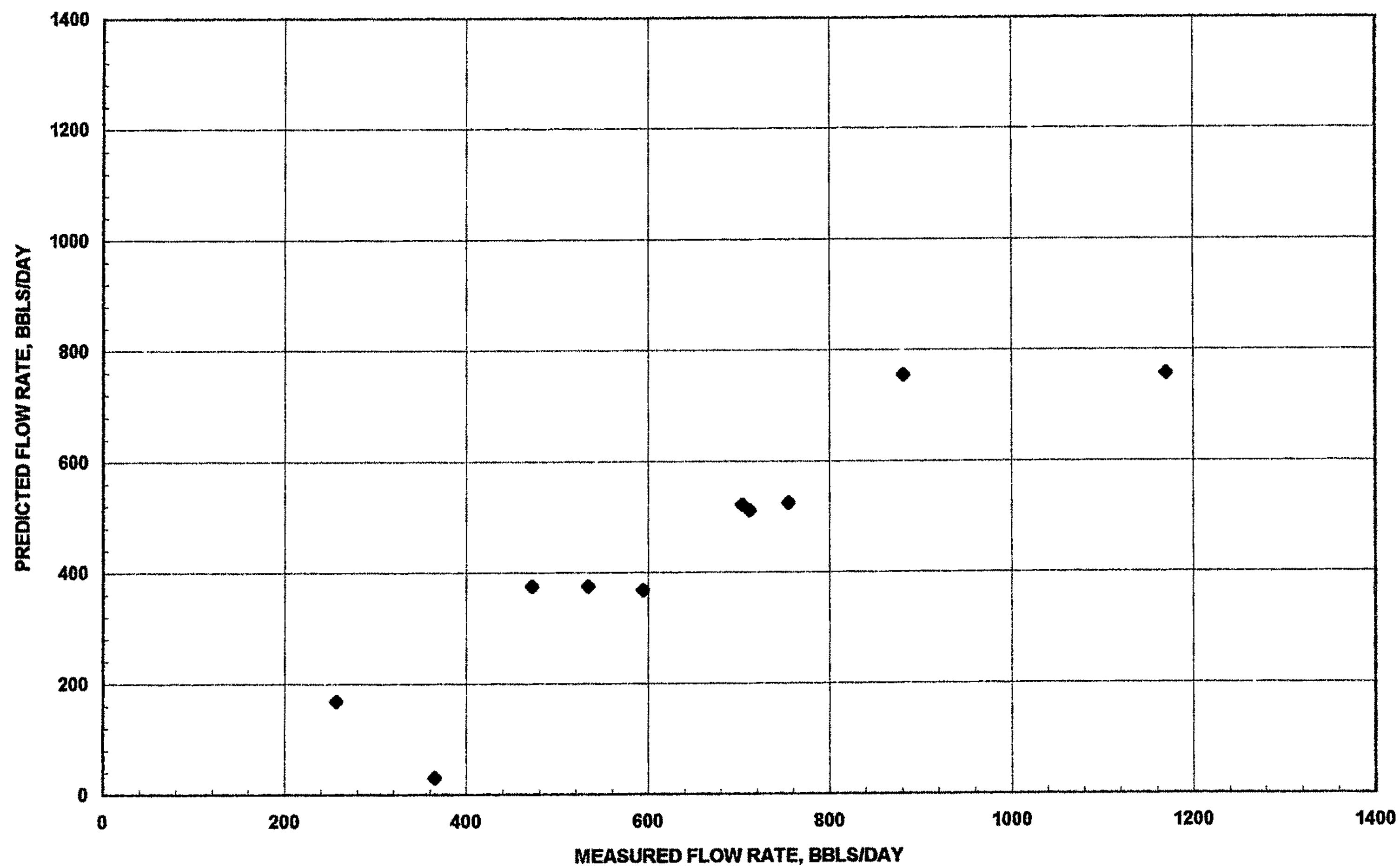


FIGURE 5.13 CROSS PLOT FOR BOTTOMHOLE CHOKE FLOW RATE - OMANA'S CORRELATION

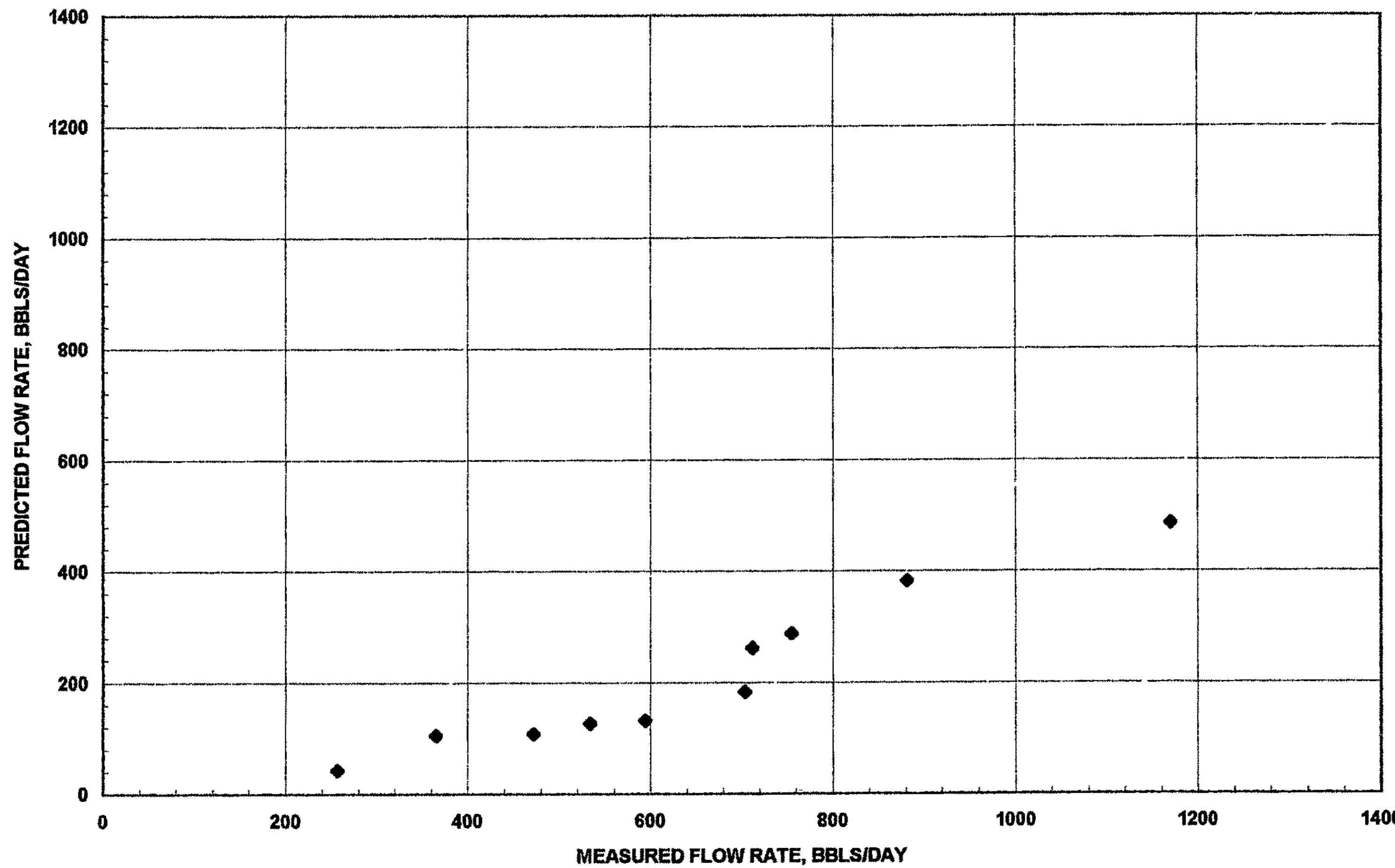


