EFFECT OF VARYING RESERVOIR FLUID PROPERTIES ON MATERIAL BALANCE CALCULATIONS, BU-ATTIFEL OIL FIELD, LIBYA

by

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ABSTRACT

The first part of this report presents an evaluation of the physical properties of oil at any elevation for the Bu-Attifel oil reservoir, Libya. This part involves correlation of a field producing gas oil ratio of comparable conditions with elevation. From the laboratory analysis data available on reservoir fluid samples from several wells, the effect of variations of separator pressure and temperature on production data were investigated. Then, the physical parameters were correlated with producing gas oil ratio for the average field operating condition of 725 psia and 176° F. These correlations then were used to evaluate the physical properties of the oil throughout the reservoir.

Analysis of subsurface oil samples with data on reservoir pressure showed that the reservoir oil is undersaturated at the initial reservoir pressure.

The second part of this report deals with applying the material balance equation to each producing well at several time intervals. The difference equation is obtained by using each pressure data as a reference point to eliminate as much of the early pressure history as desired which may yield erratic results. The variables of the material balance equation are arranged so the equation is expressed by an equation of straight line with the slope equal to oil in place.

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INTRODUCTION

Though it has been approximately 50 years since the inception of the PVT analysis of reservoir fluids, no great effort has been made to determine the variation in physical characteristics of the reservoir oil with depth. In a few instances consideration has been given to possible variance of the characteristics of the oil at various elevations within the reservoir. Many petroleum engineers have considered all the oil in the reservoir to have uniform characteristics and that equilibrium conditions prevailed in all underground accumulations.

Data available on subsurface samples from Bu-Attifel oil field indicate unusual variation of the physical characteristics with depth. For example, oil at midpoint of tested interval of -13,051 feet has a saturation pressure of 6358 psia, solution gas of 3761 standard cubic feet per stock tank barrel, and oil gravity of 41.02^{o} API. While a saturation pressure of 5760 psia, solution gas of 2073 standard cubic feet per stock tank barrel, oil gravity of 39.33^{o} API was found for oil at midpoint of tested interval of -13,820 feet. So this was the fact that these and other variable characteristics of the reservoir oil were related to the position of the oil in the structure.

As initial pressure in this reservoir is above its saturation pressure, so variation in producing gas oil would be indicative of variation in physical properties of the reservoir oil. Produced oil gravity and gas oil ratio measured at comparable conditions could give representative data for the entire field. When correlating this field data to elevation, and correlating the data from laboratory analysis to producing gas oil ratio and/or oil API gravity, an estimation of the physical properties of the oil at any depth is obtained.

In this field producing gas oil ratio was well correlated with depth and the other physical parameters rather than API gravity.

Since the early pressure history of an oil reservoir is meager or not known usually, the material balance equation would yield erratic results. By writing the material balance equation at several time intervals and then obtaining difference equations, it is possible to eliminate as much of the early pressure history as desired. This can be done by arranging the material balance variable to represent an equation of straight line in X and Y with the slope equals oil in place, considering each pressure data point as reference point. The number of X and Y values would be equal to the multiple of the pressure data points. Plotting the positive values of X and Y and using the least squares method, a good straight line will be obtained with the slope equal to original oil in place. This could be applied well by well in the field to obtain estimates of the field reserve. In this field, the initial pressure is not known for most of the wells. Plotting the cumulative oil production, in reservoir barrels, against the corresponding pressure of that production, will give a straight line for production above the saturation pressure. Extending this line to zero cumulative production would yield an estimate of initial pressure. Pressure gradient in this field was available from data, so each pressure was corrected to the depth of midpoint of perforations for each well rather than datum of the field in order to account for variation in physical properties with elevation.

BU-ATTIFEL OIL FIELD

General Description

The Bu-Attifel oil field is located in the north part of concession 100 in Cyrenica, Libya, approximately 400 kilometers southeast of Benghazi, as indicated in Figure 1.

This field was discovered in 1968 with the drilling of Well No. A1 which encountered the oil production in the First Nubian Sandstone at a depth of 13,345 feet, rotary table.

The development considered water injection when field pressure declined in June 1974. The present status of the field is the following:

Producing wells	24
Injection wells	9

Two productive reservoirs are present in the producing pay: The Main Area represented by the upthrown block, and the small West Area represented by the Western downthrown block. The latter is being drilled only by Wells 10 and 37 as shown in the structural contour maps, Figures 2 and 3. In this study the main area only would be considered.

The Bu-Attifel field went on stream in October 1972.

Geology

The productive formation is the First Nubian Sandstone of Lower Cretaceous age at an average depth of 13,800 feet subsea. Structurally, Bu-Attifel is an elongated fault block trending generally east-west. It is more than 20 kilometers long and less than five kilometers wide, containing a productive section ranging in thickness from 200 feet in the southwest to 750 feet in the northeastern area of the field as shown in the net isopach map of Figure 4. The oil water contact recognized by logs varies from well to well. However, its depths range from 14,196 to 14,245 feet subsea.

The First Nubian Sandstone unit is composed of a fine- to coarse-grained sand with numerous interbedded siltstones and shales, only few of which correlate satisfactorily between wells and within areas of the field.

The weighted averages of porosity, water saturation, and permeability are 13.4%, 18% and 110 millidarcies, respectively.

PHYSICAL PROPERTIES OF RESERVOIR OIL

Data

Subsurface and recombined samples were obtained from the producing interval of Bu-Attifel oil field from the following wells: 1, 2, 3, 4, 14, 16, 22, 28. On the well samples from Well No. 22, the amount of crude was too small to enable complete PVT analysis to be used. So it was not considered in this work. (Two samples were taken on Well No. 1 at different elevations, and it was noticed that the flash liberations were conducted at different separator temperatures and pressures.) These data were used in studying the effect of separation pressure and temperature on PVT properties.

Variation in Characteristics of the Original Oil With Elevation in Bu-Attifel Field

The possible relation between the various fluid parameters, differential liberation data (Table 2), and the mean producing depth, (Table 1), were investigated and virtually all of the relations indicated some trend with depth, thus confirming that fluid properties were variable with depth.

Effect of Variation Separator Pressure and Temperature

The effect of varying separator pressure on produced gas oil ratio, solution GOR, oil formation volume factor, stock tank GOR, and stock tank API gravity was determined from flash liberation conducted in the laboratory on a portion of the first sample from Well No. 1, (Table 3). Also, the effect of separator temperature on separator gas, separator gas gravity, stock tank API gravity of the produced oil, and stock tank gas-oil ratio was investigated. Conversion curves were constructed to correct for changes in separator GOR, separator gas gravity, and stock tank API gravity of produced oil for the variation of separator temperature for a base pressure of 725 psia. Also, conversion curve was plotted to correct for the changes in producing gas oil ratio for the variation in separator pressure for a base temperature of 176° F. The above are shown in Tables 4 and 5 and in Figures 5 to 11.

Adjustment of Fluid Data to Average Separator Operating Conditions in the Field

The data of the samples were converted to a basis of stock tank oil from a single separator operating at 725 psia and 176° F at average field operating condition, using curves in Figures 8 and 11. The flash liberation data of the sample are shown in Table 5 and the adjusted data are shown in Table 6.

Relationship of Oil Characteristics to Producing Gas Oil Ratio

Fluid parameters were correlated one with the other and indicated that gas oil ratio is the most significant one as shown in Figures 12 to 16. These relationships are expressed by the following equations:

$$P_b = 4348.06 + 1.34188\ R_s - .22363 \times 10^{-3} R_s^2 \qquad (1)$$

$$(Bo)_b = 1.2582995 + .52429 \text{ X } 10^{-3} R_s \quad (2)$$

$$(Bod)_b = 1.524534 + .57489 \text{ X } 10^{-3} R_s \quad (3)$$

$$(Rsd)_b = 632.87411 + 1.022356 R_s \quad (4)$$

$$(\rho_o)_b = .5896075 - 0.526207 \text{ X } 10^{-4} R_s \quad (5)$$

where P_b is bubble-point pressure, psia (BPP)

R_s is separator gas oil ratio (producing GOR), standard cubic feet per stock tank barrel, at an operating conditions of 725 psia and 176° F.

$(Bo)_b$ is oil formation volume factor by flash liberation from the bubble-point pressure

$(Bod)_b$ is the oil formation volume factor from differential liberation from bubble-point pressure.

$(Rsd)_b$ is the solution gas oil ratio standard cubic feet per stock tank barrel.

$(\rho_o)_b$ is the density of oil (gm/cc) at bubble-point pressure.

Variation of Producing GOR With Depth

Producing gas oil ratio was obtained from production tests carried out on the same period of time that most of the PVT samples were obtained. All this data was obtained from wells tested at the same separator pressure and the same tubing pressure, as shown in Table 7. The bottom hole pressure of the wells were above their saturation pressure.

Producing gas oil ratio was correlated with the depth of mid-point of the perforated interval and plotted as shown in Figure 17. The curve resulting from correlation is expressed by the equation as shown.

$$R_s = 1229.92 + .9852\ (14250 - D) \tag{6}$$

where D is the depth in feet. This equation is not reliable at depth outside the range of 12,750 to 14,250 feet.

Variation of Bubble-Point Pressure and Flash Oil Formation Volume Factor at Bubble-Point Pressure With Depth

The variation of the bubble-point pressure and formation volume factor at the bubble-point pressure were calculated by substituting the relationship for gas oil ratio as function of depth into the bubble-point pressure and formation volume factor equations. The resulting curves are shown in Figures 18 and 19 and are expressed by the following equations.

$$P_b = 5715.23 + .7416(14{,}250 - D) - .21325 \times 10^{-3}\ (14{,}250 - D)^2 \tag{7}$$

$$(Bo)_b = 1.939687 + .51733 \times 10^{-3}\ (14{,}250 - D) \tag{8}$$

These equations are not reliable outside the depth range of 12,750 - 14,250 feet.

Comparison of Reported Bubble-Point Pressure and Standing's Correlation Bubble-Point Pressure

The correlation developed by Standing based on the fluid properties was used to establish a curve describing bubble-point pressure in order to compare this field data with the published data.

The reported bubble-point pressure was plotted versus Standing's bubble-point pressure correlation number. Flash liberation data from fluid studies were used and the input data are presented in Table 8.

The curve established from the plot is different from the one obtained by Standing to describe the bubble-point pressure as function versus fluid properties, as shown in Figure 21. The curve is expressed by this equation.

$$P_b = 2,225.45\left[\left(\frac{R_s}{\gamma_g}\right)^{.83} \frac{.00091T}{.0125\ API}\right]^{.174984} \qquad (9)$$

where γ_g is gas gravity (air gravity = 1.0)

T is the temperature in ° F

API is the stock tank oil gravity

PREPARATION FOR MATERIAL BALANCE CALCULATIONS

After studying the variation of reservoir oil properties with pressure, it was found out that fluid parameters could be expressed in terms of producing gas oil ratio and bubble-point pressure.

Normalized Fluid Properties Curves

Differential oil formation volume factor, (Bod), data were smoothed above and below the bubble-point pressure. Data smoothing technique was done by plotting ΔV versus ΔP.

Where $\Delta V = [1 - \text{Bod}/(\text{Bod})_b]$

Bod is oil formation volume factor from differential liberation at a pressure P

$\Delta P = (P-P_b)$, above the bubble-point pressure, P_b

$\Delta P = (P_b-P)$, below the bubble-point pressure, P_b

The plots are presented in Figures 21 and 22.

The equation describing the variation of oil formation volume factor with pressure above the bubble-point pressure is shown as:

$$\text{Bod} = (\text{Bod})_b \cdot [1.0 - 4.54569 \text{ X } 10^{-3} \ (P-P_b)^{0.92468}] \tag{10}$$

The equation describing the differential oil formation volume factor below the bubble-point pressure is shown as:

$$\text{Bod} = (\text{Bod})_b [1.0 - 5.37118 \text{ X } 10^{-3} \ (P_b-P)^{.52793}] \tag{11}$$

where Bod is the oil formation volume factor from differential data at pressure P above or below the bubble-point pressure

$(Bod)_b$ is the differential oil formation volume at bubble-point pressure defined by Equation 3.

The initial gas in solution is equal to gas in solution at bubble-point pressure $(Rsd)_b$ and it is related to depth by Equations 4 and 6.

Values of solution gas oil ratios (Rsd) reported in fluid sample analyses from differential were normalized (RSD), and plotted versus normalized pressure (PD) as shown in Figure 24.

The equation of curve describing the variation of solution gas oil with pressure below bubble-point pressure is shown as

$$RSD = [4.08924 \text{ X } 10^{-2} + .128172 \text{ PD} + .128172 \text{ PD}^2] \quad (12)$$

or

$$Rsd = (Rsd)_b[4.8924 \text{ X } 10^{-2} + .128142(P/P_b) + .128172 (P/P_b)^2] \quad (13)$$

where Rsd is the solution gas oil ratio at any pressure P, below the bubble-point pressure P_b

$PD = P/P_b$

$RSD = Rsd/(Rsd)_b$

Conversion of Differential Solution Gas Oil Ratio Data To The Field Separator Condition of 725 psia and 176° F

The following equation was used to correct the solution gas oil ratio from differential liberation data to the field operating conditions of 725 psia and 176° F.

$$Rsp = \left[Rs - ((Rsd)_b - Rsd) \frac{(Bo)_b}{(Bod)_b} \right] \quad (14)$$

where Rsp is the gas in solution corrected for field operating conditions

This equation accounts for variation in pressure as well as depth because $(Bo)_b$, $(Bod)_b$ and $(Rsd)_b$ are related to depth.

Calculation Gas Formation Volume Factor (Bg)

The gas formation volume factor of the fluid sample which is adequately fitted to curve shown in Figure 25 is expressed by this next equation:

$$Bg = 1.0/[(-3.760169 + .0578045P - .218158P^2)] \quad (15)$$

Calculation of Combination and Combination Total Oil Formation Volume Factor

Combined oil volume factor is expressed as

$$Bo = \frac{(Bo)_b}{(Bod)_b} \cdot Bod \quad (16)$$

where Bo is combination oil formation factor or flash formation volume factor.

In the material balance equation, combination oil formation volume factor would be used, to combine the two liberation processes. Considering Equation 14 and 16, the combination total oil formation volume factor can be expressed as

$$Bt = Bo + [(Rsd)_b - (Rsd)]\left[\frac{(Bo)_b}{(Bod)_b} \cdot \frac{Bg}{5.61}\right] \quad (17)$$

where Bt is the combination total oil formation volume factor. Using the normalized solution gas oil ratio equation, Equation 13, and data-smoothing equations, Equations 10 and 11, fluid properties can be known for any elevation, from knowledge of their values at bubble-point pressure. The bubble-point pressure and the fluid parameters at the bubble-point pressure are defined as function of depth from the correlation relations. Then, by Equations 3, 4, 6, 7, 8, 10, 11, and 13, the solution gas and the total combination oil formation volume factor can be calculated for any pressure and depth in the range of reliability of these correlation equations. The computer program for the material balance equation calculations was designed to use these relations for the required physical parameters.

AN ACCURATE METHOD OF FITTING MATERIAL BALANCE EQUATION TO STRAIGHT LINE IN EARLY PRODUCTION HISTORY

The material balance equation for estimating the oil in place of each well in this reservoir was expressed as

$$N[(Bt_j-Bt_i) + Bt_iF(\gamma)]=Np[Bt_j + (\frac{Rp-Rs_i}{5\cdot 61}) Bg] + Wp_j \qquad (A)$$

where $F(\gamma) = [(C_w \cdot S_{wi}+C_f)/(1-S_{wi})][(P_i-P)]$ (i)

N is stock tank barrel of oil originally in place

Np is the cumulative oil productions stock tank barrel

Rp is the cumulative gas oil ratio, standard cubic feet per stock tank barrel

i is the original condition

j refers to the time interval.

In Equation A if we write the left-hand side as:

$$x_j = [(Bt_j-Bt_i) + Bt_jF(\gamma)] \qquad (ii)$$

and the right-hand side as

$$y_j = Np[Bt_j + \frac{(Rp-Rs_i)}{5.61} Bg_j] + Wp_j \qquad (iii)$$

A plot of x_j against y_j should result in a straight line going through the origin (assuming that there is no water influx) with "N" being the slope as shown in Figure 26.

↑
? 25

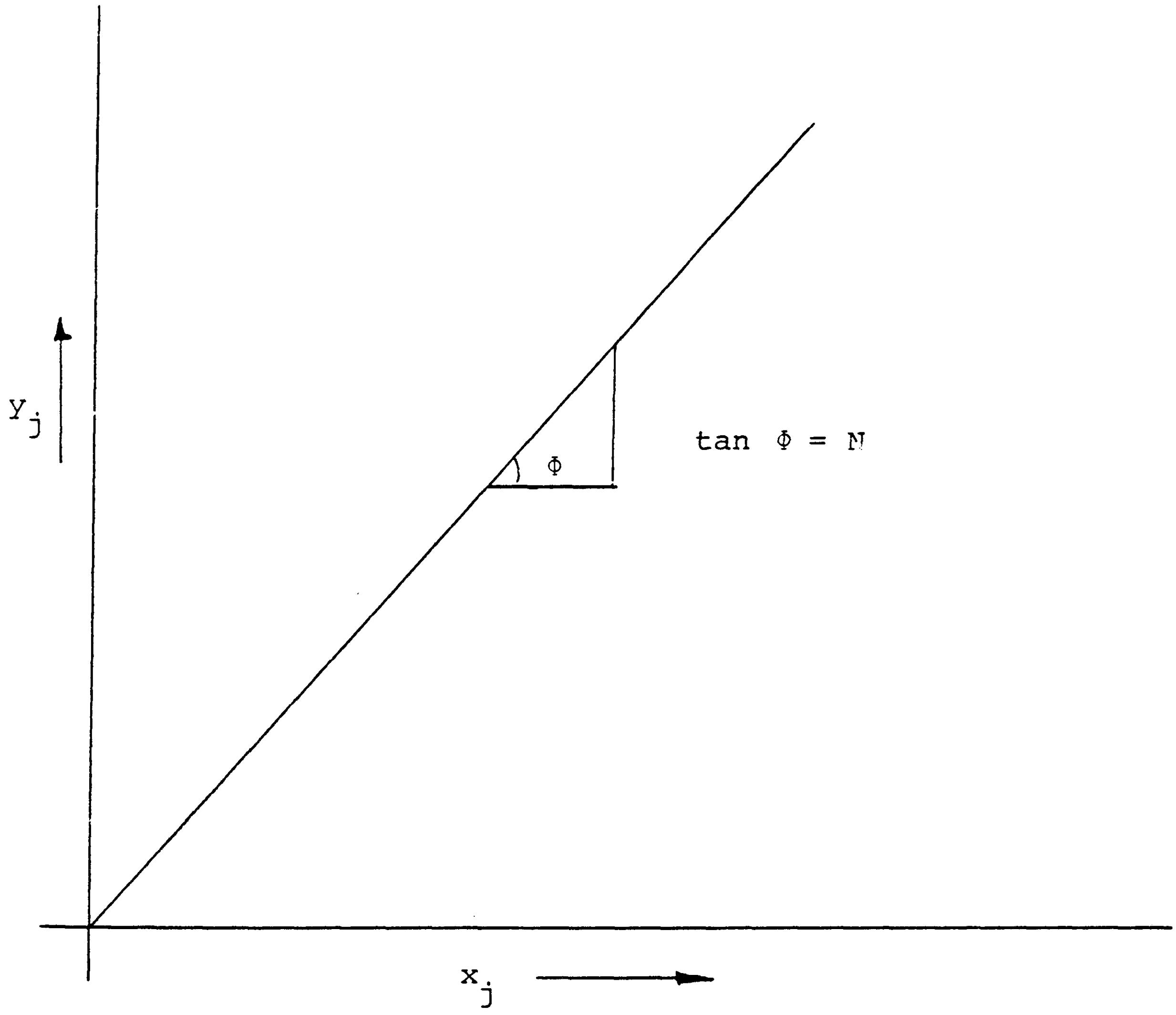

Figure 25: x_j vs. y_j Plot for undersaturated oil reservoir with no water influx.