FIGURE 5.14 CROSS PLOT FOR BOTTOMHOLE CHOKE FLOW RATE - SACHDEVA'S CORRELATION

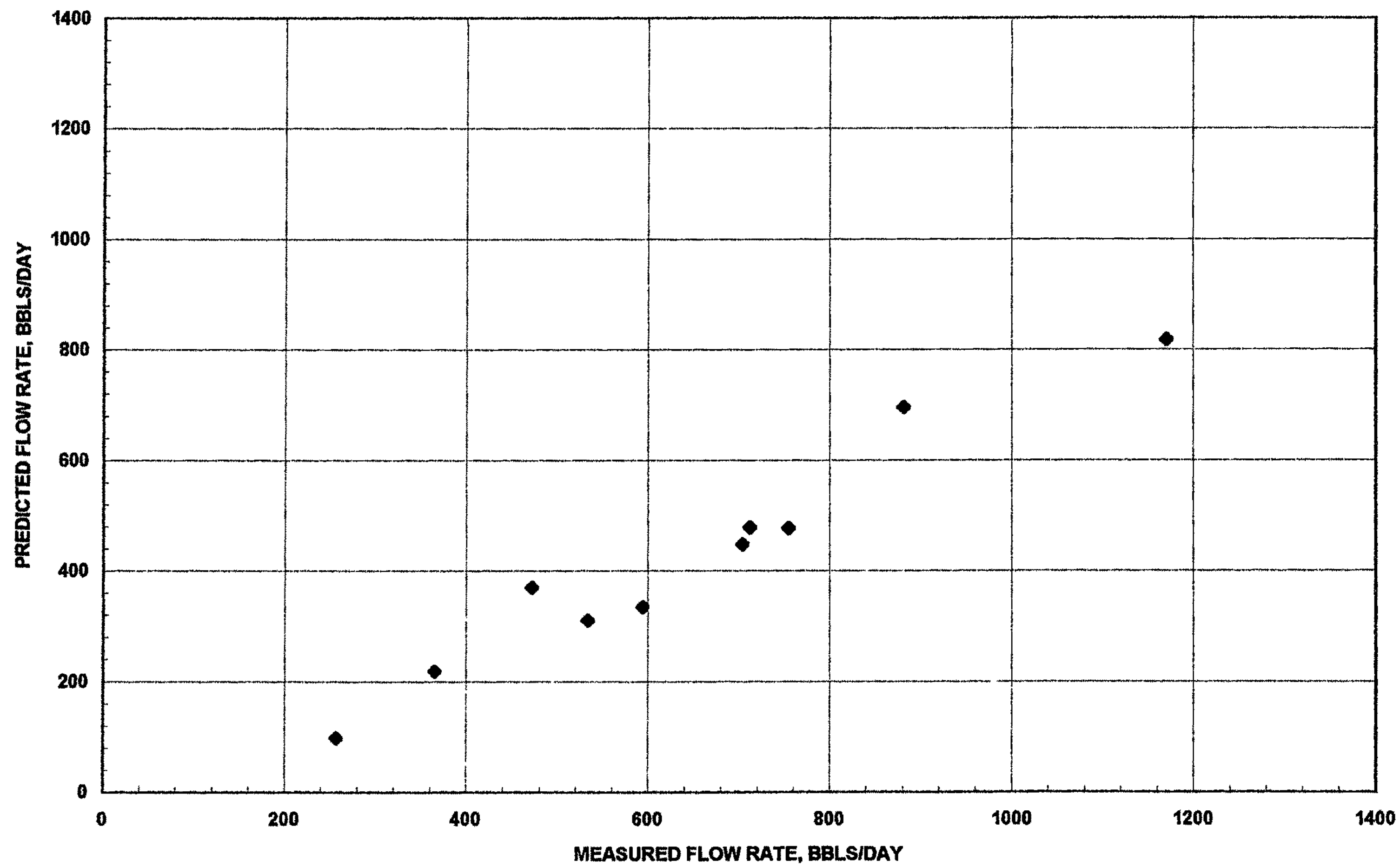


FIGURE 5.15 CROSS PLOT FOR BOTTOMHOLE CHOKE FLOW RATE - PERKIN'S CORRELATION

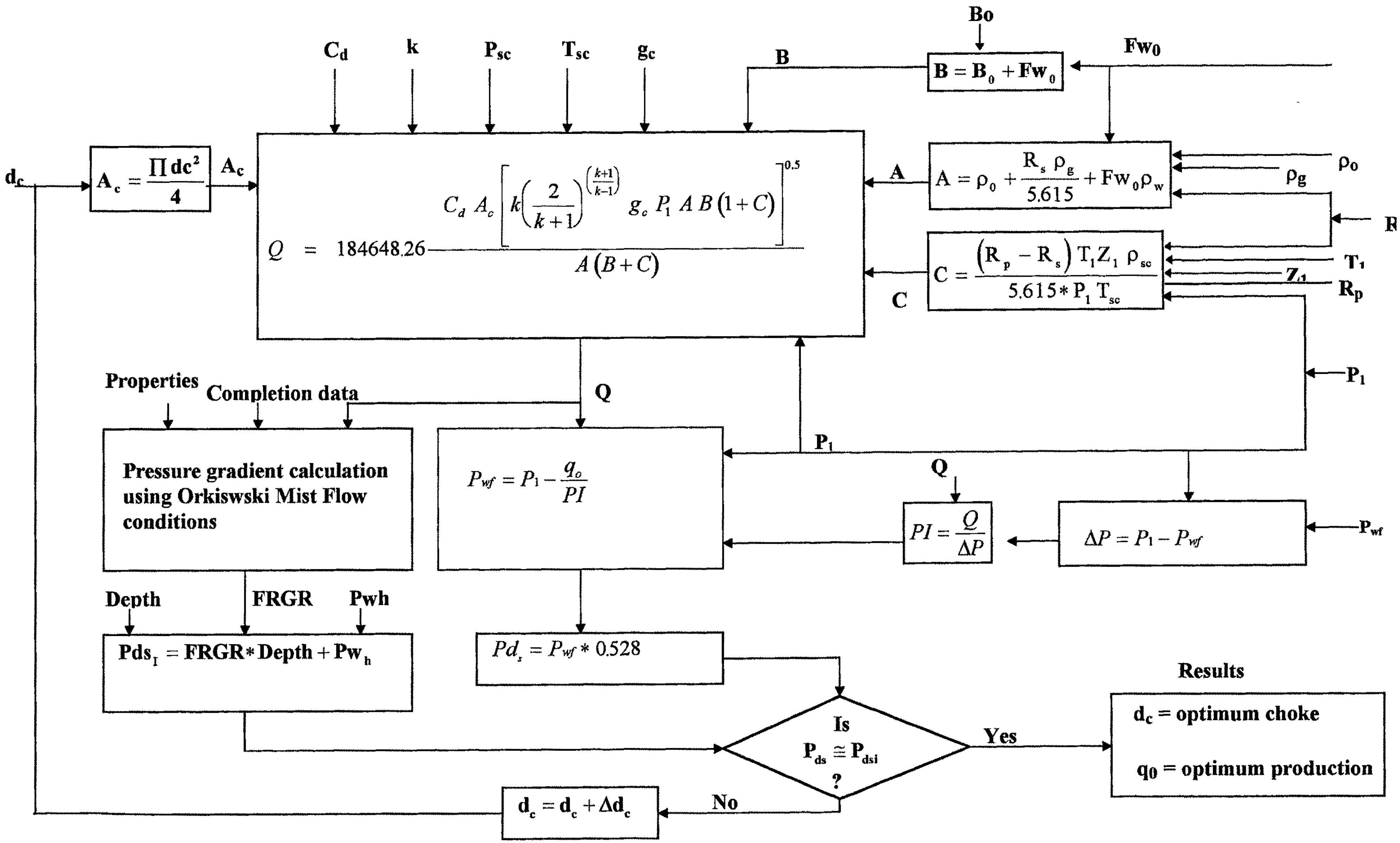


Fig. 5.17 Block diagram for choke size selection

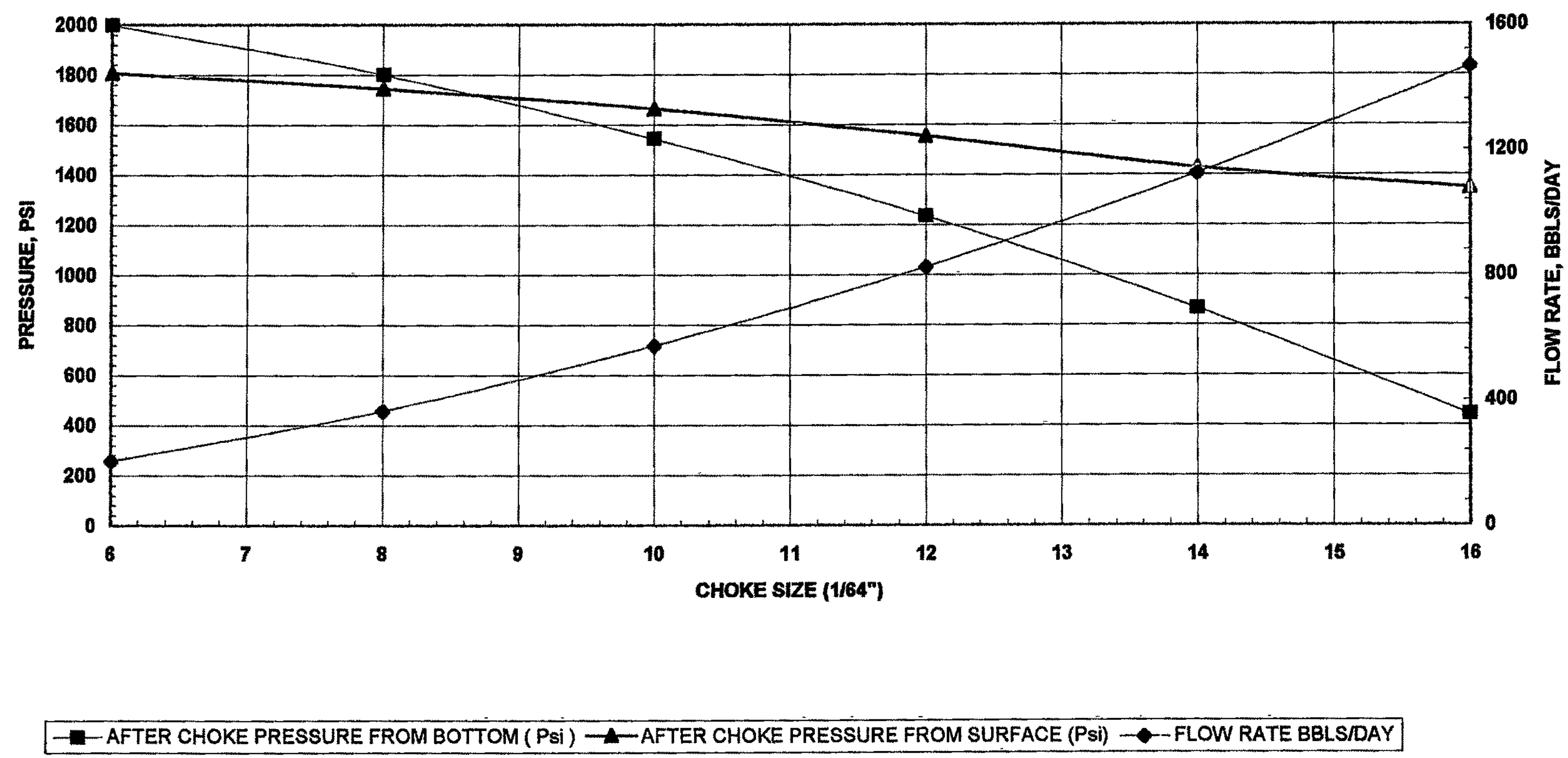


FIGURE 5.18 BOTTOMHOLE CHOKE SIZE SELECTION (TEST NO. 1)