This is not always the case in the early pressure history. So a better way to get a good straight line is by obtaining the difference equations after applying Equation A for several time intervals which is explained by the following expression:

$$N[(Bt_j - Bt_k) + Bt_i(F(\gamma)_j - F(\gamma)_k)]_j =$$

$$[Np(Bt + (\frac{Rc-Rsi}{5.61})\ Bg) + W_p]_j - [Np(Bt + (\frac{Rc-Rsi}{5.61})Bg) + W_p]_k \qquad (B)$$

where k represents each pressure data point of each time interval used as a reference in calculation

$k = 1, 2, 3, \ldots m$ excluding j

If $k < j$ we get positive values

If $k > j$ we get negative values.

Equation B does not include any terms dependent on initial pressure, which is always in mistake.

Writing the left-hand side of Equation B as

$$x_j - x_k = [(Bt_j - Bt_k) + Bt_i(F(\gamma)_j - F(\gamma)_k)] \qquad (iv)$$

and the left-hand side as

$$y_j - y_k = [Np(Bt + (\frac{Rc-Rsi}{5.61})\ Bg) + W_p]_j \qquad (v)$$

$$-[Np(Bt + (\frac{Rc-Rsi}{5.61})\ Bg) + W_p]_k$$

A plot with the positive values of (x_j-x_k) and (y_i-y_k) against each other should result in a straight line going through the origin (assuming that there is no water influx) with N being the slope as shown in Figure 2~~7~~. 26

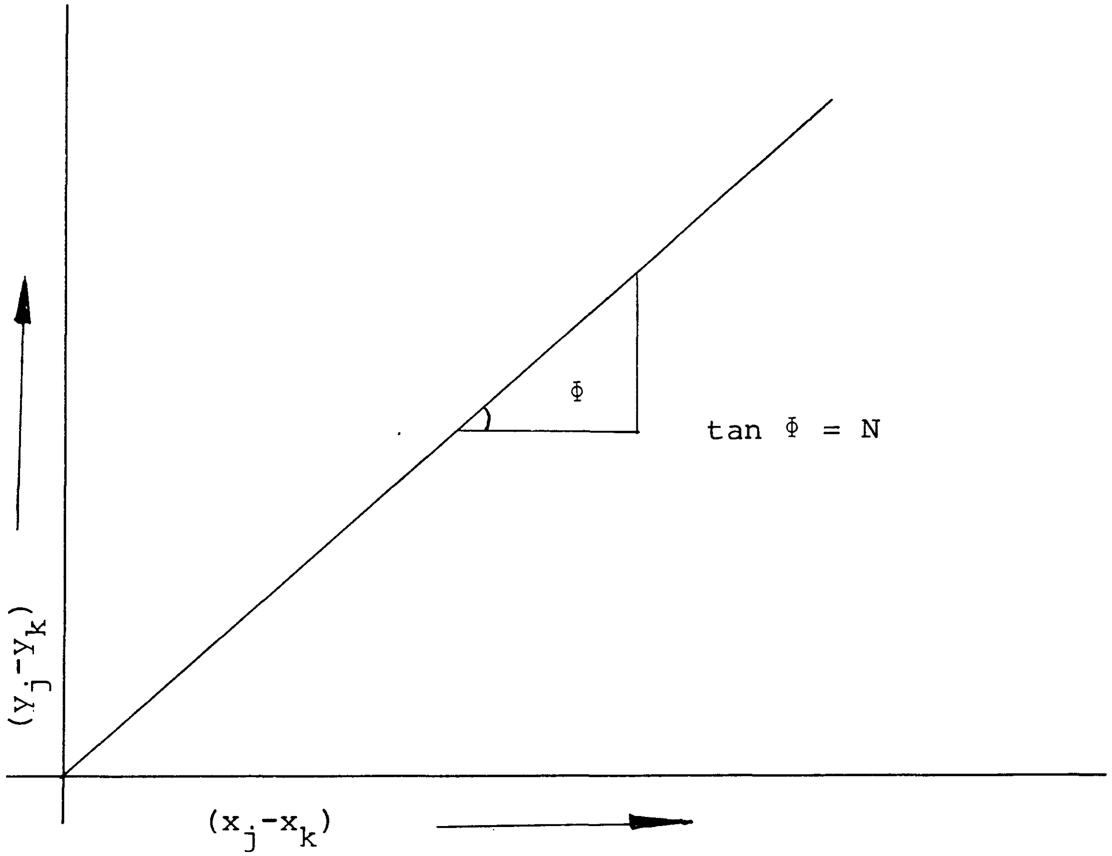

Figure 26. (x_j-x_k) vs. (y_j-y_k) plot for undersaturated oil reservoir with no water influx.

So Equation B can be represented by an equation of a straight line

$$y = Nx$$

With the intercept equal to zero assuming no water influx.

CALCULATED RESULTS

The pressure and physical properties of the oil of each well was corrected to the depth of mid-point of perforated interval. Equation B was solved for oil in place by plotting the positive values of (x_j-x_k) versus (y_j-y_k), then taking the slope of the best line drawn through these points being equal to oil in place. The (x_j-x_k) versus (y_j-y_k) plot of the wells are shown in Figures 31 to 50 and the summary of the results is presented in Table 10.

An example of computer output for the adjustment to the depth of mid-point of the perforated interval and calculating the initial pressure is shown in Table 11. B(0) is the intercept which equals to initial pressure.

The output of calculations of oil in place is shown in Table 12. B(1) equals to slope which is equal to oil in place. Solution of Equation B for each reference pressure is also shown in Figures 27 to 30. Figure 31 shows the plot of all the positive values. In Figure 27 reference pressure #1 refers to initial pressure, which is the solution of Equation A.

The above calculations have been done for the whole reservoir and the results are presented in tables 13, 14 and in Figure 51.

Volumetric estimation of oil in place of the reservoir has also been done and the result is shown in Table 15.

CONCLUSION

1. The reservoir oil is initially undersaturated at all locations tested.

2. The variation of separator pressure and temperature materially influenced the producing gas oil ratio, stock tank oil gravity, separator gas gravity and oil formation volume factor.

3. The study of the effect of separator pressure and temperature on the above parameters developed from the need to investigate variation of physical properties of reservoir oil at different elevations for comparable separator operating conditions.

4. The producing gas ratio measured at common separator pressure and temperature was correlated with the subsea depth of midpoint for the perforated interval. This correlation indicated a decrease in gas oil ratio with depth, which amounted to 98 standard cubic feet per stock tank barrel per 100 feet.

5. The physical properties of reservoir oil from the seven PVT samples (sample from well No. 14 was considered not representative) showed significant correlation with producing gas oil ratio, except for API gravity.

6. The bubble point pressure, oil formation volume factor, and solution gas oil ratio indicate a decrease with depth, while oil density increased with depth.

7. Using the Standing's correlation number, the bubble point pressure from PVT sample data was correlated with gas oil ratio, oil API gravity, gas gravity and temperature. The correlation obtained was different from Standing's.

8. The values of bubble point fluid parameter was determined from the fluid parameters correlation with gas oil ratio and gas oil ratio correlation with depth.

9. The variation of the reservoir oil properties for any pressure above or below the bubble point pressure at any elevation was estimated from the correlation and the normalized equations. Normalized equations were expressed in terms of bubble point value of fluid parameter and the pressure difference from the bubble point pressure (In normalized solution gas, the ratio of pressure to the bubble point pressure was used rather than the difference).

10. Gas formation volume factor on all the samples were adequately fitted by Equation 15.

11. For the computation of a more realistic total volume factor, the flash and differential liberation processes should be combined. As a result, the total formation volume factor which appears in the material equation was used as the total combination volume factor.

12. The initial pressure was needed for each well for Equation A. Since the initial pressue was not available in most cases, a computer program was set up to adjust the physical oil properties for the depth of mid-point of perforations.

Then, the program calculated the initial pressure using a straight line fit for a cumulative production (reservoir barrels) versus pressure. This method showed a good agreement for wells which had available initial pressure from build-up tests.

13. Equation B was solved for oil in place for each well. A computer program was worked out to do the calculations. The program also makes the plots for each pressure reference and plots the best line through the positive values using the least mean square method.

14. In these calculations if more pressure data were available, a more accurate result would be obtained. This calculation has also illustrated the use of the method explained in the text, and had shown to be a valid method.

15. Oil in place was calculated for each well; and from the data available, the total oil in place was found to be 4.949 MMMSTB.

16. Oil in place was calculated by applying equation B to the whole reservoir, and it was found to be 4.085 MMMSTB.

17. Oil in place estimated from volumetric calculation was equal to 3.580 MMMSTB.

18. The value of oil in place calculated by applying Equation B on well by well was different from the other two values. This is because on some wells only two pressure data are available, which may be one of them or both are wrong.

19. The latest average pressure of the reservoir measured at the datum (-13,800 feet) was 6232 psia and the bubble point pressure at this depth is 6005 psia. This reservoir pressure is equivalent to 6002 psia at the highest point in the reservoir (-12750 feet). Since the bubble point pressure at -12,750 feet is 6348 psia, this means that a secondary gas cap would be formed at the top of the structure. This would be another reason for differences in the value obtained for oil in place. Because in this case the material balance equation when applied at datum for the whole reservoir will yield a higher value of oil in place. Another thing should be mentioned here is that in such a situation water injection would have to be closely controlled.

TABLE 1

FLUID SAMPLES AVAILABLE ON BU-ATTIFEL OIL FIELD

Well Number	Sampling Date M/D/Y	Type of Sample	Top of Pay Zone ft, ss	Bottom of Pay Zone ft,ss	Thickness of Pay Zone ft	Midpoint of Pay Zone ft	Top of Perforations ft,ss	Bottom of Performations ft, ss	Perfor. Interv. ft, ss	Midpt. perforn interv. ft, ss
1	8/22/68	Bottomhole	13,131	13,888	757	13,509.5	13,293	13,835	542	13,564
1	12/3/68	Recombined	13,131	13,888	757	13,509.5	13,293	13,835	542	13,564
2	3/10/73	Bottomhole	13,500	14,304	804	13,902	13,544	14,126	642	13,865
3	6/18/69	Bottomhole & Recomb.	13,411	14,134	723	13,772.5	13,640	13,999	359	13,819.5
4	4/12/73	Bottomhole	13,375	14,338	692	13,856.5	13,445	14,019	574	13,732
14	3/29/73	Bottomhole	12,977	13,542	565	13,259.5	13,267	13,535	286	13,401
16	4/6/73	Bottomhole	13,298	14,253	955	13,755.5	13,481	14,009	528	13,745
22	4/3/73	Bottomhole	12,887	13,497	660	13,192	13,265	13,459	194	13,362
28	5/12/72	Recombined	12,922	13,625	653	13,298.2	13,460	13,614	154	13,537

TABLE 2

SUMMARY OF THE DIFFERENTIAL GAS LIBERATION DATA ON BU-ATTIFEL OIL FIELD, LIBYA

Well Number	Midpoint of Pay Zone ft,ss	Saturation Pressure psia	Reservoir Temperature °F	Solution Gas SCF/STB (2)	O.F.V.F. Bbl/STB (2)	Saturated Oil Density gm/cc (1)	Residual Oil Density gm/cc (2)	Residual Oil Gravity API (1)
1	13509.5	5789*	285.5	2251.5	2.3998	.5075	.8211	40.83
2	13092.0	5945	296.6	2230.8	2.4178	.5061	.8330	38.37
3	13772.5	5760	296.6	2073.1	2.3034	.5202	.8283	39.33
4	13856.5	6101	296.6	2580.5	2.6387	.4892	.8330	38.33
14	13259.5	6344	291.6	2388.4	2.5099	.5052	.8360	37.76
16	13755.5	6044	296.6	2536	2.6347	.4882	.8320	38.57
28	13298.5	6358	296.6	3761.2	3.2768	.4291	.8201	41.04

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(1) At standard condition of 14.33 psi and 60° F .

(2) At saturation pressure

* To be corrected to reservoir temperature of 296.6° F as

$$(5789)\left(\frac{296.6 + 460}{285.5 + 460}\right) = 5875 \text{ psia}$$

TABLE 3

FLASH LIBERATION ANALYSIS DATA FROM WELL #1 FIRST SAMPLE SHOWING EFFECT OF SEPARATION

PRESSURE, AT FIXED TEMPERATURE, ON GAS LIBERATION

Separator Pressure psia	Separator Temperature °F	Separator GOR SCF/Bbl	Stock Tank GOR SCF/Bbl	Stock Tank Oil Density gm/cc	Stock Tank Oil Gravity API	O.F.V.F. Bbl/STB (1)	O.F.V.F. Bbl/STB (2)	Specific Gravity of Gas From Separator (3)
725	122	1315.6	248	.815	42.12	1.923	1.117	.6937
440	122	1413.7	178.1	.818	41.48	1.918	1.097	.7071
228	122	1504.6	94.3	.814	42.33	1.939	1.071	.7253
85.3	122	1596.1	28.1	.818	41.48	1.972	1.039	.743
14.7	122	1678	0	.821	40.85	2.010	1.019	--
725	140	1337	241.5	.819	41.27	1.940	1.131	.6572
440	140	1420	151.0	.820	41.06	1.929	1.116	.6865
228	140	1554	82.0	.817	41.69	1.961	1.090	.6696
85.3	140	1651	26.3	.820	41.06	2.008	1.064	.6572
725	176	1368.7	229.8	.824	40.22	1.955	1.143	.7435
440	176	1460.4	141.7	.822	40.64	1.948	1.125	.7094
228	176	1582.8	68.8	.821	40.85	1.985	1.103	.6842
85.3	176	1702.1	21.5	.821	40.85	2.038	1.077	.6720
725	212	1409.9	210.6	.822	40.64	1.982	1.9 1.191	.7587
440	212	1504.9	121.0	.823	40.43	1.981	1.168	.7179
228	212	1623.1	56.8	.825	40.02	2.013	1.140	.6927
85.3	212	1732.5	19.7	.827	39.6	2.064	1.115	.6827

---

(1) Volume of reservoir oil at bubble point pressure and reservoir temperature/volume of stock tank oil at 60° F.
(2) Volume of Separator oil at indicated pressure and temperature/volume of stock tank oil at 60° F.
(3) Calculated from composition of the gas flashed at the indicated separator pressure and temperature.

TABLE 4

EFFECT OF SEPARATOR TEMPERATURE ON PRODUCING GOR, STOCK TANK GOR, OIL API AND SEPARATOR GAS GRAVITY

Separator Temperature (°F)	Separator Pressure (psia)	Separator GOR SCF/Bbl	Stock Tank GOR SCF/STB	API Gravity of Stock Tank Oil	Gas Gravity γ_g
122	725	1315.6	248	42.12	.6937
140	725	1337.0	241.5	41.27	.6573
176	725	1368.7	229.8	40.22	.7435
212	725	1409.9	210.6	40.64	.7587

TABLE 5

FLASH LIBERATION DATA

Well Number	Temperature of Reservoir	Saturation Pressure psia	Separator Pressure psia	Separator Temperature °F	Separator GOR SCF/Fbl	Stock Tank GOR SCF/Bbl	Stock Tank Oil Dens. gm/cc	Stock Tank Oil Grav. API	O.F.V.F. Bbl/STB (1)	O.F.V.F. Bbl/STB (2)	Specific Grav. of Separator Gas (3)
1	285.5	5789	725	176	1663.4	259.1	.815	42.12	2.123	1.149	.6993
			440	176	1743.0	173.9	.817	41.70	2.100	1.108	.7083
			228	176	1480.6	92.51	.819	41.27	2.219	1.077	.7257
			85.3	176	1922.6	25.25	.820	41.06	2.172	1.050	.7512
			14.7	176	1976.4	0	.822	40.64	2.198	1.036	--
2	298.4	5945	725	212	1552.36					1.2543	.7450
			278	212	85.18					1.1710	.8192
			43	194	65.42					1.1110	1.0979
			14.7	194	29.42		.822	40.64	2.090	1.0724	--
3	296.6	6100.4	725	176	1480.5	248.0	.815	41.48	2.090	1.146	.6933
			440	176	1564.6	171.0	.816	41.91	2.071	1.121	.7073
			288	176	1683.0	94.3	.815	42.12	2.089	1.092	.7258
			85.3	176	1784.5	37.0	.818	41.48	2.089	1.063	.7538
			14.7	176	1385.6	0	.820	41.06	2.131	1.046	--
4	291.6	6342.1	725	212	1922.5					1.242	.7212
			228	212	119.4					1.164	.8157
			43	194	81.1					1.105	1.0511
			14.7	194	32.8		.823	40.43	2.220	1.072	--
14	296.6	6358	725	212	1832.0					1.2312	.7069
			228	212	115.3					1.1603	.8101
			43	194	73.9					1.1021	1.0081
			14.7	194	32.8		.826	39.81	2.173	1.0707	--
16	296.6	6043.5	725	212	1806.2					1.179	.7169
			228	212	116.6					1.118	.806
			43	194	79.3					1.078	1.0100
			14.7	194	35.0		.824	40.22	2.109	1.072	--
28	296.6	6354	725	138	3019.5	316.3	.801	45.15	2.887	1.136	.7076
			440	138	3195.3	211.3	.801	45.15	2.888	1.124	.7136
			228	138	3365.6	123.0	.800	45.38	2.920	1.103	.7279
			14.7	138	3533.4	0	.802	44.93	3.092	1.044	.7376

---

(1) Volume of reservoir oil at bubble point pressure and reservoir temperature/volume of stock tank oil at 60° F.

(2) Volume of Separator oil at indicated pressure and temperature/volume of stock tank oil at 60° F.

(3) Calculated from composition of the gas flashed at the indicated separator pressure and temperature.

TABLE 6

FLASH LIBERATION DATA FOR CORRELATING GOR, API, Bo_b, and γ_g WITH EACH OTHER

Well Number	GOR SCF/Bbl	Stock Tank Oil Gravity API	OFVF @BPP Bo_b Bbl/STB	Gas Gravity γ_g	BPP (psia)
1	1663.4	42.12	2.123	.6693	5875*
1	1368.7	40.22	1.955	.7435	5795*
2	1506	41.14	2.090	.7299	5945
3	1480.5	41.48	2.090	.6933	5760
4	1864.5	40.93	2.220	.7060	6101
14	1777	40.31	2.175	.6917	6344
16	1751.8	41.14	2.109	.7017	6044
28	3080	44.0	2.887	.7601	6358

. The separator operating conditions was 725 psia and 176° F.

* These bubble-point pressures were corrected from 285.5° F to the reservoir temperature of 296.6° F.