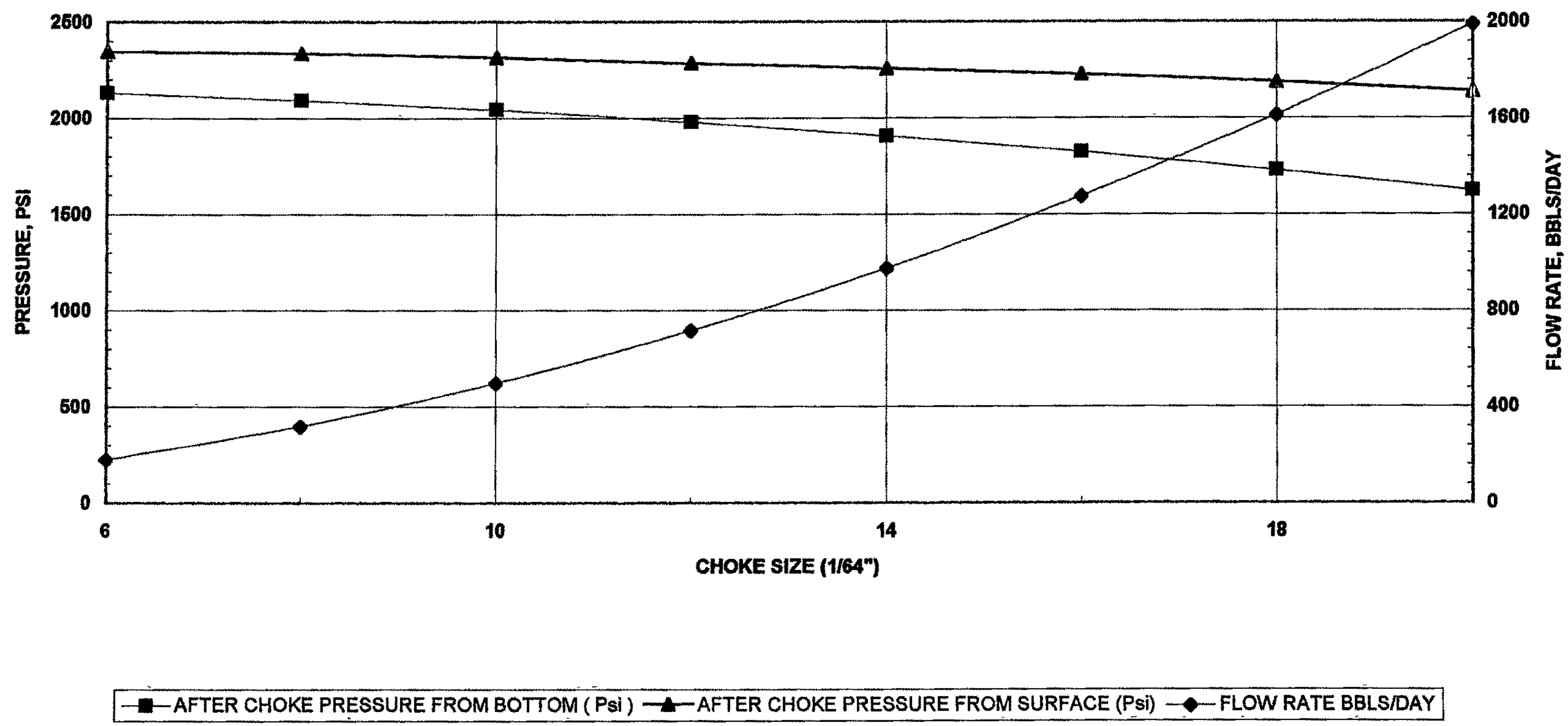


FIGURE 5.19 BOTTOMHOLE CHOKE SIZE SELECTION (TEST NO. 2)

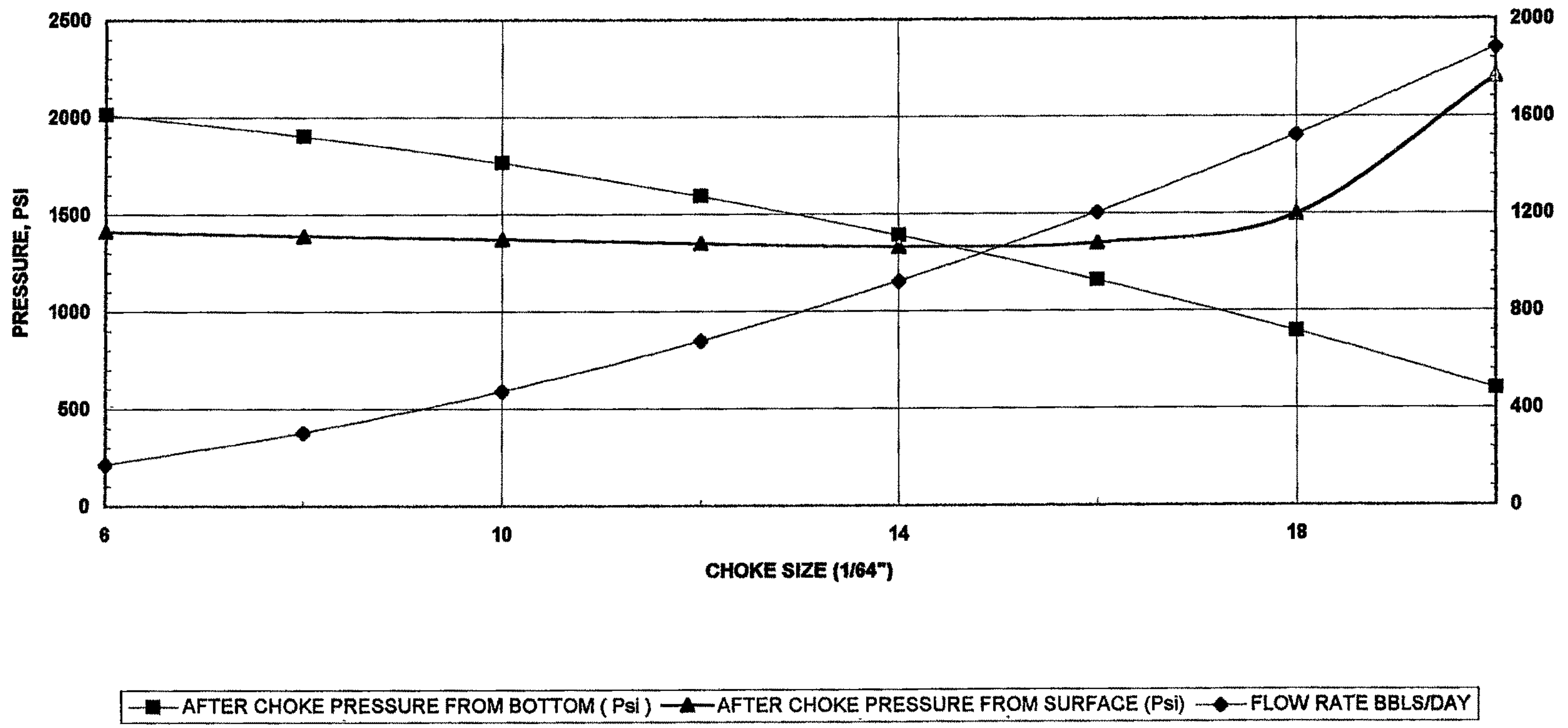


FIGURE 5.20 BOTTOMHOLE CHOKE SIZE SELECTION (TEST NO. 3)

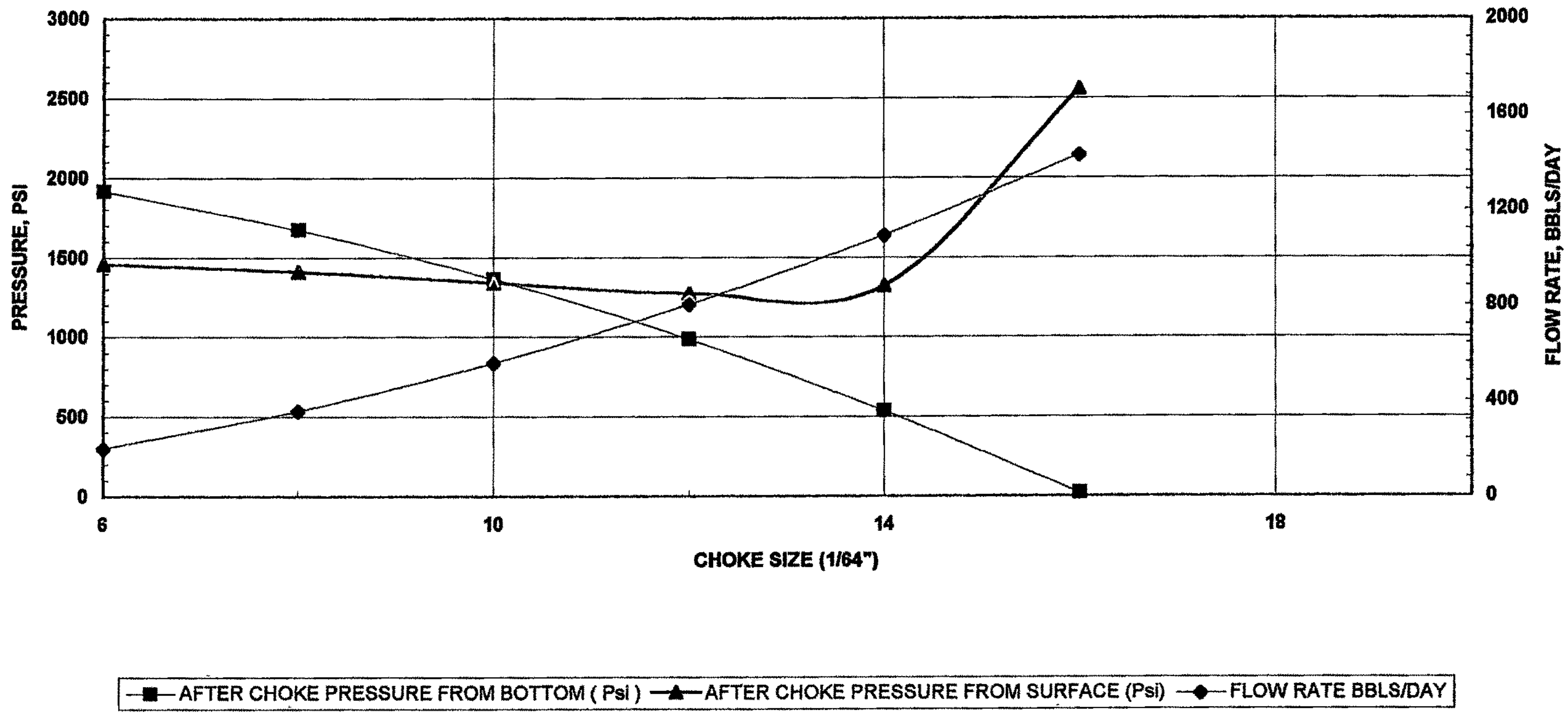


FIGURE 5.21 BOTTOMHOLE CHOKE SIZE SELECTION (TEST NO. 4)

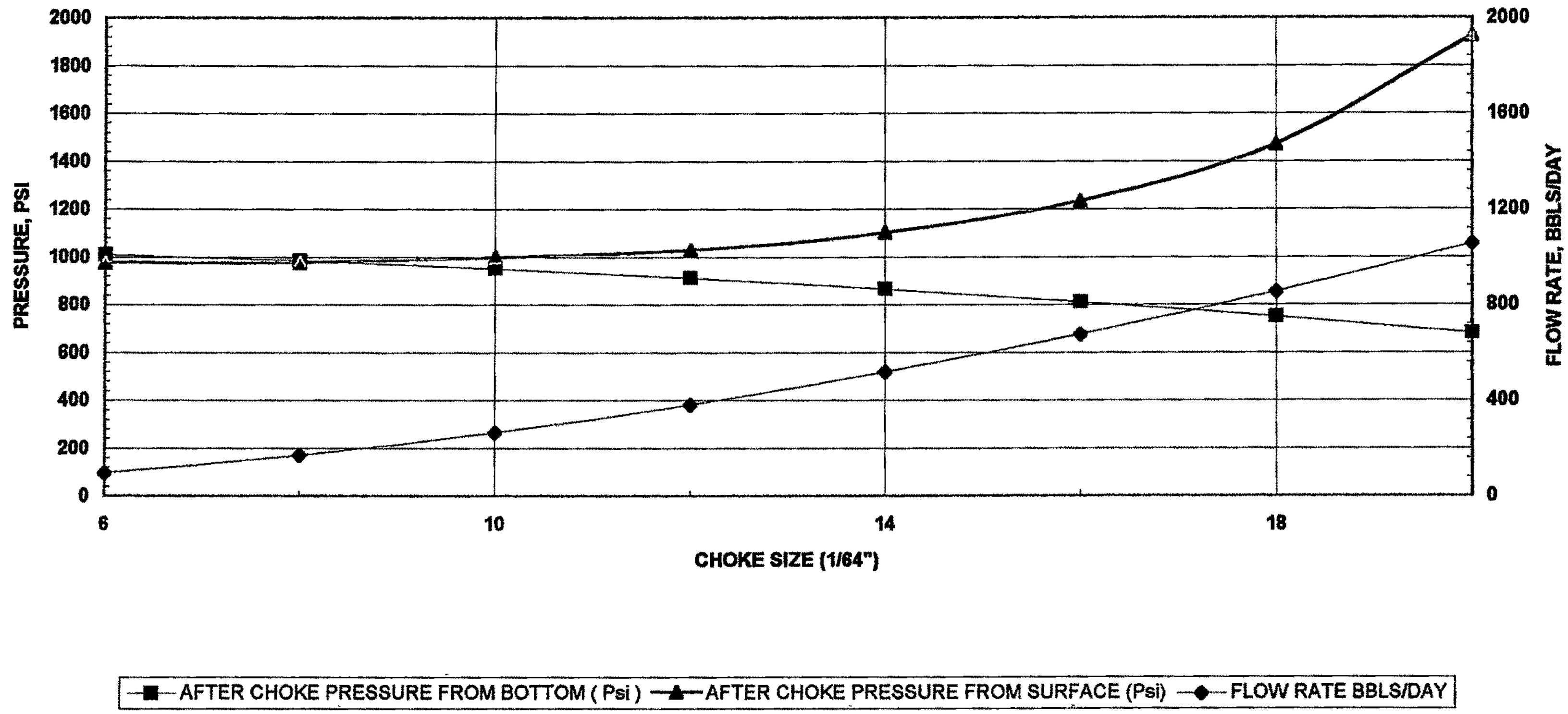


FIGURE 5.22 BOTTOMHOLE CHOKE SIZE SELECTION (TEST NO.5)