TABLE 7

AVERAGE PRODUCING GAS OIL RATIOS AND API GRAVITY FROM PRODUCTION TESTS ON THE WELLS

January - April 1973

Well Number	Depth ft. ss	Choke Size 64"	Tubing Pressure psi	Gas Oil Ratio GOR SCF/STB	API Gravity
1	13,564	59	1300	2100	41.70
2	13,865	90	1400	1740	41.30
11	13,592	84	1300	1776	41.95
12	13,915	62	1250	1474	41.10
14	13,401	56	1300	1975	41.70
15	13,441	101	1300	2001	41.30
17	13,716	84	1300	1825	41.77
18	13,743	80	1300	1802	41.60
20	13,624	101	1300	1986	41.90
21	13,813	84	1300	1855	41.40
22	13,362	84	1300	2275	42.30

TABLE 8

INPUT DATA FOR STANDING'S BUBBLE-POINT PRESSURE CORRELATION

WELL NUMBER	GOR SCF/STB	STOCK TANK OIL GRAVITY API	O.F.V.F. @ BPP Bbl/STB	GAS GRAVITY γ_g	RESIDUAL OIL DENSITY	ACTUAL BPP psia	BPP CORRELATING NUMBER	BPP FROM STANDING'S CORRELATION *
1	1663.4	42.12	2.123	.6693	.81	5895	283.023	5000
1	1368.7	40.22	1.955	.7435	.82	5795	233.0142	4200
2	1506	41.14	2.090	.7299	.82	5945	249.457	4500
3	1480.5	41.48	2.090	.6933	.82	5760	254.105	4600
4	1864.5	40.93	2.220	.7060	.82	6101	308.030	5500
14	1777	40.31	2.175	.6917	.82	6344	306.474	5500
16	1751.8	41.14	2.109	.7017	.82	6044	292.211	5300
28	3080	44.00	2.887	.7601	.81	6358	402.285	7200

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* Bubble-point pressure correlating number = $\left(\frac{R_s}{\gamma_g}\right)^{.83} \cdot \frac{10^{0.00091T}}{10^{0.025API}}$

TABLE 9 . Production Data Available per Well on Bu-Attifel Oil Field

Well Number	Date M/D/yr	Pressure @ -13800 ft (psi)	Cumulative Oil Produc. Np (MSTB)	Cumulative Gas Oil Ratio Rc (SCF/STB)	REMARK
1	5/7/73	6614	652	2025.0	D=13564' Φ=.136 c_f=4.2X10^{-6} psi^{-1} Sw_i=.216
	7/7/73	6510.7	978.1	1968.0	
	12/19/73	6312.7	2208.9	1817.0	
	11/19/74	6171.5	3615.5	1796.0	
2	2/15/73	6698.0	1100.0	1731.0	D=13,865' Φ=.112 c_f=4.6X10^{-6}psi^{-1} Swi=.236
	10/8/73	6395.0	3323.4	1679.0	
	5/8/74	6225.0	4562.5	1665.0	
3	6/8/69	6883.0	0	1484.0	D=13820' Φ=.138 c_f=4.3X10^{-6}psi^{-1} Swi=.107
	2/6/74	6222.9	3385.2	1737.0	
	1/4/75	6131.7	4518.1	1664.0	
4	4/13/73	6689.0	932.9	1706.0	D=13732' Φ=.113 c_f=4.5X10^{6}psi^{-1} Swi=.31
	11/16/74	6117.8	3814.4	1697.0	
7	11/7/72	6795.0	339.0	1520.0	D=13798' Φ=.132 c_f=4.4X10^{-6}psi^{-1} Swi=.168
	5/31/73	6736.0	1114.3	1624.0	
	6/31/73	6692.0	1212.0	1653.0	
	2/12/74	6226.7	1810.5	1689.0	
8	11/12/72	6780.0	181.2	1877.0	D=13738' Φ=.151 c_f=4.0X10^{-6} psi^{-1} Swi=.131
	11/8/74	6170.0	6773.1	1804.0	
9	10/5/73	6390.0	369.7	1341.0	D=13911' Φ=.124 c_f=4.8X10^{-6} Swi=.109
	1/7/75	6209.8	2728.0	1400.0	

TABLE 9 (Cont'd)

11	5/18/73*	6537.0	1688.7	1762.0	D=13592'
	11/24/73	6276.0	3685.4	1756.0	Φ=.127
	7/19/74	6123.5	5892.8	1759.0	$c_f=4.3X10^{-6}psi^{-1}$
					Swi=.107
12	2/26/73	6649.0	665.9	1684.0	D=13915'
	10.1/73	6405.0	1399.1	1679.0	Φ=.109
	11/2/73	6372.2	1425.6	1684.0	$c_f=4.6X10^{-6}$ psi^{-1}
	3/28/74	6296.0	1429.5	1679.0	Swi=.286
	5/21/74	6209.6	1462.3	1679.0	
13	7/1/74	6553.4	3138.6	1884.0	D=13609'
	1/10/74	6358 0	5133.4	1803.0	Φ=.12
	7/30/74	6205.1	6789.1	1780.0	$c_f=4.0X10^{-6}psi^{-1}$
					Swi=.143
14	3/30/74	6684.0	549.9	1722.0	D=13401'
	10/29/73	6358.6	1226.2	2024.0	Φ=.138
	12/31/74	6180.7	1773.4	2020.0	$c_f=4.2X10^{-6}psi^{-1}$
					Swi=.118
15	11/1/72	6822.0	294.0	1710.0	D=13550.5'
	5/18/73	6602.0	2919.0	1893.0	Φ=.131
	7/31/74	6196.0	9140.5	1861.0	$c_f=4.3X10^{-6}psi^{-1}$
					Swi=.107
16	1/22/73	6736.0	456.8	1761.0	D=13745'
	3/9/74	6281.2	1924.9	1706.0	Φ=.121
	8/8/74	6175.0	2090.8	1701.0	$c_f=4.5X10^{-6}psi^{-1}$
					Swi=.172
17	3/10/72	6884.0	27.1	1485.0	D=13715.5'
	10/29/72	6886.0	210.1	1654.0	Φ=.14
	6/29/73	6534.7	2729.3	1856.0	$c_f=4.6X10^{-6}psi^{-1}$
	7/27/74	6168.9	6736.9	1739.0	Swi=.14
18	3/26/74	6228.1	3112.9	1744.0	D=13743'
	11/11/74	6177.1	3650.6	1730.0	Φ=.121
					$c_f=4.5X10^{-6}psi^{-1}$
					Swi=.203
20	11/15/72	6792.0	238.9	1643.1	D=13623.5'
	12/19/74	6204.0	6426.4	1901.0	Φ=.12
					$c_f=4.5X10^{-6}psi^{-1}$
					Swi=.107

TABLE 9 (Cont'd)

21	3/21/74	6190.0	3130.3	1833.4	D=13813'
	11/9/74	6146.4	3638.2	1823.3	Φ=.12
	1/30/75	6125.9	3917.1	1823.3	c_f=4.5X10^{-6}psi^{-1}
					Swi=.174
22	2/4/73	6699.0	830.9	2223.8	D=13362'
	3/30/74	6325.2	2480.0	2290.0	Φ=.125
					c_f=4.3X10^{-6}psi^{-1}
					Swi=.172
25	9/16/73	6453.8	38.9	1501.8	D=13780'
	2/2/74	6295.3	590.2	1783.4	Φ=.131
	7/20/74	6170.8	1644.1	1659.4	c_f=4.3X10^{-6}psi^{-1}
					Swi=.171
26	8/31/73	6547.3	0	0	D=13723.5'
	12/15/73	6437.4	696.5	1800.2	Φ=.119
	4/5/74	6348.2	1452.0	1689.5	c_f=4.5X10^{-6}psi^{-1}
	11/18/74	6152.7	3315.8	1625.5	Swi=.189

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*These data are before water injection.
*c_f and c_w are from published correlation
*c_w = 3.5 X 10^{-6}

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Table 10. Summary of Calculated Oil In Place

Well Number	Oil In Place N (MMSTB)
1	197.838
2	220.611
3	391.356
4	143.118
7	43.338
8	337.995
9	398.567
11	235.964
12	94.654
13	330.001
14	63.995
15	454.901
16	94.917
17	305.086
18	296.374
20	322,342
21	366.646
22	129.145
25	249.627
26	272.983
TOTAL	4,948.579

```
        CALCULATIONS OF INNIIAL PRESSURE
              FOR WELL NO. 2

          Np.Bo             P, (PSIA)

       INDEPENDENT       DEPENDENT        PREDICTED          RESIDUAL
        VARIABLE          VARIABLE         VARIABLE            VALUE

    0.23035774E+07   0.67278750E+04   0.67277142E+04  -0.16076660E+00
    0.70156602E+07   0.64248750E+04   0.64253207E+04   0.44573975E+00
    0.96760918E+07   0.62548750E+04   0.62545900E+04  -0.28497314E+00

DEGREE OF EQUATION = 1

     B(0) = 0.68755442E+04
     B(1) =-0.64174070E-04

SUM OF SQUARES OF DEVIATION =  0.30573951E+00
```

Table 11. Calculations of Initial Pressure of Well No. 2

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INFORMATION FROM WA2.DAT


INTIAL WATER SATURATION (FRACTIONAL) :   0.2360000
FORMATION COMPRESSIBILITY (1/PSIA) :   0.4600000E-05
WATER COMPRESSIBILITY (1/PSIA) :   0.3500000E-05



   P (PSIA)       NP (STB)        RC (SCF/STB)   BT (BBL/STB)  BG (CF/SCF)    WP (STB)


  6875.544      0.0000000E+00   1679.461        2.096159       0.0000000E+00  0.0000000E+00
  6727.875       1100000.       1679.461        2.094161       0.0000000E+00  0.0000000E+00
  6424.875       3323400.       1679.461        2.110989       0.0000000E+00  0.0000000E+00
  6254.875       4562500.       1679.461        2.120787       0.0000000E+00  0.0000000E+00


REFERENCE PRESSURE:  1
PRESSURE        DELTA P            X              Y
  6875.544      0.0000000E+00  0.0000000E+00  0.0000000E+00
  6727.875       147.6690      0.1018989E-01   2303577.
  6424.875       450.6690      0.3150717E-01   7015661.
  6254.875       620.6690      0.4382390E-01   9676091.


REFERENCE PRESSURE:  2
PRESSURE        DELTA P            X              Y
  6875.544      -147.6690     -0.1018989E-01  -2303577.
  6727.875      0.0000000E+00  0.0000000E+00  0.0000000E+00
  6424.875       303.0000      0.2131728E-01   4712084.
  6254.875       473.0000      0.3363401E-01   7372514.


REFERENCE PRESSURE:  3
PRESSURE        DELTA P            X              Y
  6875.544      -450.6690     -0.3150717E-01  -7015661.
  6727.875      -303.0000     -0.2131728E-01  -4712084.
  6424.875      0.0000000E+00  0.0000000E+00  0.0000000E+00
  6254.875       170.0000      0.1231673E-01   2660430.


REFERENCE PRESSURE:  4
PRESSURE        DELTA P            X              Y
  6875.544      -620.6690     -0.4382390E-01  -9676091.
  6727.875      -473.0000     -0.3363401E-01  -7372514.
  6424.875      -170.0000     -0.1231673E-01  -2660430.
  6254.875      0.0000000E+00  0.0000000E+00  0.0000000E+00
     INDEPENDENT        DEPENDENT          PREDICTED          RESIDUAL
       VARIABLE          VARIABLE           VARIABLE            VALUE

   0.10189891E-01   0.23035771E+07   0.22533846E+07   -0.50192531E+05
   0.31507170E-01   0.70156609E+07   0.69564744E+07   -0.59196438E+05
   0.43823896E-01   0.96760906E+07   0.96738323E+07   -0.22583750E+04
   0.21317279E-01   0.47120833E+07   0.47083463E+07   -0.37375625E+04
   0.33634005E-01   0.73725136E+07   0.74257040E+07    0.53190438E+05
   0.12316727E-01   0.26604298E+07   0.27226141E+07    0.62184375E+05

DEGREE OF EQUATION = 1

     B(0) = 0.52563333E+04
     B(1) = 0.22062337E+09

SUM OF SQUARES OF DEVIATION =  0.12737513E+11
```

TABLE 12. Calculations of Oil In Place of Well No. 2.

Table (13) Calculations of Initial Pressure of the Whole Reservoir

```
C        CALCULATION OF IINITIAL RESESREVOIR PRESS.
C                 OF THE BU ATTIFEL FIELD

C        NP.80                   P

      INDEPENDENT          DEPENDENT            PREDICTED             RESIDUAL
       VARIABLE            VARIABLE             VARIABLE               VALUE

   0.13456062E+08    0.68127300E+04    0.67813139E+04   -0.31416077E+02
   0.21540282E+08    0.67507300E+04    0.67530854E+04    0.23554077E+01
   0.37235537E+08    0.66897300E+04    0.66992807E+04    0.95507202E+01
   0.77851762E+08    0.65377300E+04    0.65564568E+04    0.18726868E+02
   0.11622718E+09    0.63947300E+04    0.64224575E+04    0.27727478E+02
   0.16014992E+09    0.62687300E+04    0.62690880E+04    0.35797119E+00
   0.17809491E+09    0.62327300E+04    0.62064276E+04   -0.26302368E+02

 DEGREE OF EQUATION = 1

      B(0) = 0.68282998E+04
      B(1) =-0.34918021E-05

 SUM OF SQUARES OF DEVIATION =  0.28770840E+04
```

Table (14) Calculations of Oil In Place Of The Whole Reservoir

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INFORMATION FROM A100.DAT


INTIAL WATER SATURATION (FRACTIONAL) :    0.1800000
FORMATION COMPRESSIBILITY (1/PSIA) :    0.4200000E-05
WATER COMPRESSIBILITY (1/PSIA) :    0.3500000E-05


   P (PSIA)        NP (STB)        RC (SCF/STB)    BT (BBL/STB)  BG (CF/SCF)       WP (STB)


   6828.300      0.0000000E+00   1743.539          2.123573       0.0000000E+00  0.0000000E+00
   6812.730       6333959.       1743.539          2.124431       0.0000000E+00  0.0000000E+00
   6750.730      0.1012297E+08   1743.539          2.127862       0.0000000E+00  0.0000000E+00
   6689.730      0.1747115E+08   1743.539          2.131258       0.0000000E+00  0.0000000E+00
   6537.730      0.3638229E+08   1743.539          2.139826       0.0000000E+00  0.0000000E+00
   6394.730      0.5410800E+08   1743.539          2.148059       0.0000000E+00  0.0000000E+00
   6268.730      0.7429804E+08   1743.539          2.155507       0.0000000E+00  0.0000000E+00
   6232.730      0.8254000E+08   1743.539          2.157680       0.0000000E+00  0.0000000E+00


REFERENCE PRESSURE:  1
PRESSURE         DELTA P               X              Y
   6828.300      0.0000000E+00   0.0000000E+00   0.0000000E+00
   6812.730       15.57001       0.1052764E-02   0.1345606E+08
   6750.730       77.57001       0.5259275E-02   0.2154028E+08
   6689.730       138.5700       0.9418290E-02   0.3723553E+08
   6537.730       290.5700       0.1988755E-01   0.7795175E+08
   6394.730       433.5700       0.2990926E-01   0.1162272E+09
   6268.730       559.5700       0.3893330E-01   0.1601499E+09
   6232.730       595.5700       0.4155661E-01   0.1730949E+09


REFERENCE PRESSURE:  2
PRESSURE         DELTA P               X              Y
   6828.300      -15.57001      -0.1052764E-02 -0.1345606E+08
   6812.730      0.0000000E+00   0.0000000E+00   0.0000000E+00
   6750.730       62.00000       0.4206511E-02    8084224.
   6689.730       123.0000       0.8365526E-02   0.2377947E+08
   6537.730       275.0000       0.1383479E-01   0.6439569E+08
   6394.730       413.0000       0.2385649E-01   0.1027711E+09
   6268.730       544.0000       0.3788053E-01   0.1466937E+09
   6232.730       580.0000       0.4050384E-01   0.1646389E+09


REFERENCE PRESSURE:  3
PRESSURE         DELTA P               X              Y
   6828.300      -77.57001      -0.5259275E-02 -0.2154028E+08
   6812.730      -62.00000      -0.4206511E-02  -8084224.
   6750.730      0.0000000E+00   0.0000000E+00   0.0000000E+00
   6689.730       61.00000       0.4159015E-02   0.1569525E+08
   6537.730       213.0000       0.1462827E-01   0.5631147E+08
   6394.730       356.0000       0.2464998E-01   0.9468689E+08
   6268.730       482.0000       0.3367402E-01   0.1336097E+09
   6232.730       518.0000       0.3629733E-01   0.1565546E+09
```

Table (14) continued

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REFERENCE PRESSURE:  4
PRESSURE        DELTA P              X               Y
  6828.300      -138.5700      -0.9418290E-02 -0.3723553E+08
  6812.730      -123.0000      -0.8365526E-02 -0.2377947E+08
  6750.730      -61.00000      -0.4159015E-02 -0.1569525E+08
  6689.730      0.0000000E+00   0.0000000E+00  0.0000000E+00
  6537.730       152.0000       0.1046926E-01  0.4061622E+08
  6394.730       295.0000       0.2049097E-01  0.7899165E+08
  6268.730       421.0000       0.2951501E-01  0.1229144E+09
  6232.730       457.0000       0.3213832E-01  0.1408594E+09


REFERENCE PRESSURE:  5
PRESSURE        DELTA P              X               Y
  6828.300      -290.5700      -0.1988755E-01 -0.7785175E+08
  6812.730      -275.0000      -0.1883479E-01 -0.6439569E+08
  6750.730      -213.0000      -0.1462827E-01 -0.5631147E+08
  6689.730      -152.0000      -0.1046926E-01 -0.4061622E+08
  6537.730      0.0000000E+00   0.0000000E+00  0.0000000E+00
  6394.730       143.0000       0.1002171E-01  0.3837543E+08
  6268.730       269.0000       0.1904575E-01  0.8229820E+08
  6232.730       305.0000       0.2166906E-01  0.1002432E+09


REFERENCE PRESSURE:  6
PRESSURE        DELTA P              X               Y
  6828.300      -433.5700      -0.2990926E-01 -0.1162272E+09
  6812.730      -418.0000      -0.2885649E-01 -0.1027711E+09
  6750.730      -356.0000      -0.2464998E-01 -0.9468689E+08
  6689.730      -295.0000      -0.2049097E-01 -0.7899165E+08
  6537.730      -143.0000      -0.1002171E-01 -0.3837543E+08
  6394.730      0.0000000E+00   0.0000000E+00  0.0000000E+00
  6268.730       126.0000       0.9024041E-02  0.4392277E+08
  6232.730       162.0000       0.1164735E-01  0.6186773E+08


REFERENCE PRESSURE:  7
PRESSURE        DELTA P              X               Y
  6828.300      -559.5700      -0.3893330E-01 -0.1601499E+09
  6812.730      -544.0000      -0.3788053E-01 -0.1466939E+09
  6750.730      -482.0000      -0.3367402E-01 -0.1386097E+09
  6689.730      -421.0000      -0.2951501E-01 -0.1229144E+09
  6537.730      -269.0000      -0.1904575E-01 -0.8229820E+08
  6394.730      -126.0000      -0.9024041E-02 -0.4392277E+08
  6268.730      0.0000000E+00   0.0000000E+00  0.0000000E+00
  6232.730       36.00000       0.2623308E-02  0.1794496E+08


REFERENCE PRESSURE:  8
PRESSURE        DELTA P              X               Y
  6828.300      -595.5700      -0.4155661E-01 -0.1780949E+09
  6812.730      -580.0000      -0.4050384E-01 -0.1646389E+09
  6750.730      -518.0000      -0.3629733E-01 -0.1565546E+09
```

Table (14) continued

```
6689.730        -457.0000       -0.3213832E-01 -0.1408594E+09
6537.730        -305.0000       -0.2166906E-01 -0.1002432E+09
6394.730        -162.0000       -0.1164735E-01 -0.6186773E+08
6268.730        -36.00000       -0.2623308E-02 -0.1794496E+08
6232.730        0.0000000E+00   0.0000000E+00  0.0000000E+00
   INDEPENDENT          DEPENDENT          PREDICTED          RESIDUAL
     VARIABLE            VARIABLE           VARIABLE            VALUE