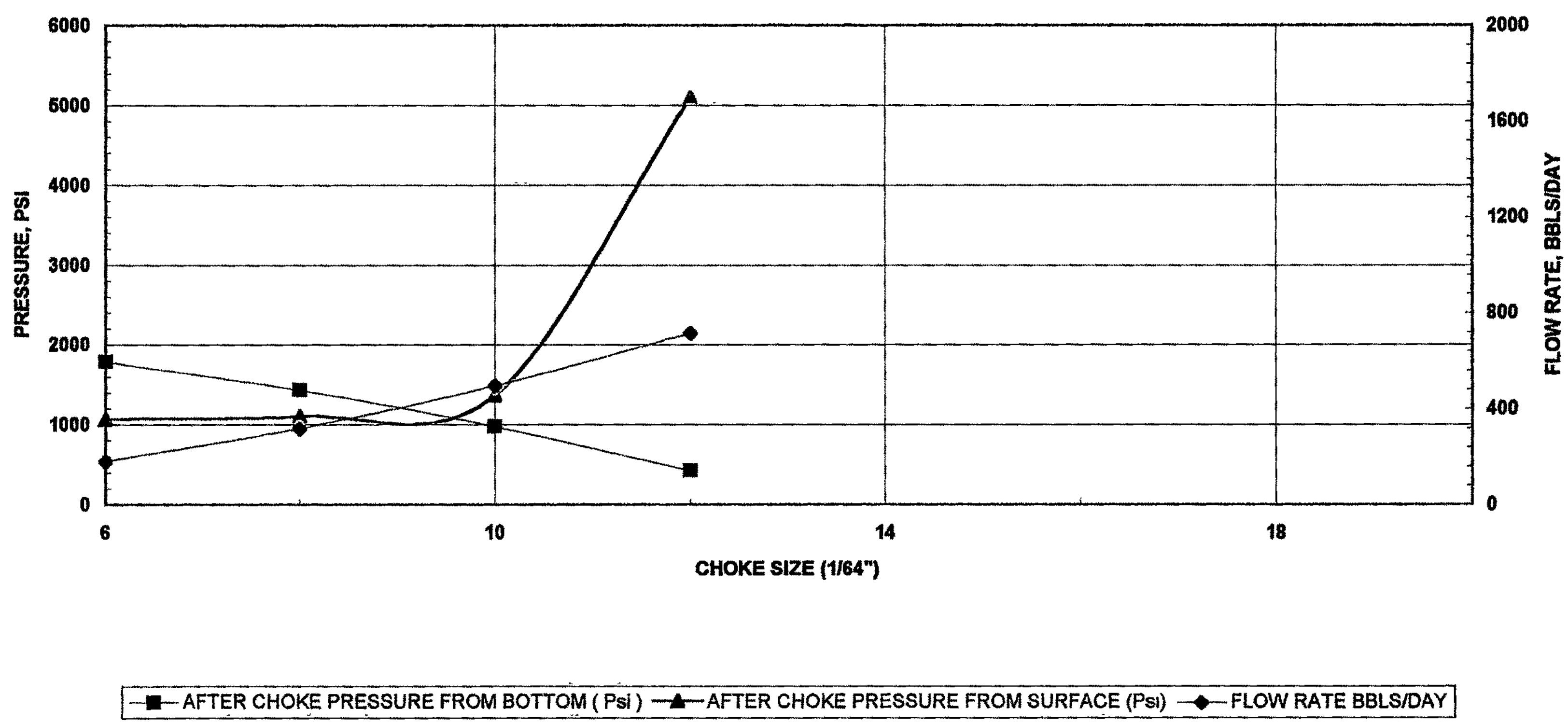


FIGURE 5.23 BOTTOMHOLE CHOKE SIZE SELECTION (TEST NO. 6)

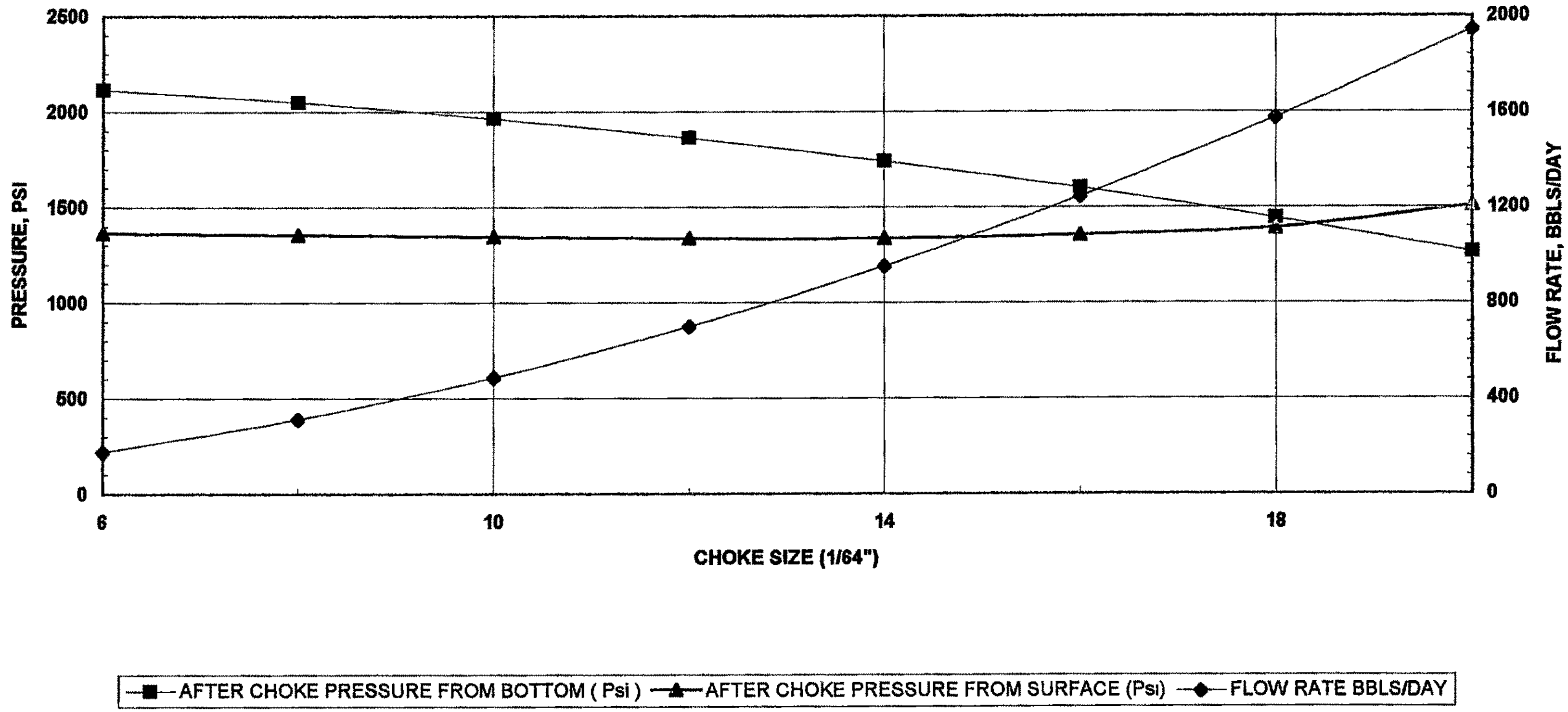


FIGURE 5.24 BOTTOMHOLE CHOKE SIZE SELECTION (TEST NO. 7)

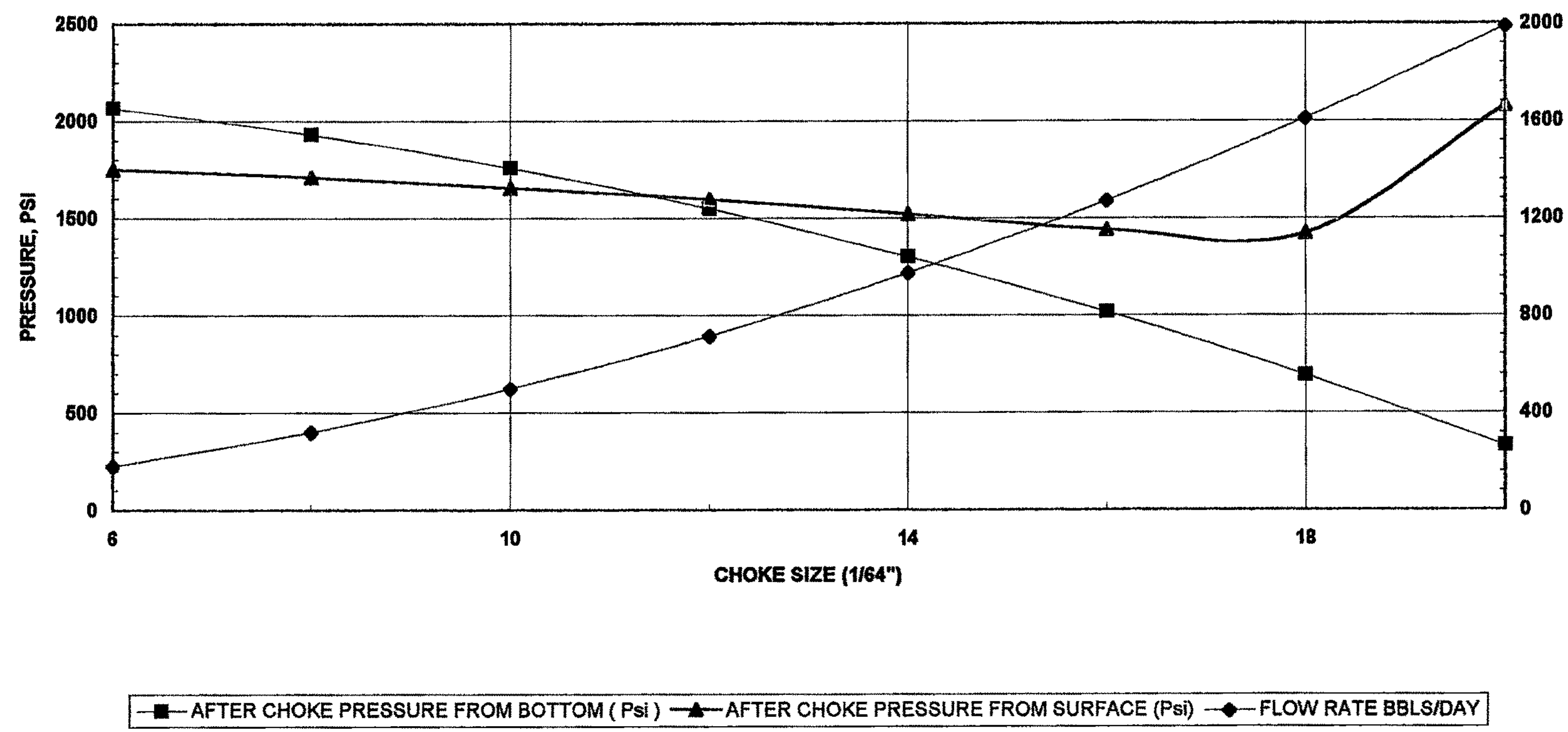


FIGURE 5.25 BOTTOMHOLE CHOKE SIZE SELECTION (TEST NO. 8)

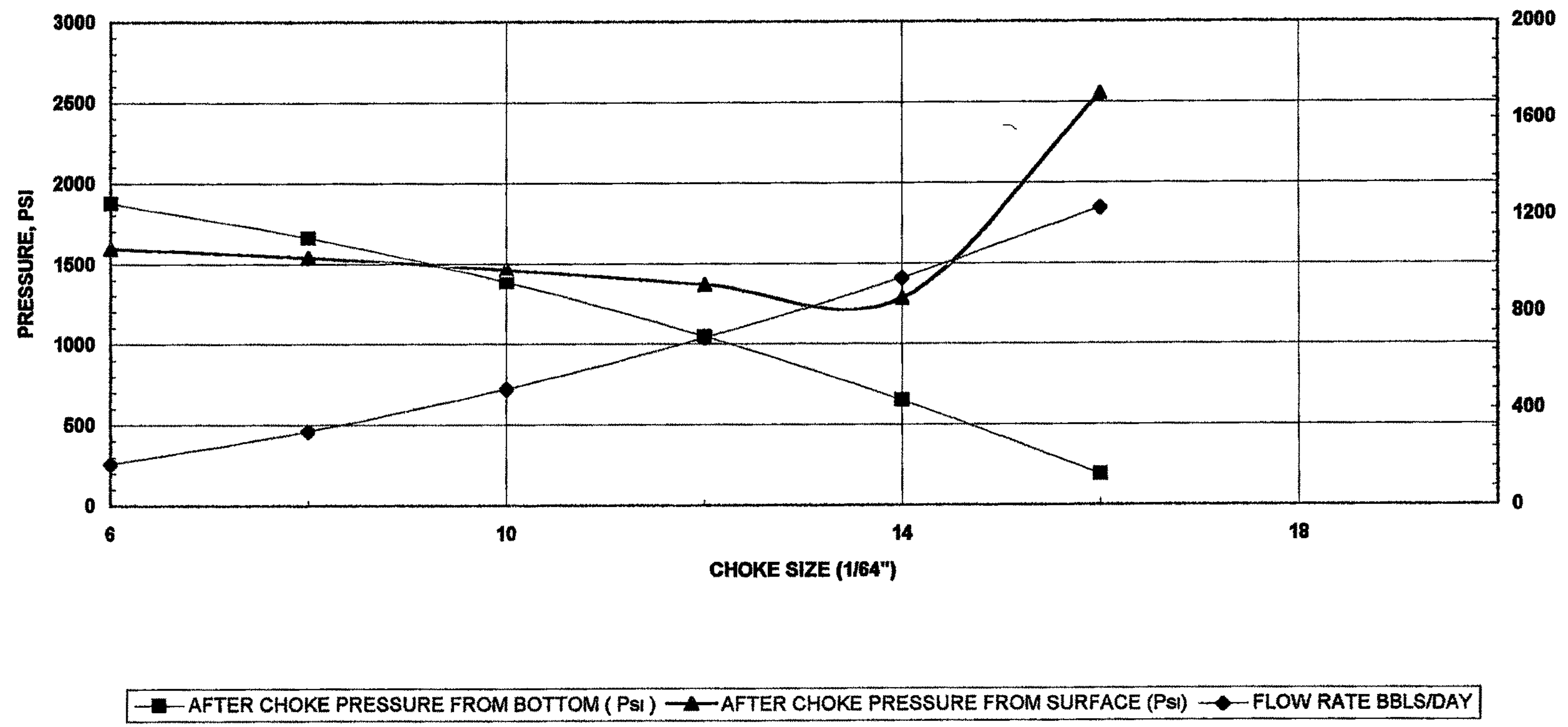


FIGURE 5.26 BOTTOMHOLE CHOKE SIZE SELECTION (TEST NO. 9)