 0.10527642E-02   0.13456059E+08   0.42205449E+07   -0.92355141E+07
 0.52592750E-02   0.21540283E+08   0.21405534E+08   -0.13474950E+06
 0.94182896E-02   0.37235529E+08   0.38396485E+08    0.11609565E+07
 0.19887550E-01   0.77851749E+08   0.81166877E+08    0.33151280E+07
 0.29909256E-01   0.11622718E+09   0.12210887E+09    0.58816890E+07
 0.38933298E-01   0.16014995E+09   0.15897506E+09   -0.11748860E+07
 0.41556606E-01   0.17809491E+09   0.16969214E+09   -0.84027680E+07
 0.42065109E-02   0.80842243E+07   0.17104644E+08    0.90204198E+07
 0.83655255E-02   0.23779470E+08   0.34095595E+08    0.10316126E+08
 0.18834785E-01   0.64395690E+08   0.76865986E+08    0.12470296E+08
 0.28856492E-01   0.10277112E+09   0.11780798E+09    0.15036857E+08
 0.37880533E-01   0.14669389E+09   0.15467417E+09    0.79802820E+07
 0.40503841E-01   0.16463885E+09   0.16539125E+09    0.75240000E+06
 0.41590146E-02   0.15695245E+08   0.16910606E+08    0.12153605E+07
 0.14628275E-01   0.56311466E+08   0.59680998E+08    0.33695320E+07
 0.24649981E-01   0.94686894E+08   0.10062299E+09    0.59360930E+07
 0.33674023E-01   0.13860966E+09   0.13748918E+09   -0.11204820E+07
 0.36297331E-01   0.15655462E+09   0.14820626E+09   -0.83483620E+07
 0.10469260E-01   0.40616221E+08   0.42690047E+08    0.20738260E+07
 0.20490967E-01   0.78991649E+08   0.83632035E+08    0.46403860E+07
 0.29515008E-01   0.12291442E+09   0.12049823E+09   -0.24161380E+07
 0.32138316E-01   0.14085938E+09   0.13121531E+09   -0.96440680E+07
 0.10021707E-01   0.38375428E+08   0.40861644E+08    0.24862160E+07
 0.19045748E-01   0.82298197E+08   0.77727839E+08   -0.45703580E+07
 0.21669056E-01   0.10024316E+09   0.88444920E+08   -0.11798239E+08
 0.90240412E-02   0.43922769E+08   0.36785850E+08   -0.71369190E+07
 0.11647349E-01   0.61867731E+08   0.47502931E+08   -0.14364800E+08
 0.26233080E-02   0.17944962E+08   0.10636736E+08   -0.73082259E+07

DEGREE OF EQUATION = 1

     B(0) =-0.80345143E+05
     B(1) = 0.40853309E+10

SUM OF SQUARES OF DEVIATION =  0.15585485E+16
```

Table (15) Volumetric Calculations of Oil In Place

Productive Area	Area Acre	Isopach Interval ft	DV_b ac/ft
A0	163	---	---
A1	31,537	100	1,075,073
A2	29,456	50	1,524,833
A3	27,798	50	1,431,359
A4	23,994	50	1,294,810
A5	19,888	50	1,079,051
A6	16,256	50	903,609
A7	11,607	50	696,550
A8	5,657	50	431,605
A9	3,674	50	233,274
A10	1,138	50	81,355
A11	260	50	23,924
A0′	1,723	50	---
A1′	910	50	65,834
A2′	325	50	22,270
			8,863,547

$N = 7758\ Ah\phi(1-Swi)/Bo_i$

$= 7758 \times 8{,}863{,}547 \times .134\ (1 - .18)/2.123573 = 3.558$ MMMSTB

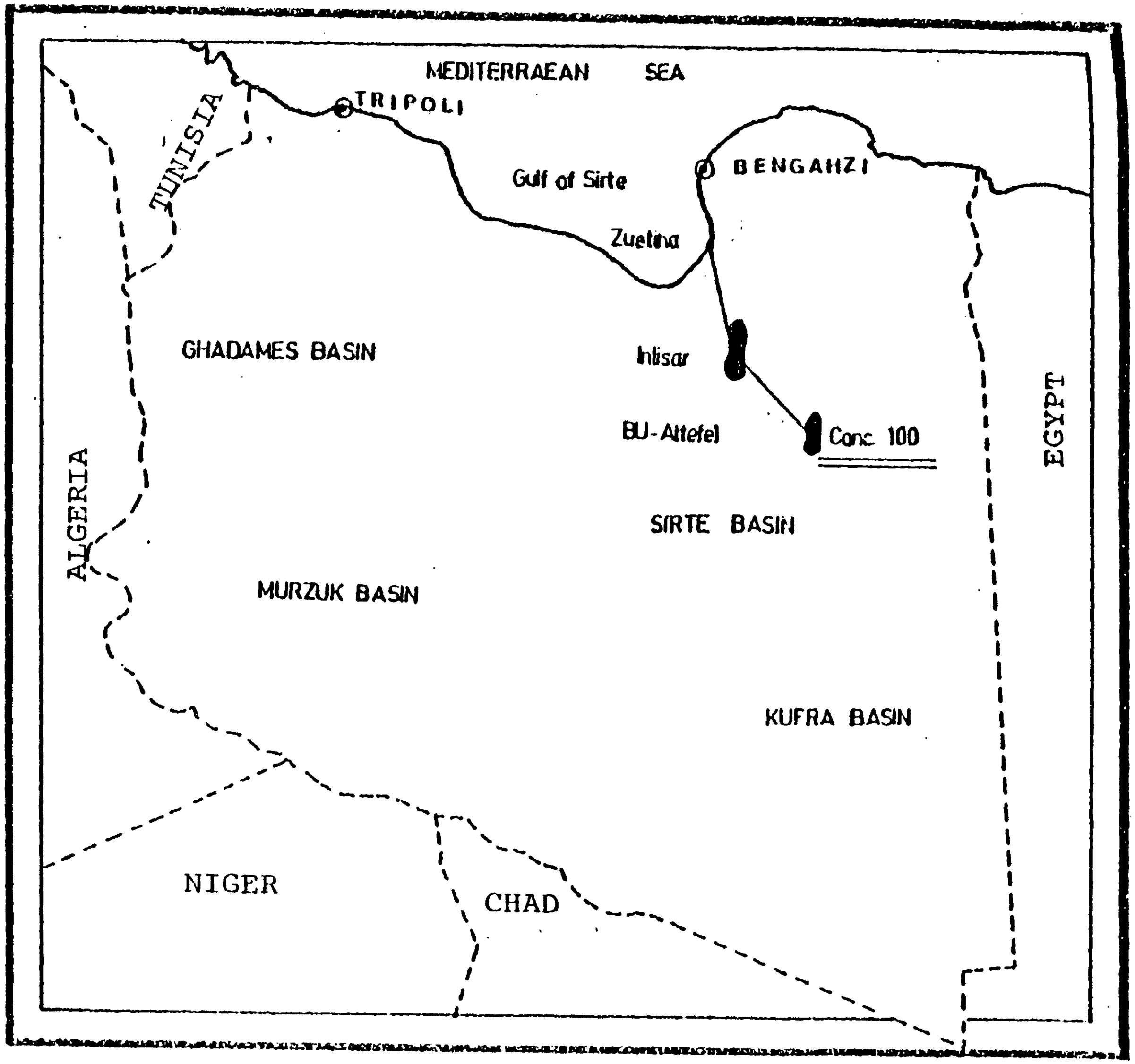

Fig. (1) Location Map of Bu-Attifel Oil Field, Libya

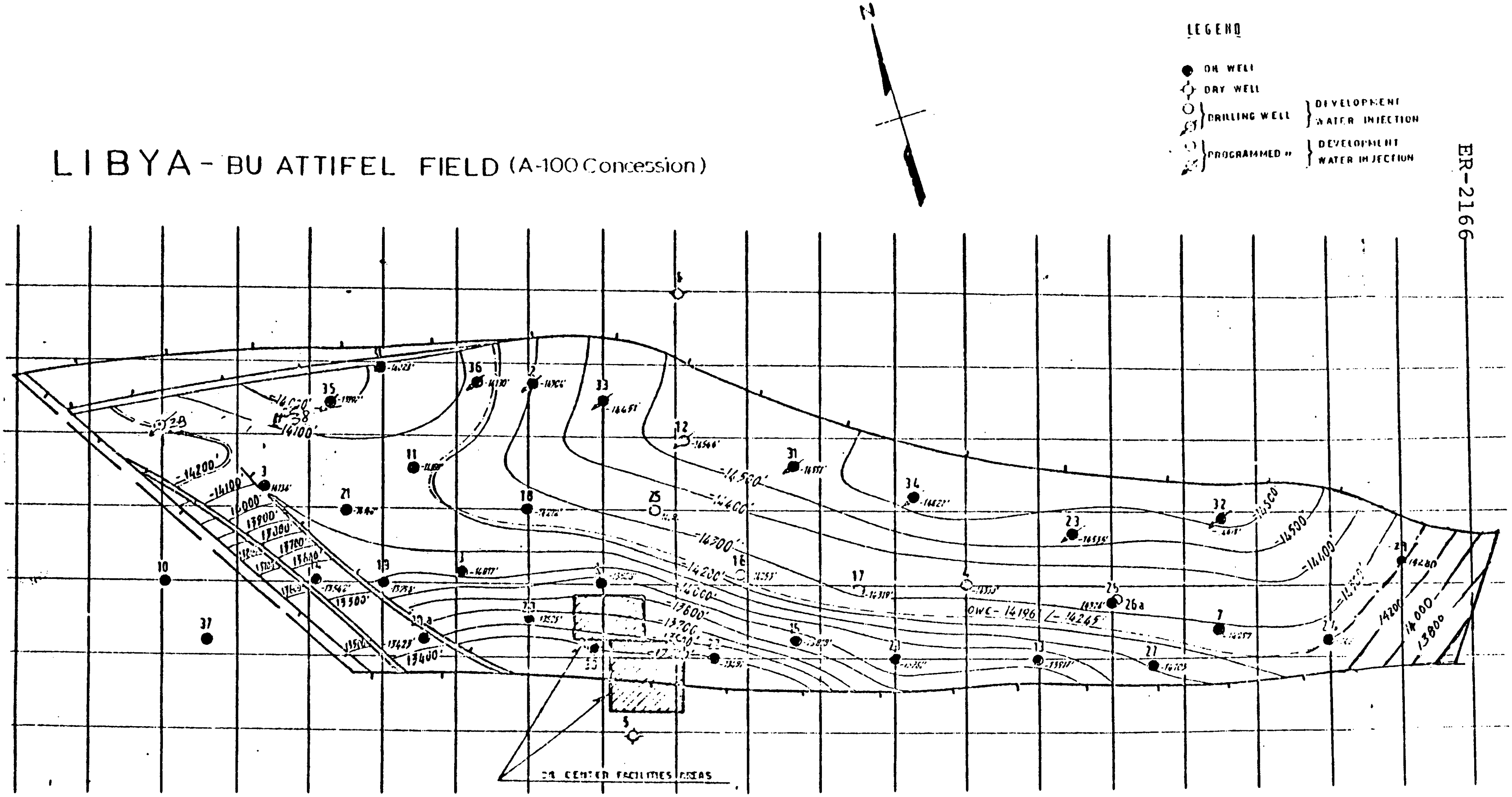