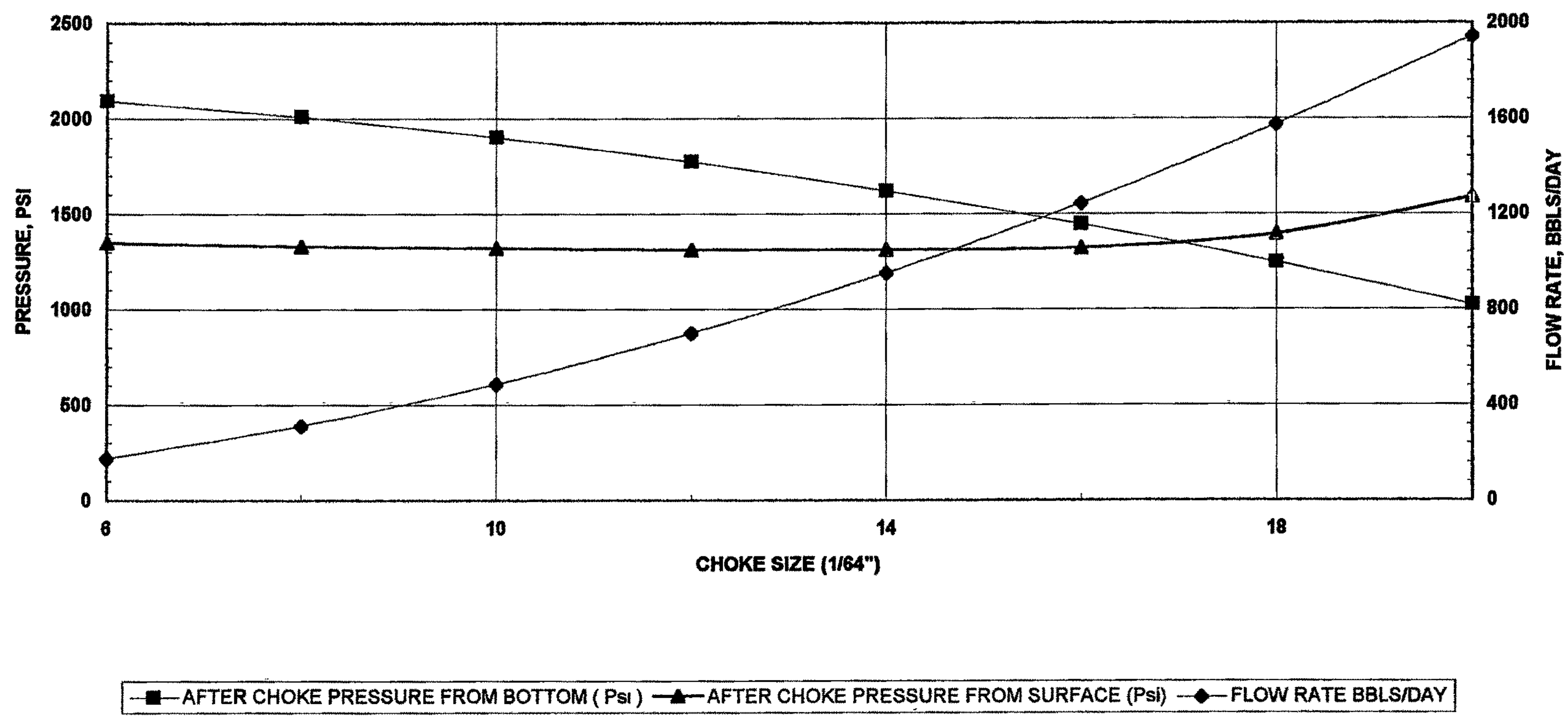


FIGURE 5.27 BOTTOMHOLE CHOKE SIZE SELECTION (TEST NO. 10)

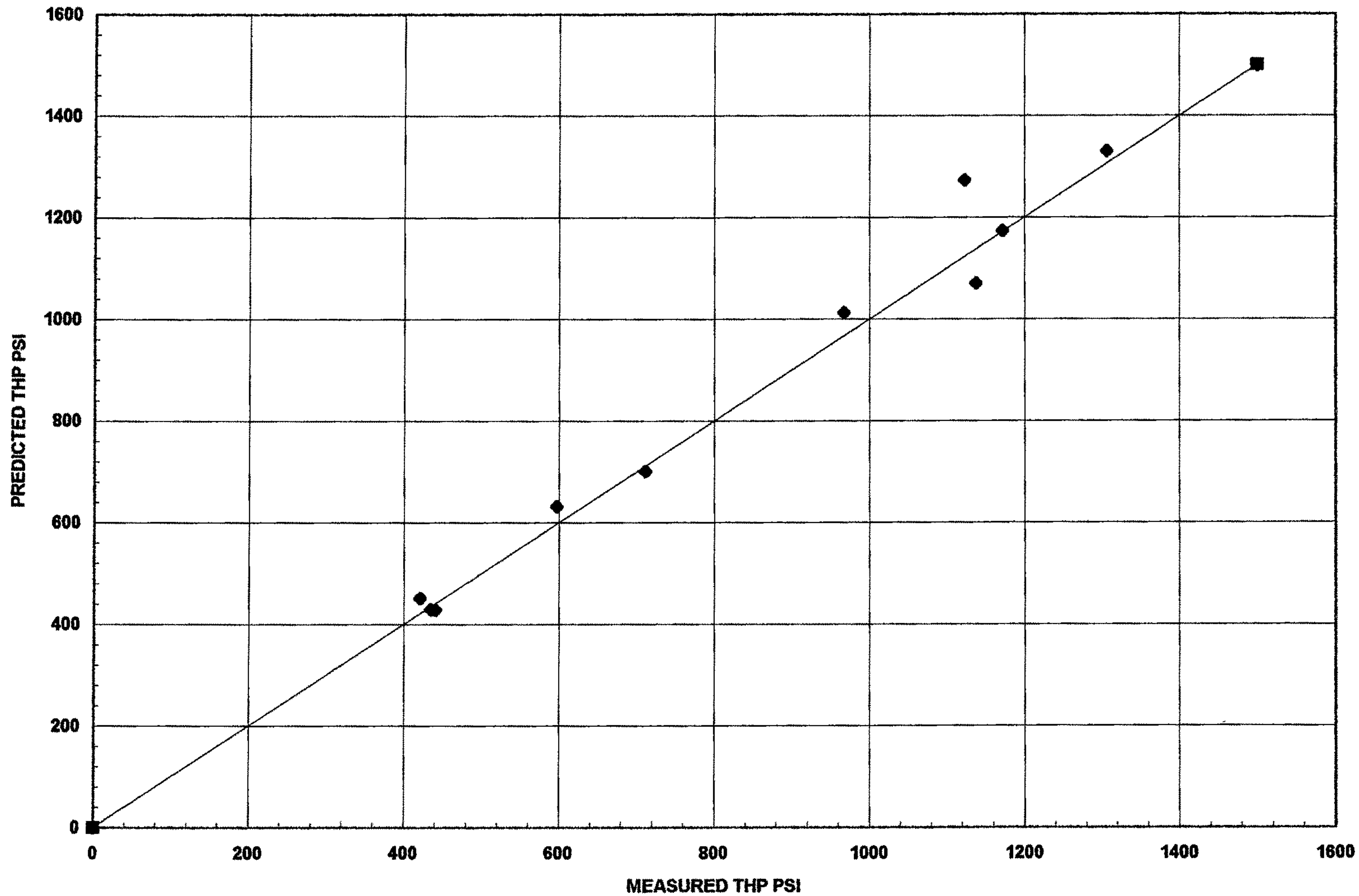


FIGURE 5.28 CROSS PLOT FOR TUBINGHEAD PRESSURE