Fig. (2) Bu-Attifel Structural Contour Map, Bottom of the First Nubian Sandstone

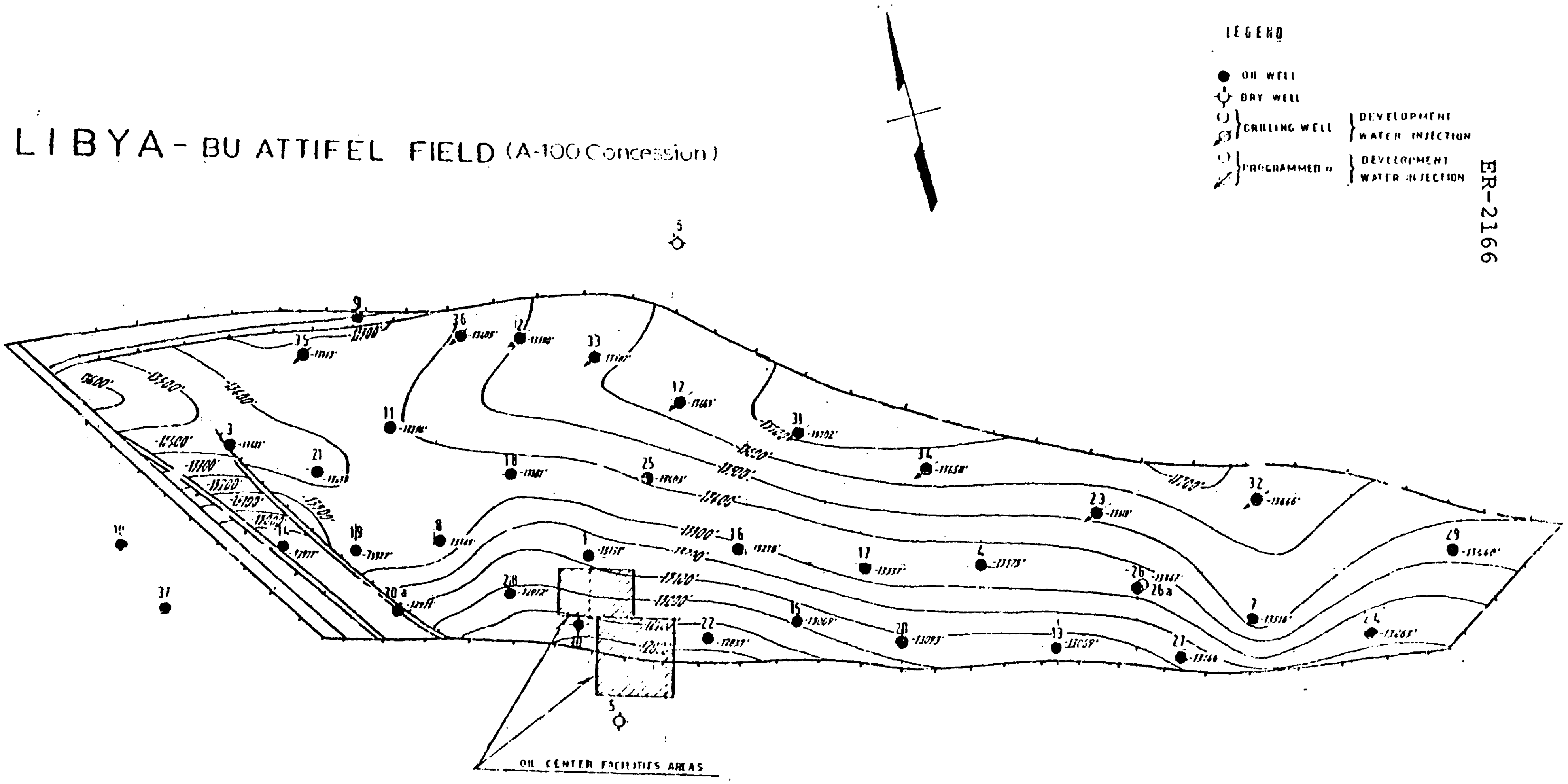

Fig. (3) Bu-Attifel Structural Contour Map, Top of the First Nubian Sandstone

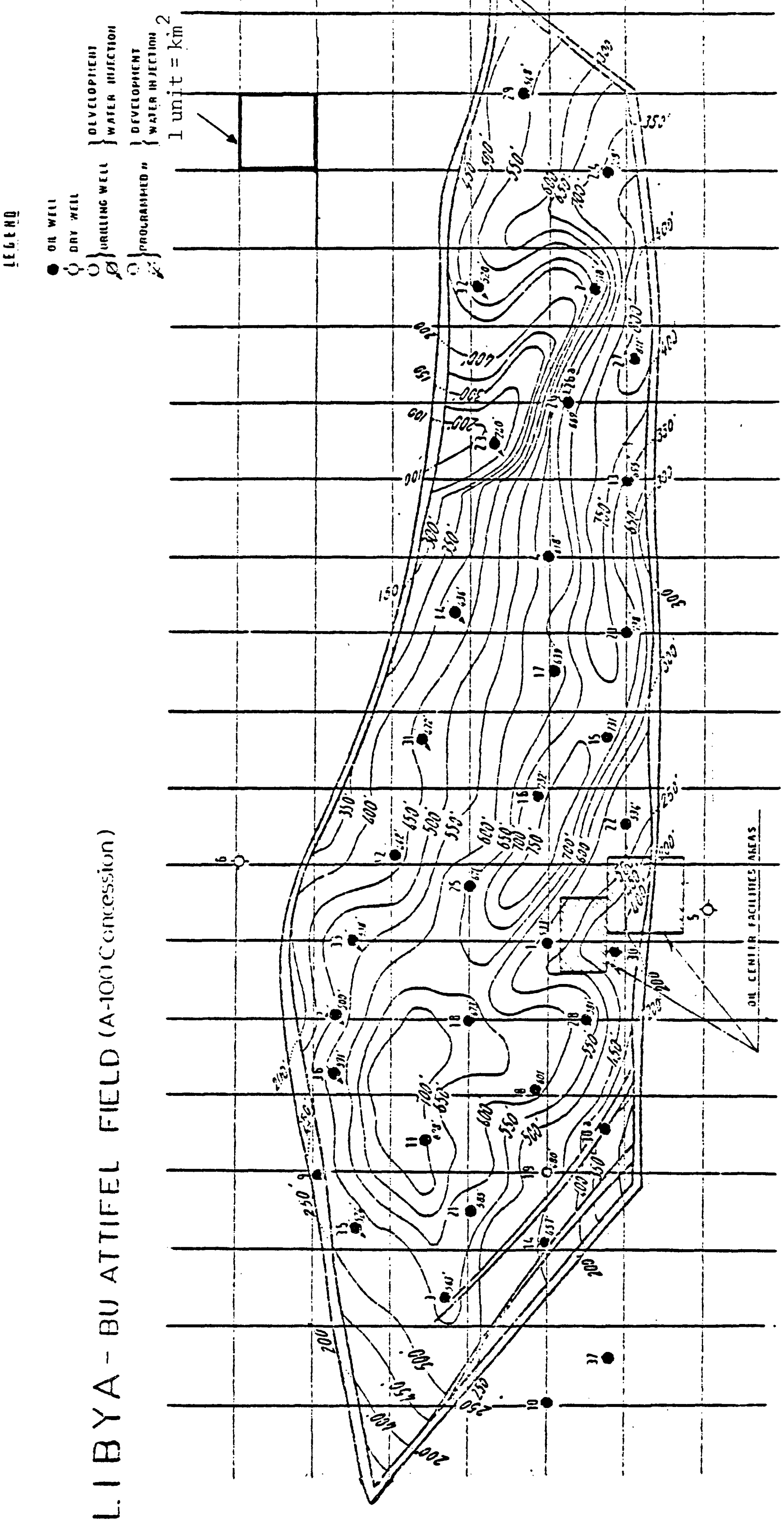

Fig. (4) Bu-Attifel Net Isopach Map, The First Nubian Sandstone

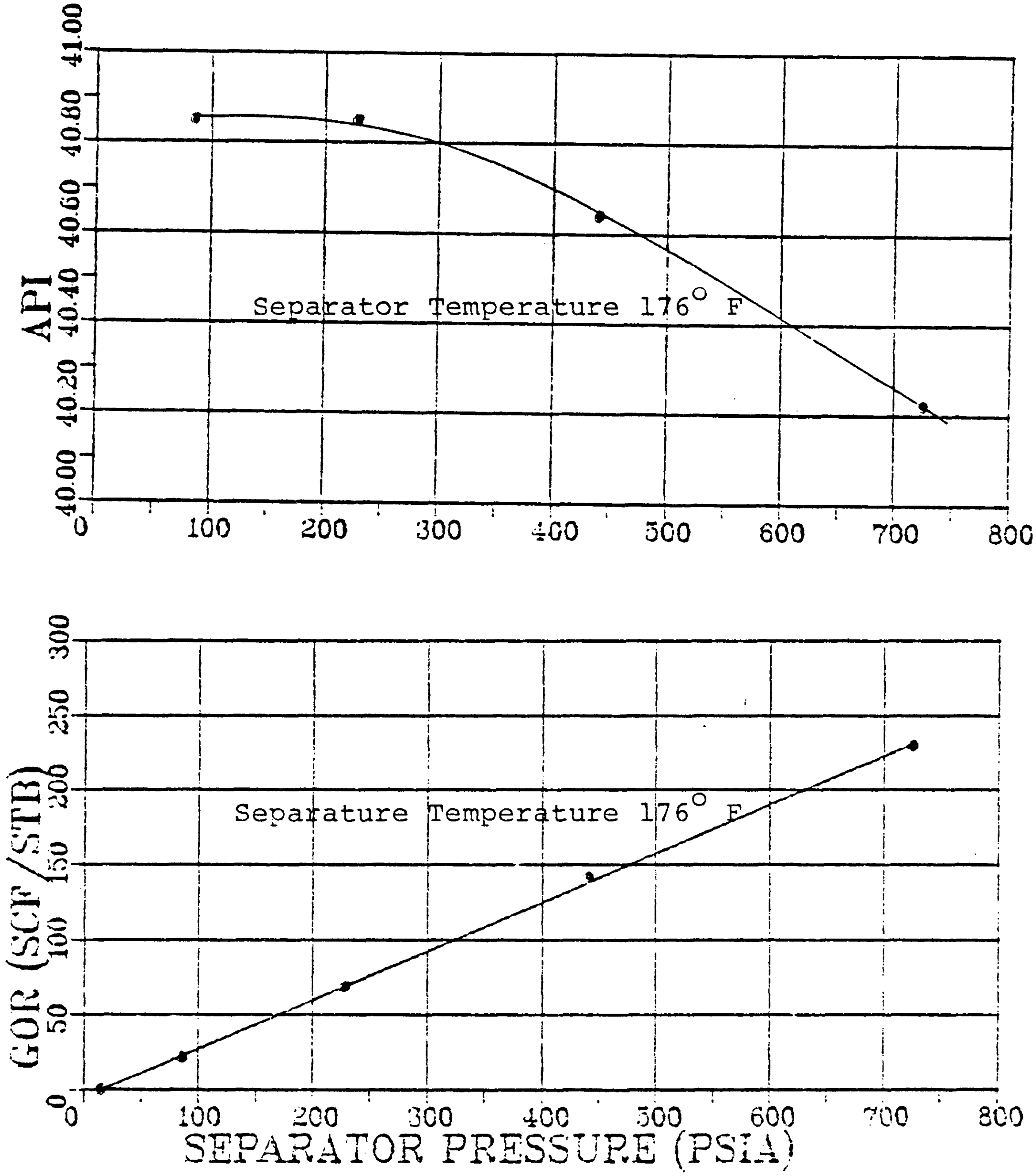

Fig. (5). Separator Pressure Effect on Stock Tank GOR and API Gravity

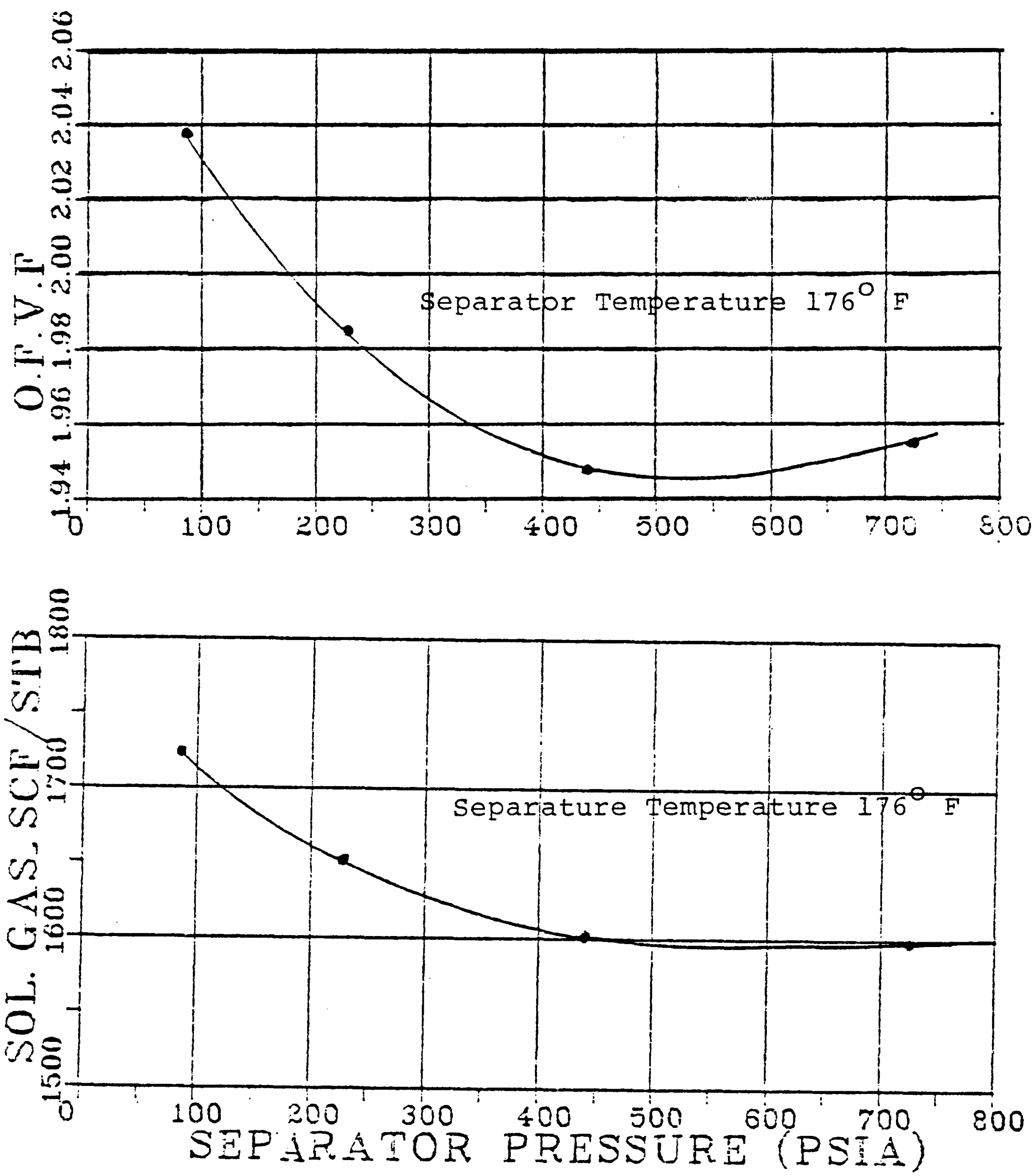

Fig. (6). Separator Pressure Effect On Initial Solution GOR and Bubble Point Oil Formation Volume Factor

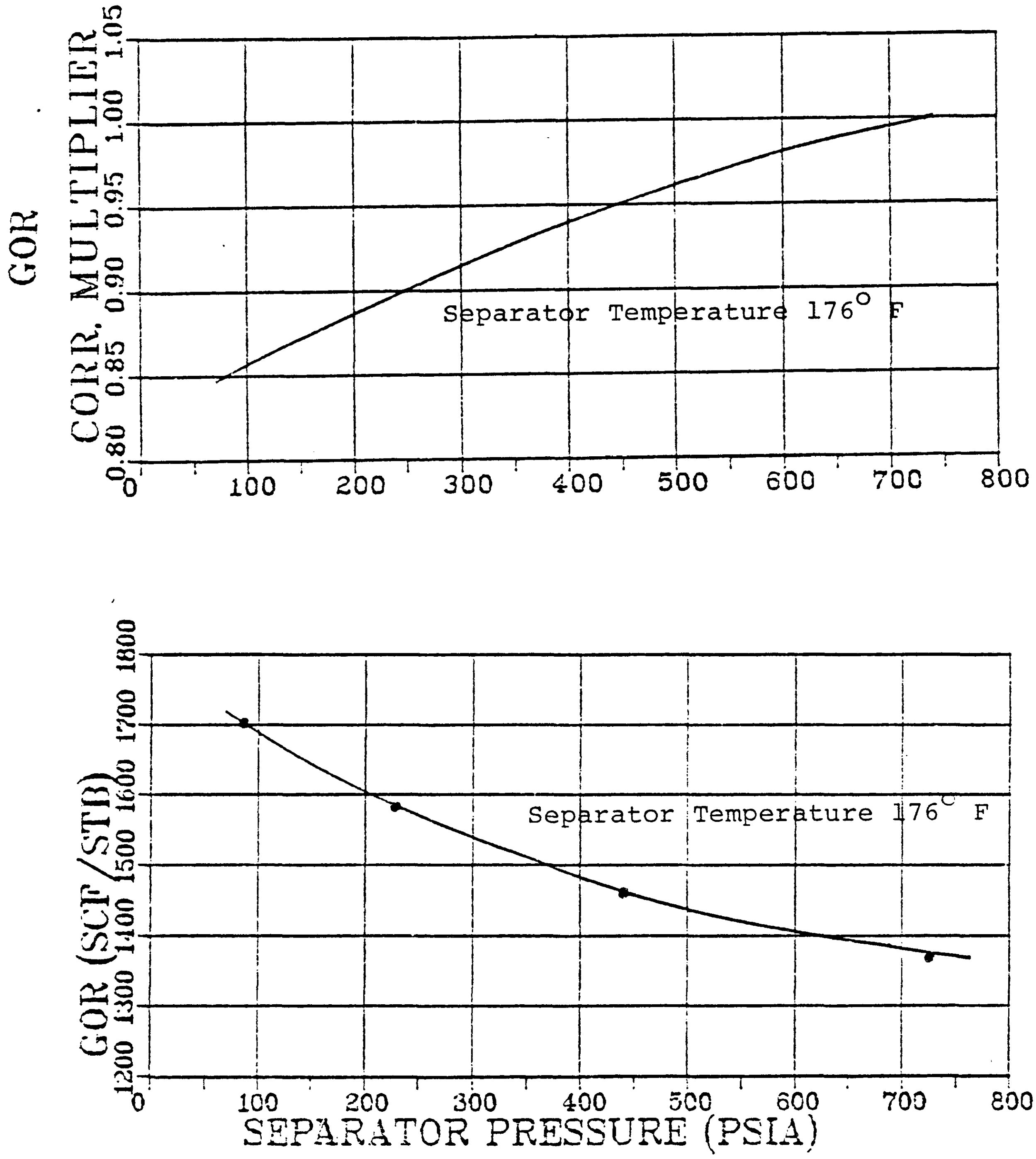

Fig. (7). Separator Pressure Effect on Producing GOR and Correction to 725 psia

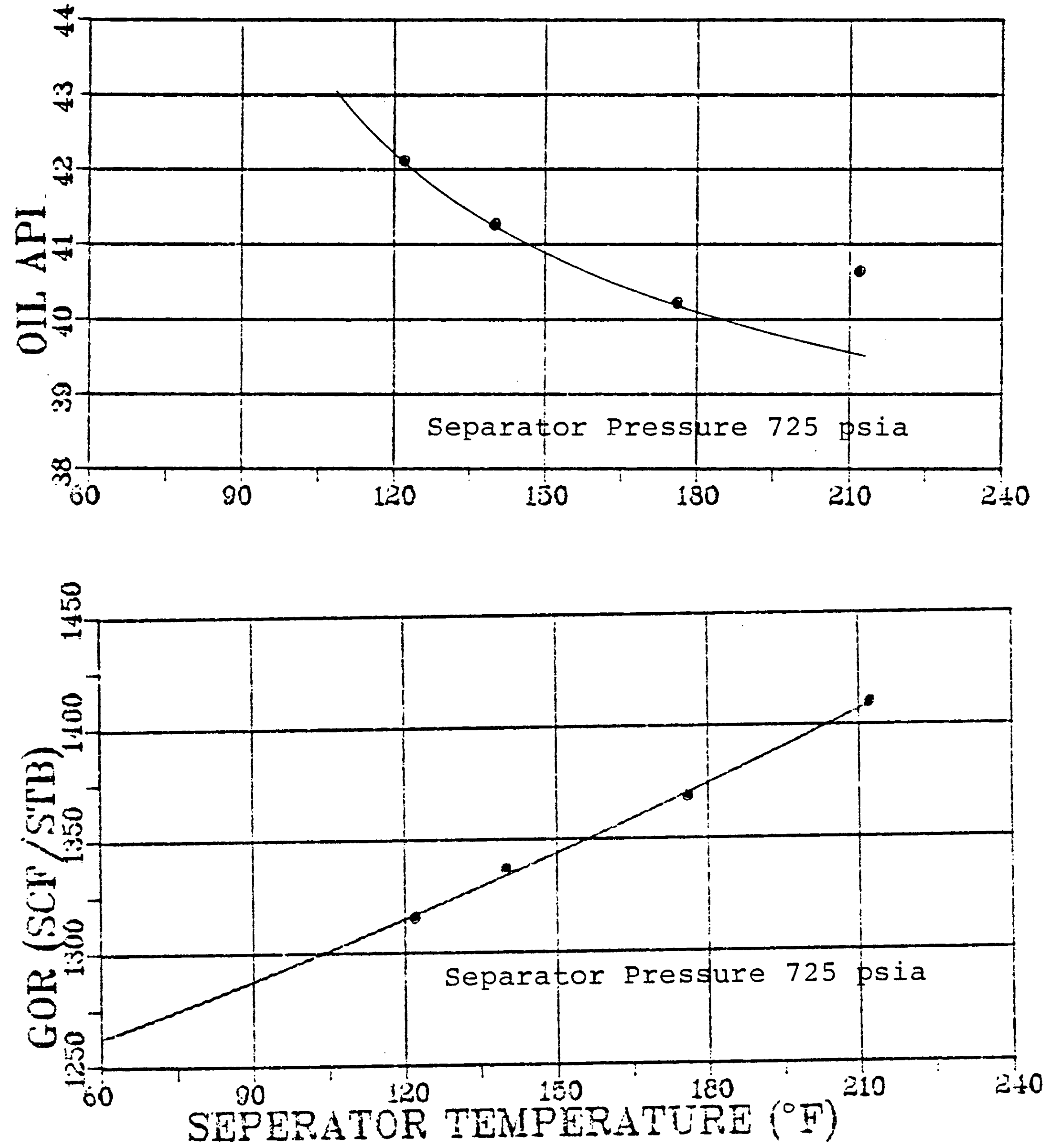

Fig. (8). Separator Temperature Effect on Producing GOR and API Gravity

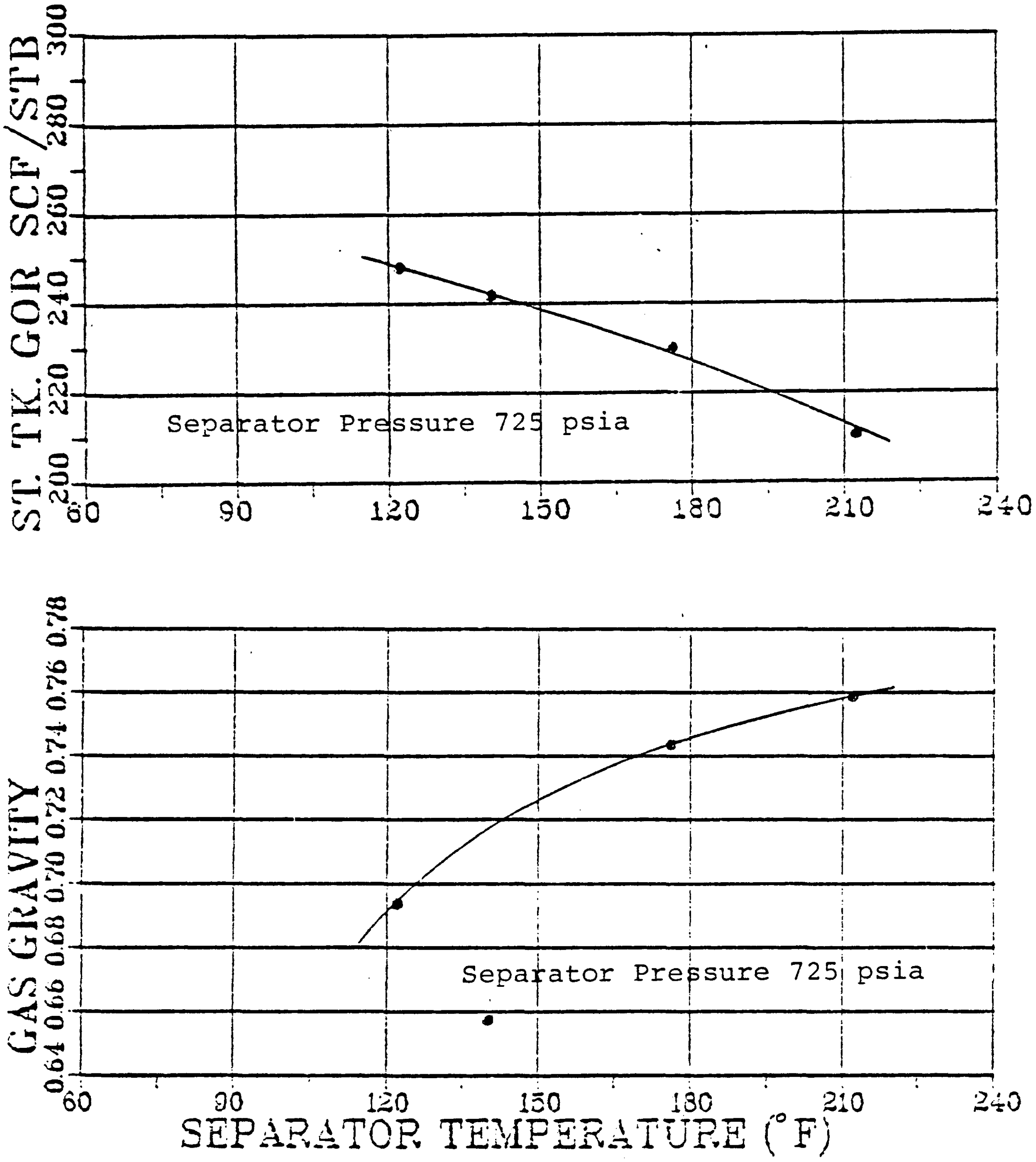

Fig. (9). Separator Temperature Effect on Gas Gravity and Stock Tank GOR

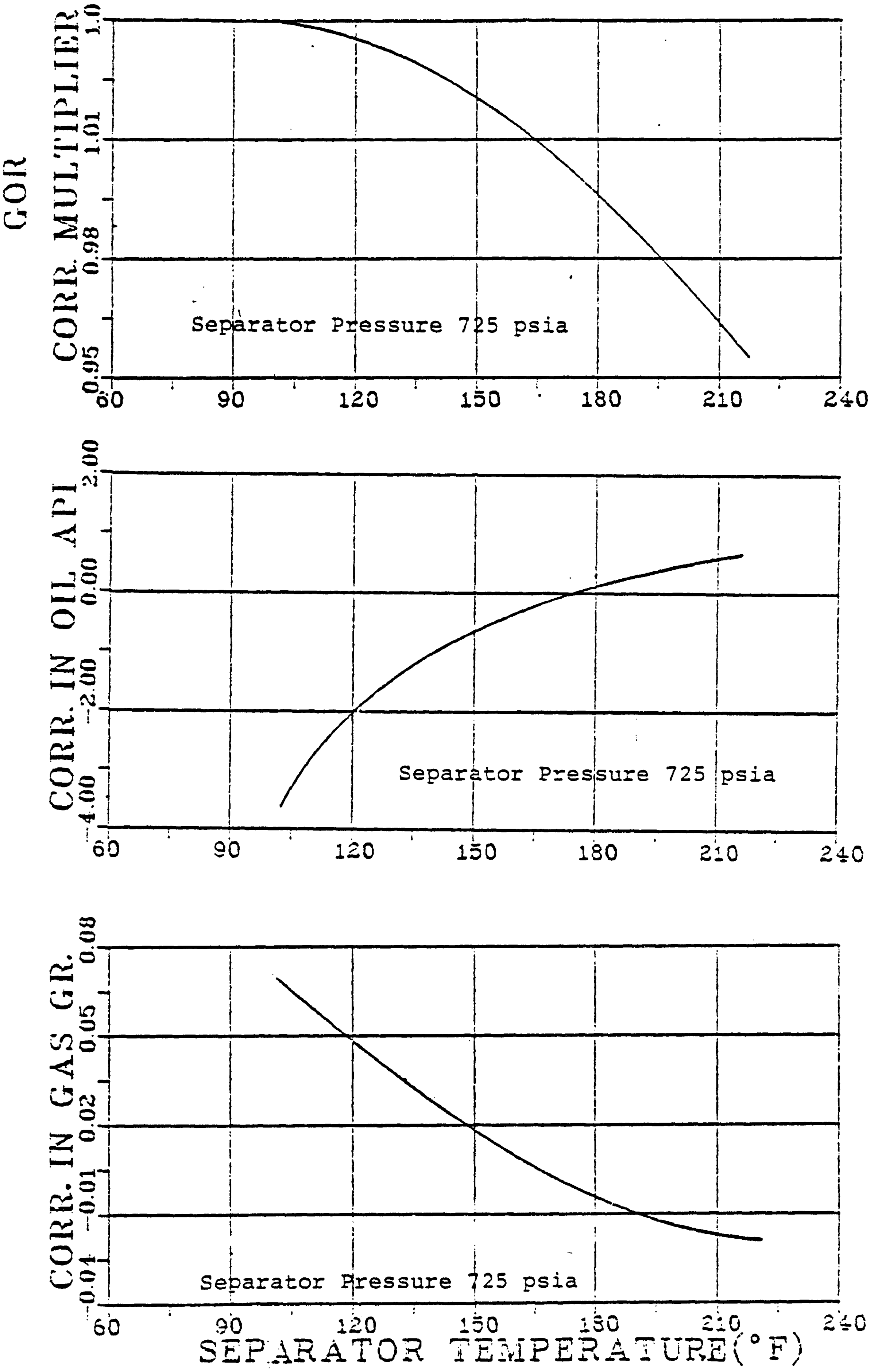

Fig. (10). Correction in Producing GOR, API and Gas Gravity to Separator Temperature of (176° F).

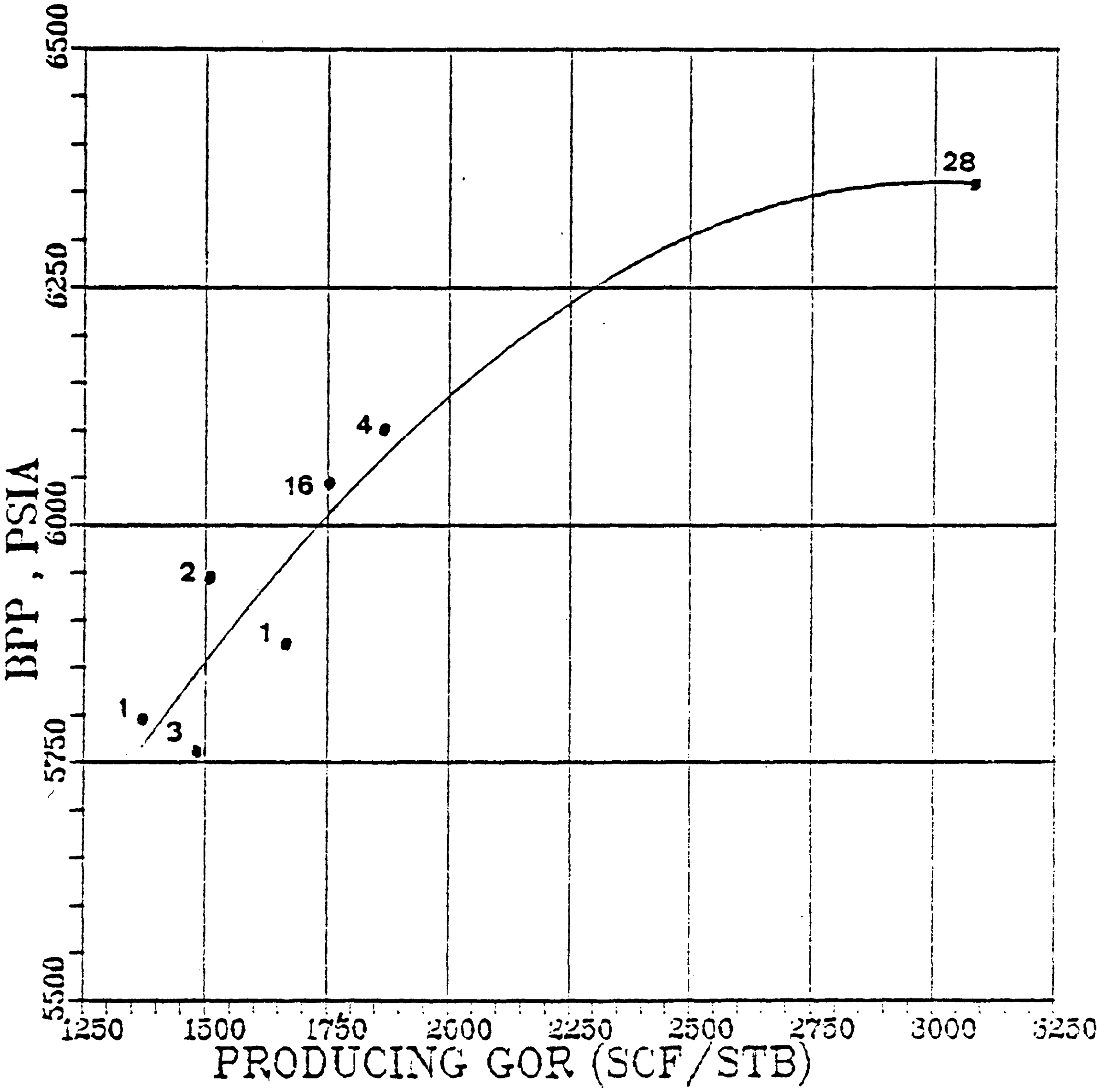

Fig. (11). Variation of BPP With Producing GOR

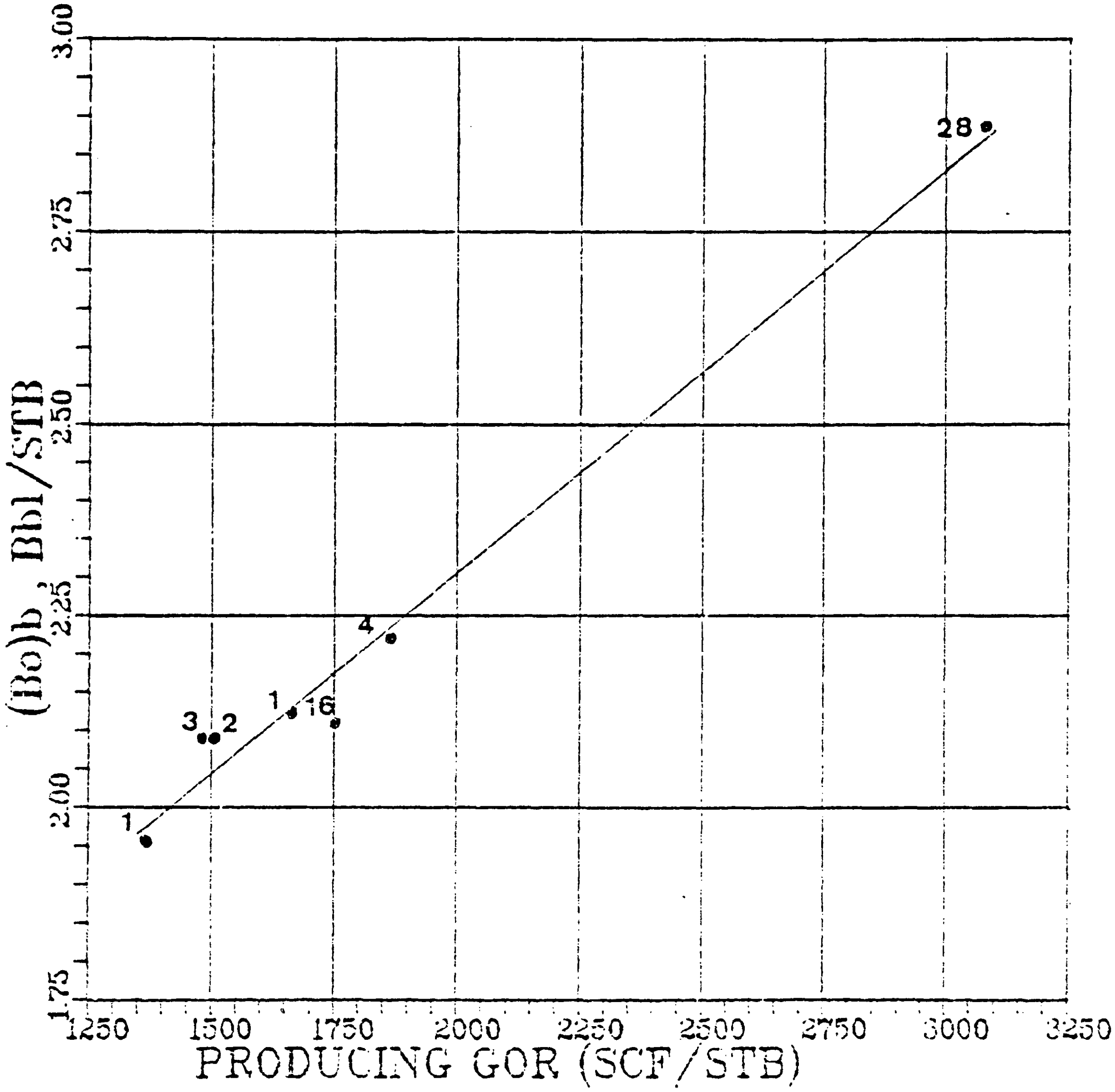

Fig. (12). Variation of O.F.V.F. @ BPP With Producing GOR

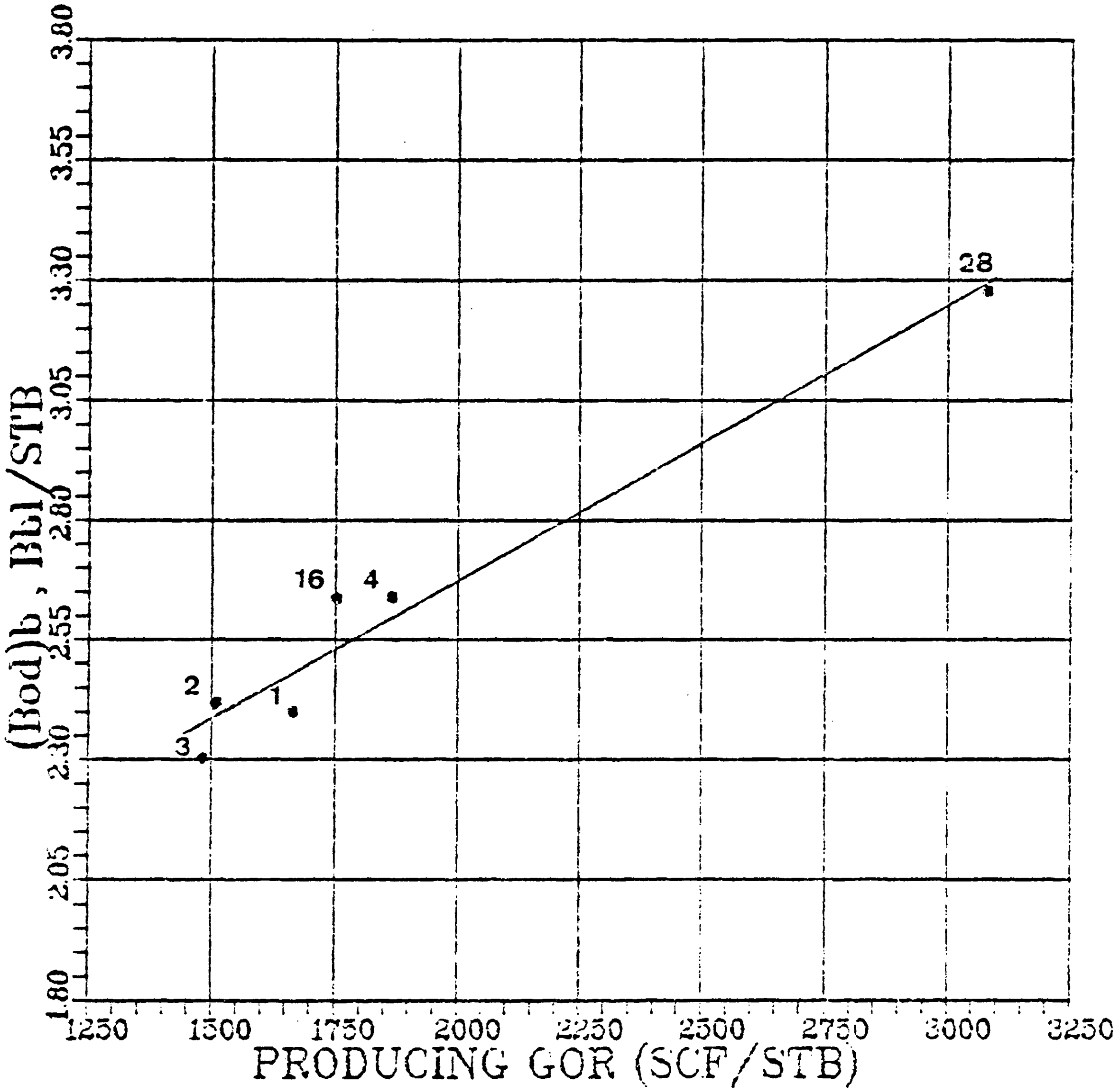

Fig. (13). Variation of (Bod)b with Producing GOR

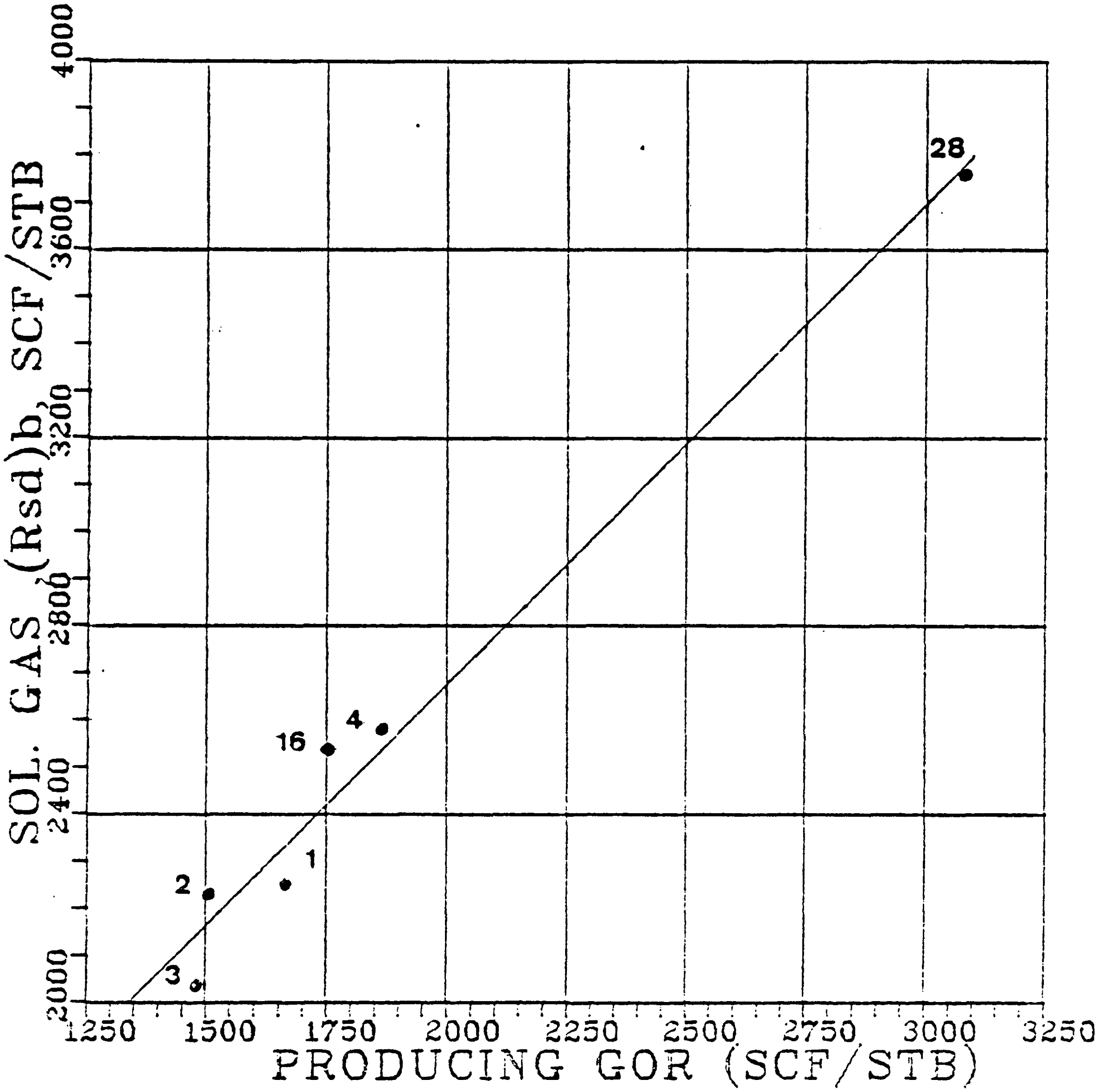

Fig. (14). Variation of (Rsd)b with Producing GOR

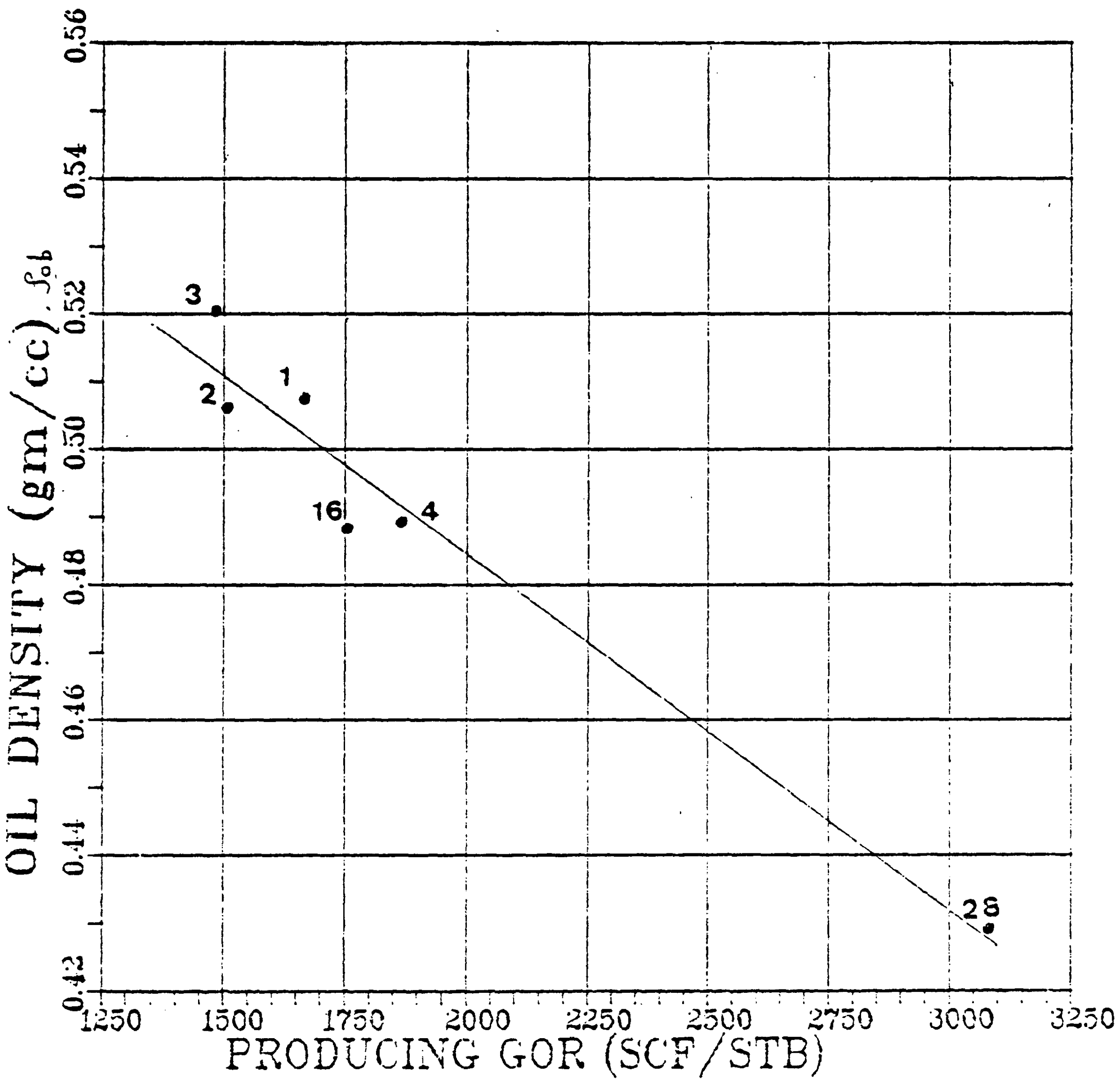

Fig. (15). Oil Density Variation with Producing GOR

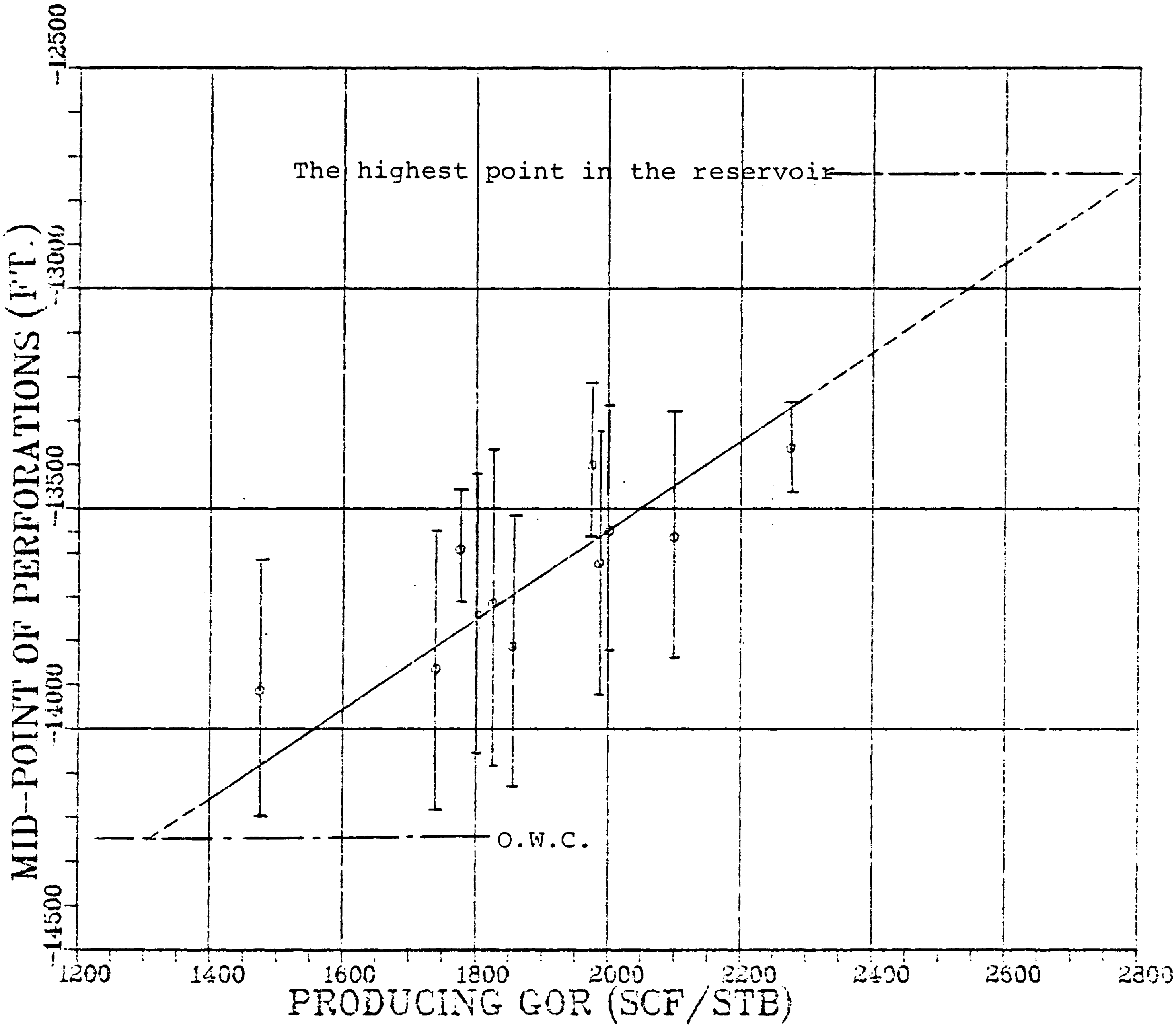

Fig. (16). Variation of Producing GOR With Depth

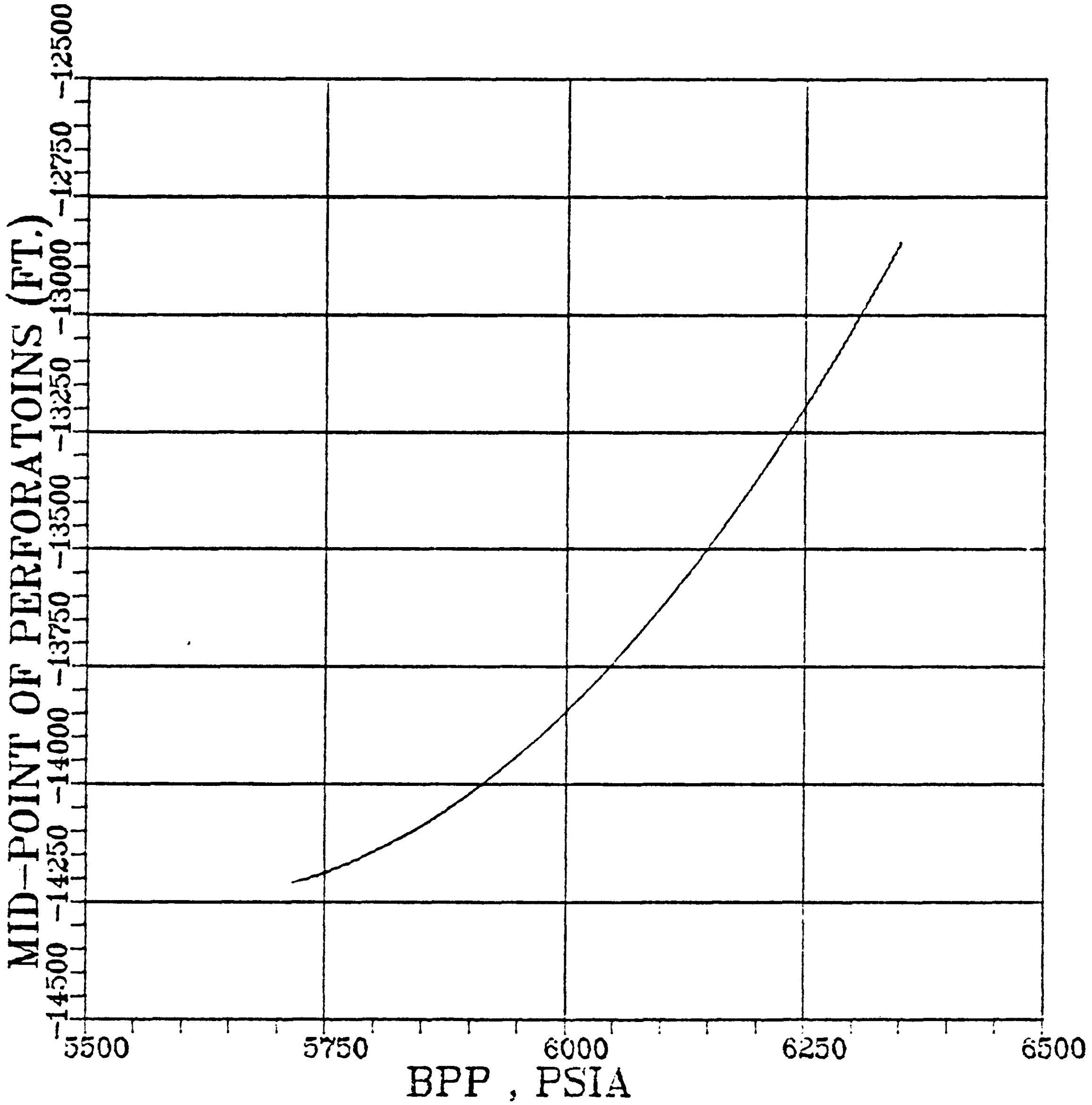

Fig. (17). Variation of BPP With Depth

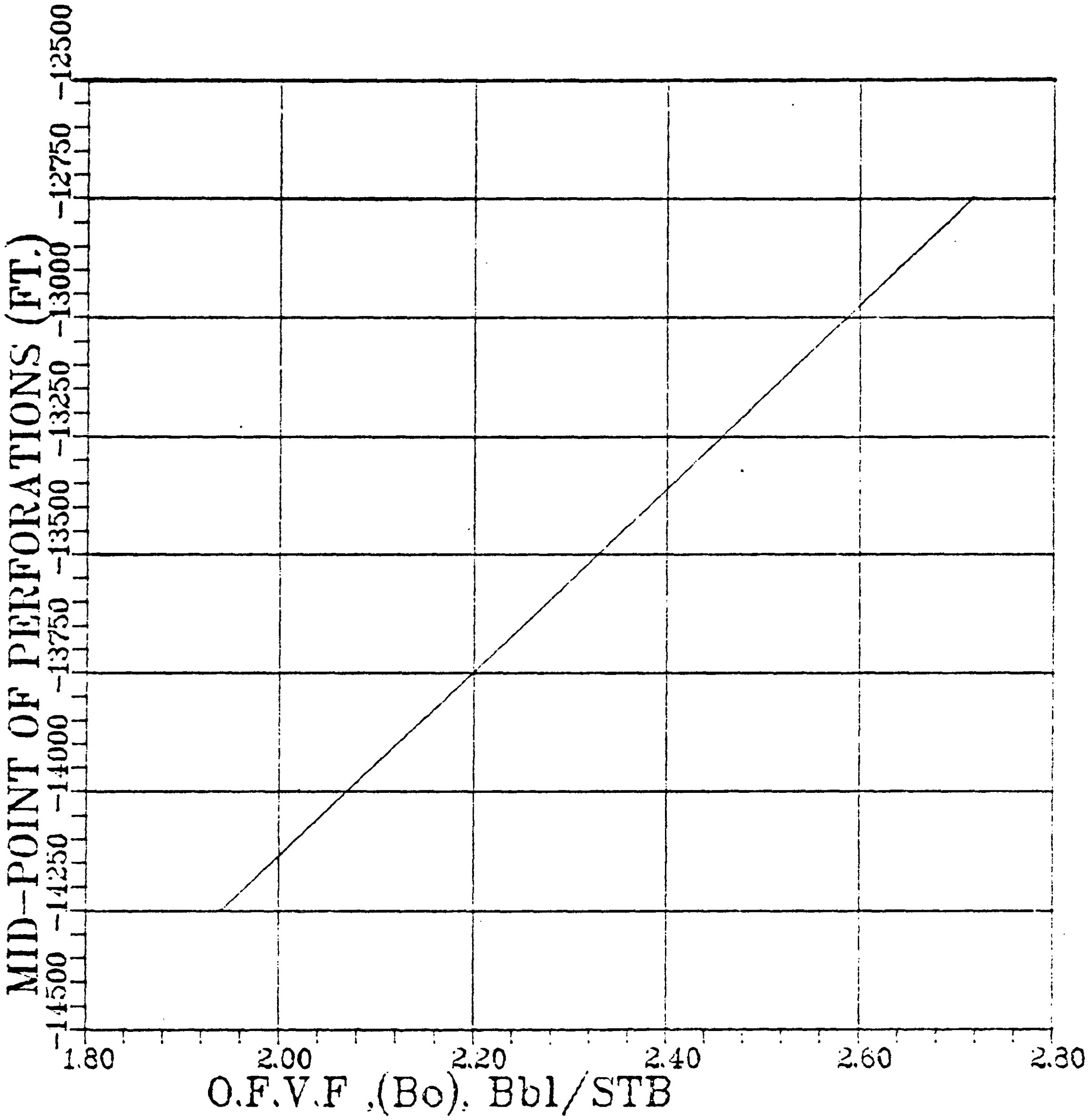

Fig. (18). Variation of (Bo)b with Depth

BU ATTIFEL FIELD

STATIC PRESSURE PROFILE (After tests)

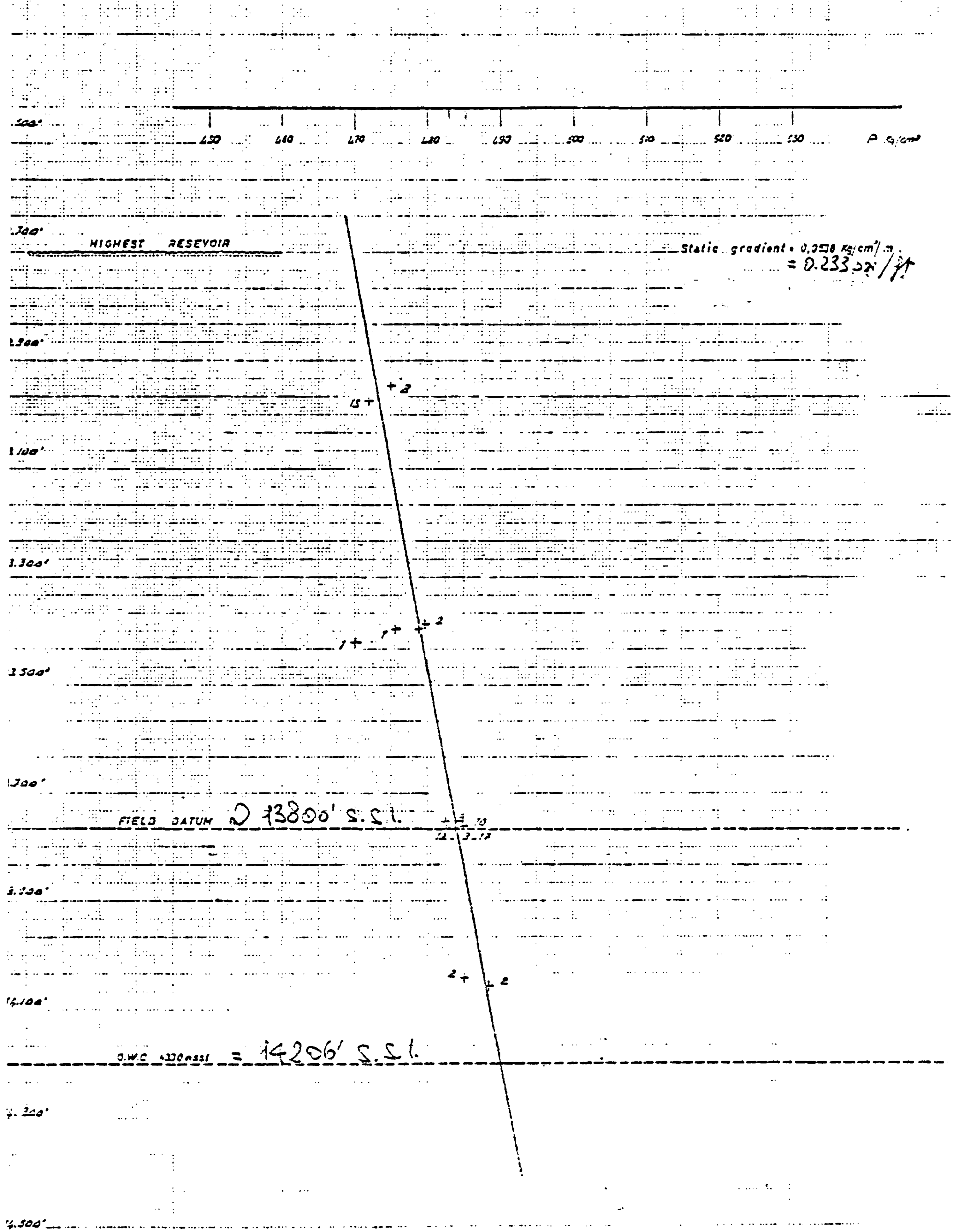

Fig. (19). Variation of Original Static Pressure With Depth

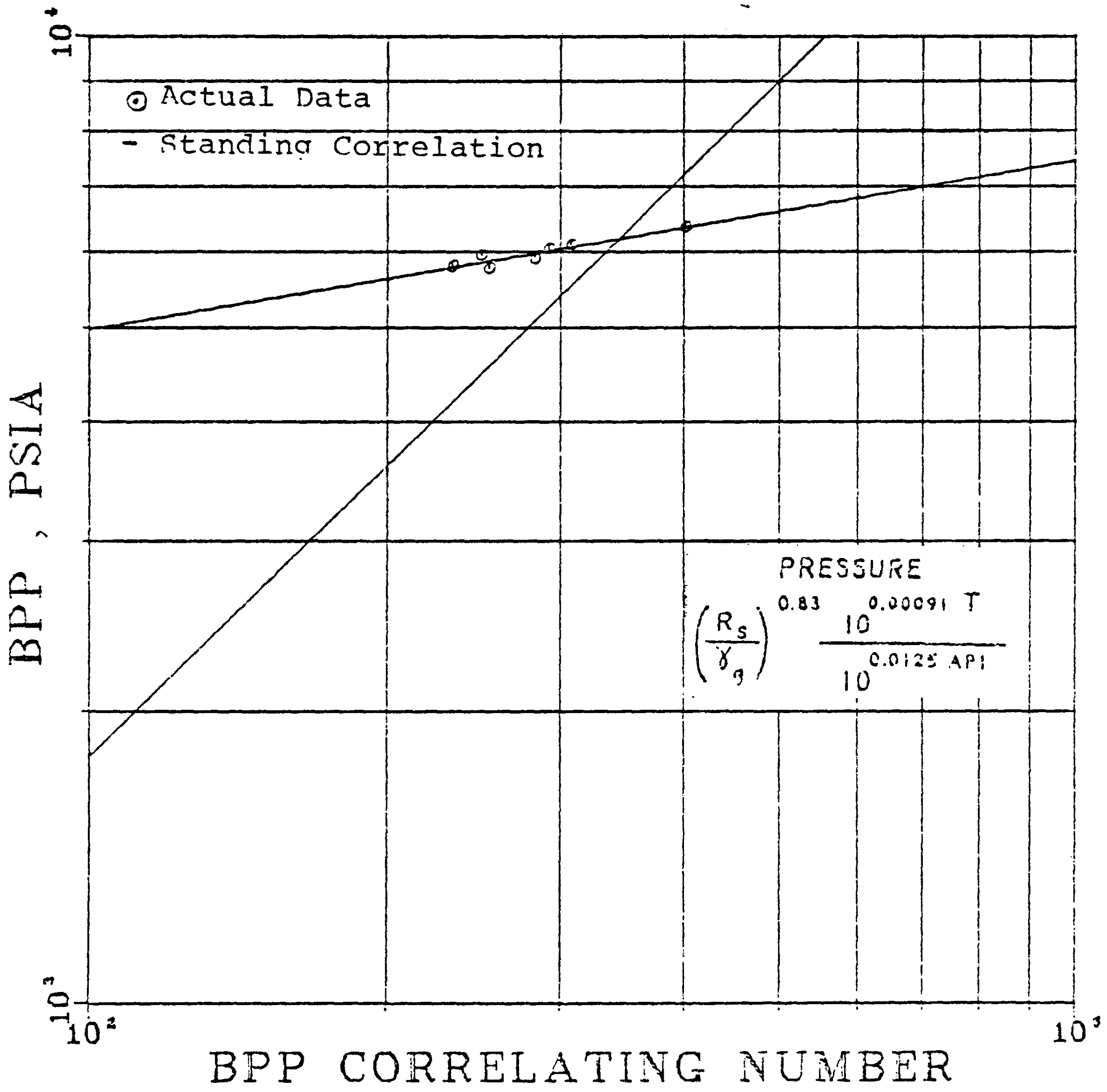

Fig. (20). Standing Correlation of BPP

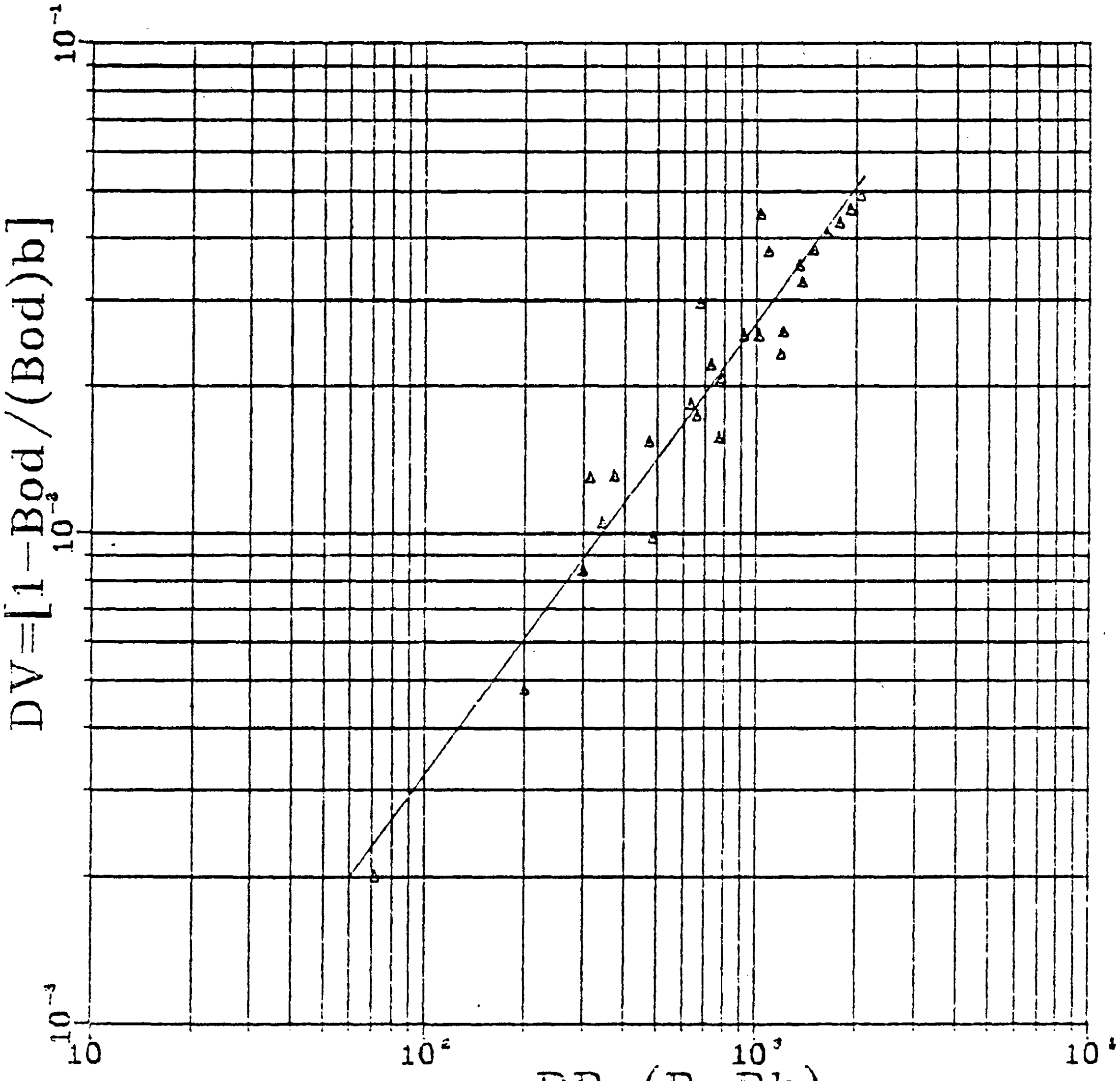

Fig. (21). Normalized O.F.V.F. Above BPP

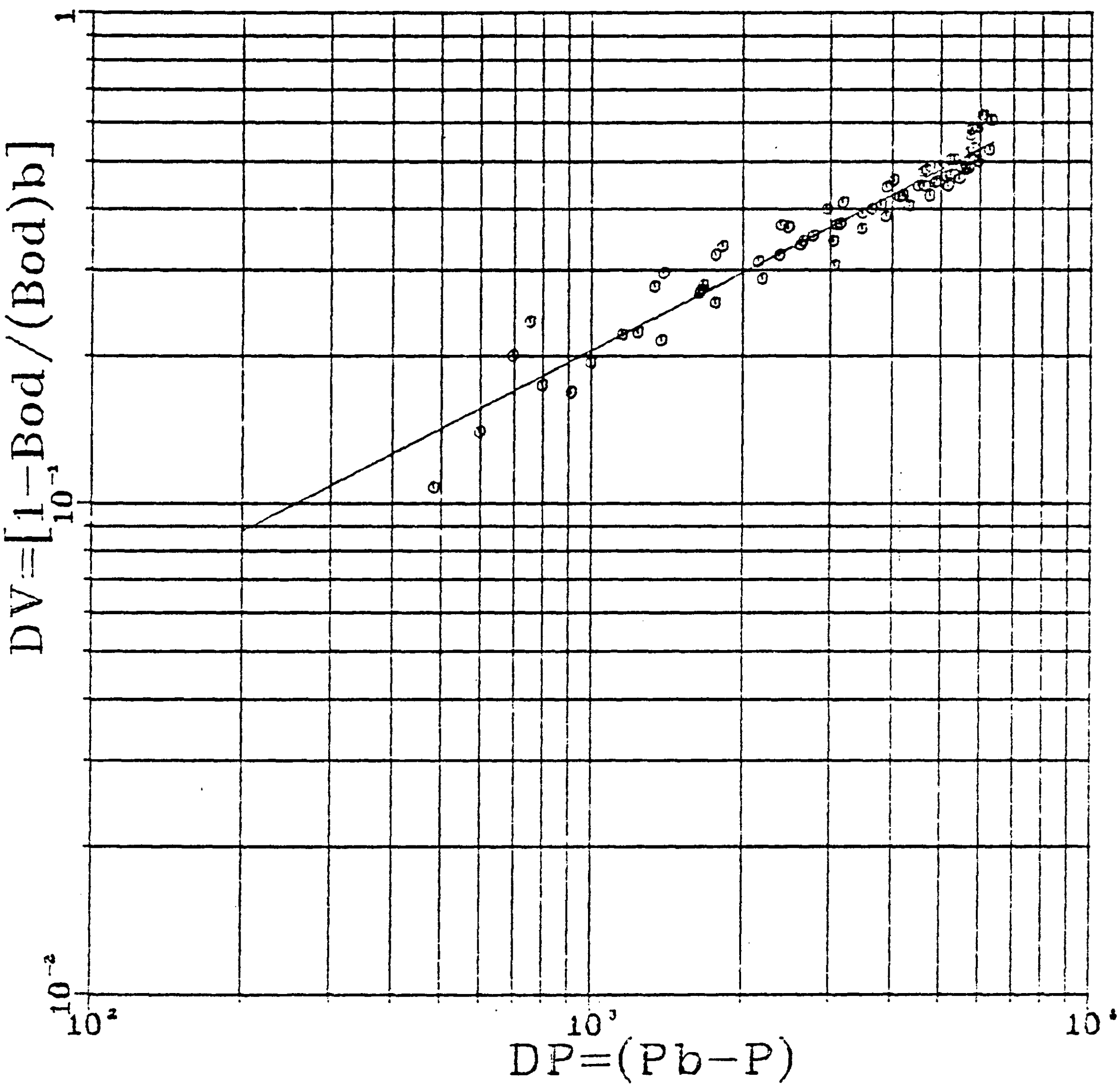

Fig. (22). Normalized O.F.V.F. Below BPP

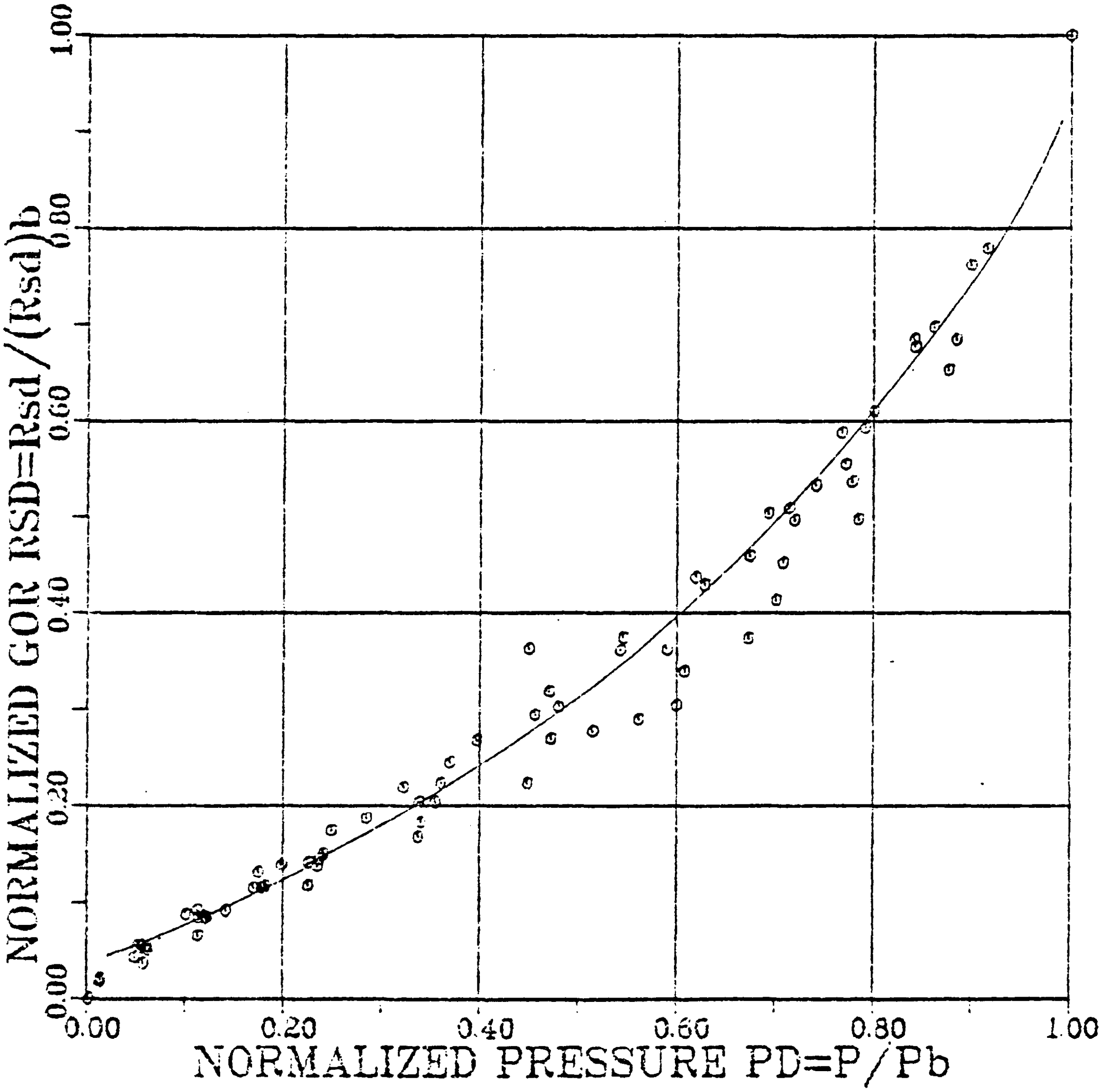

Fig. (23). Normalized Differential Solution GOR

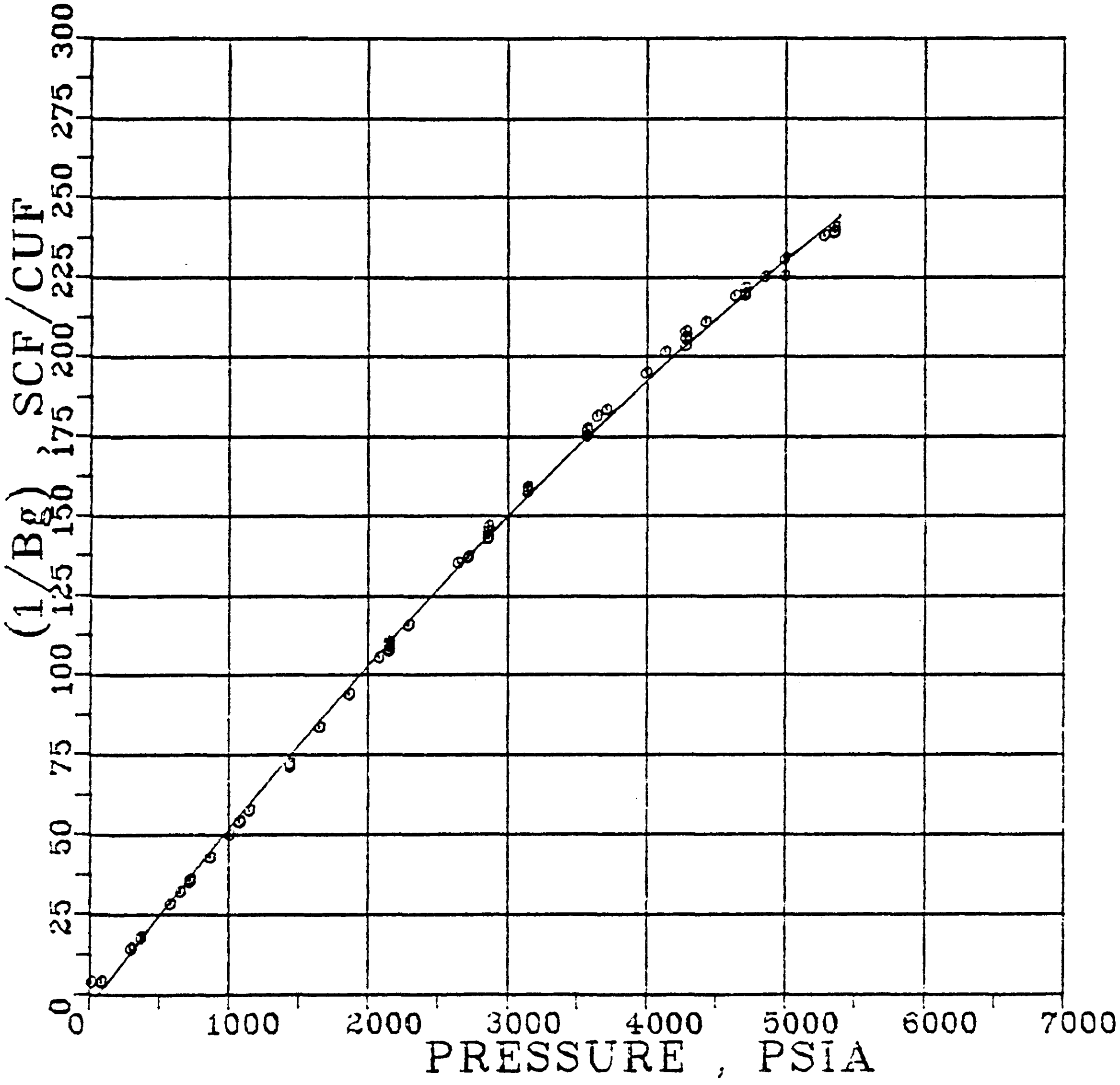

Fig. (24). Variation of (1/Bg) With Pressure

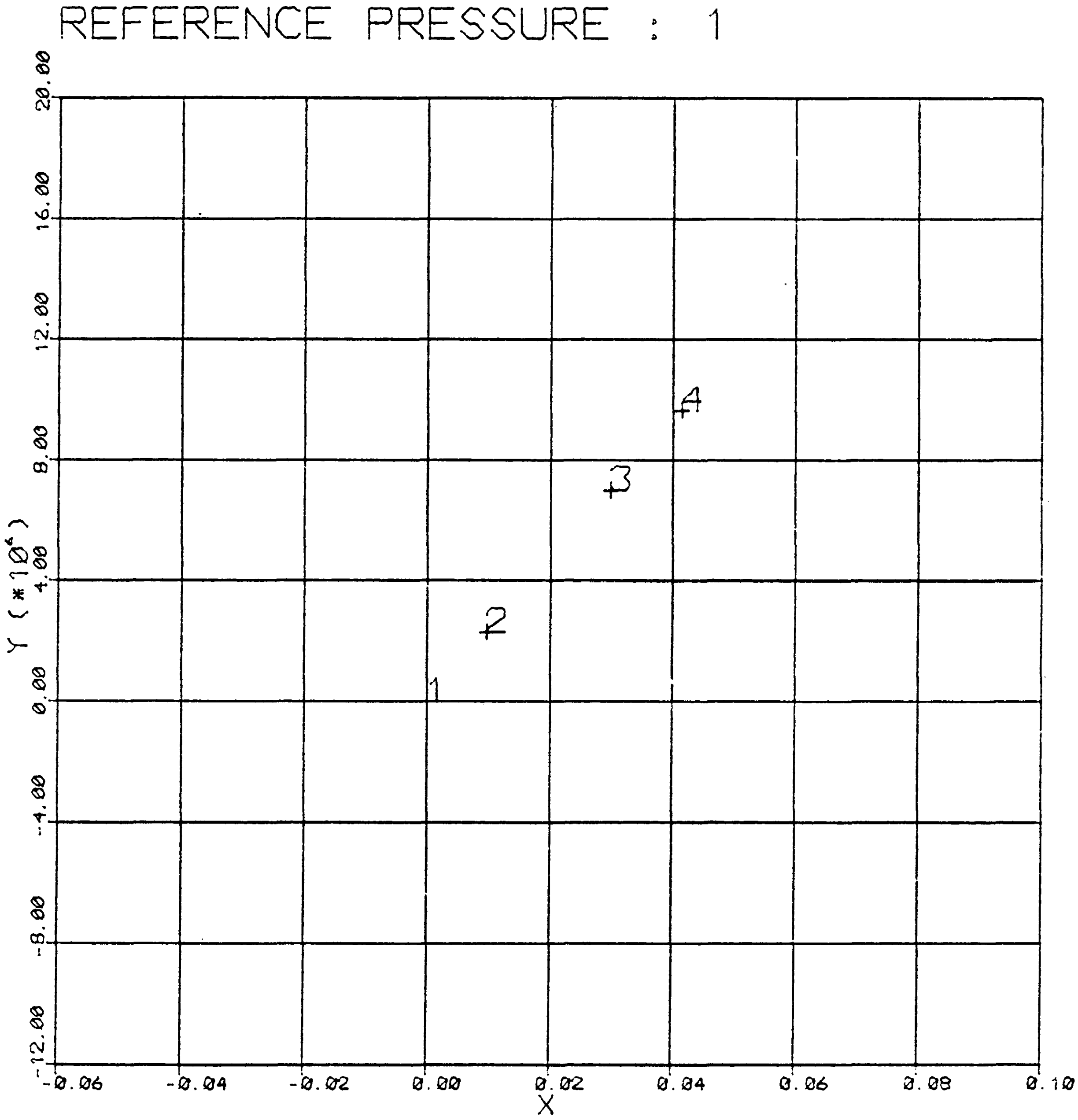

Figure 27. (x_j-x_k) versus (y_j-y_k) plot initial pressure as reference, which is also x_j versus y_j plot of Well No. 2.

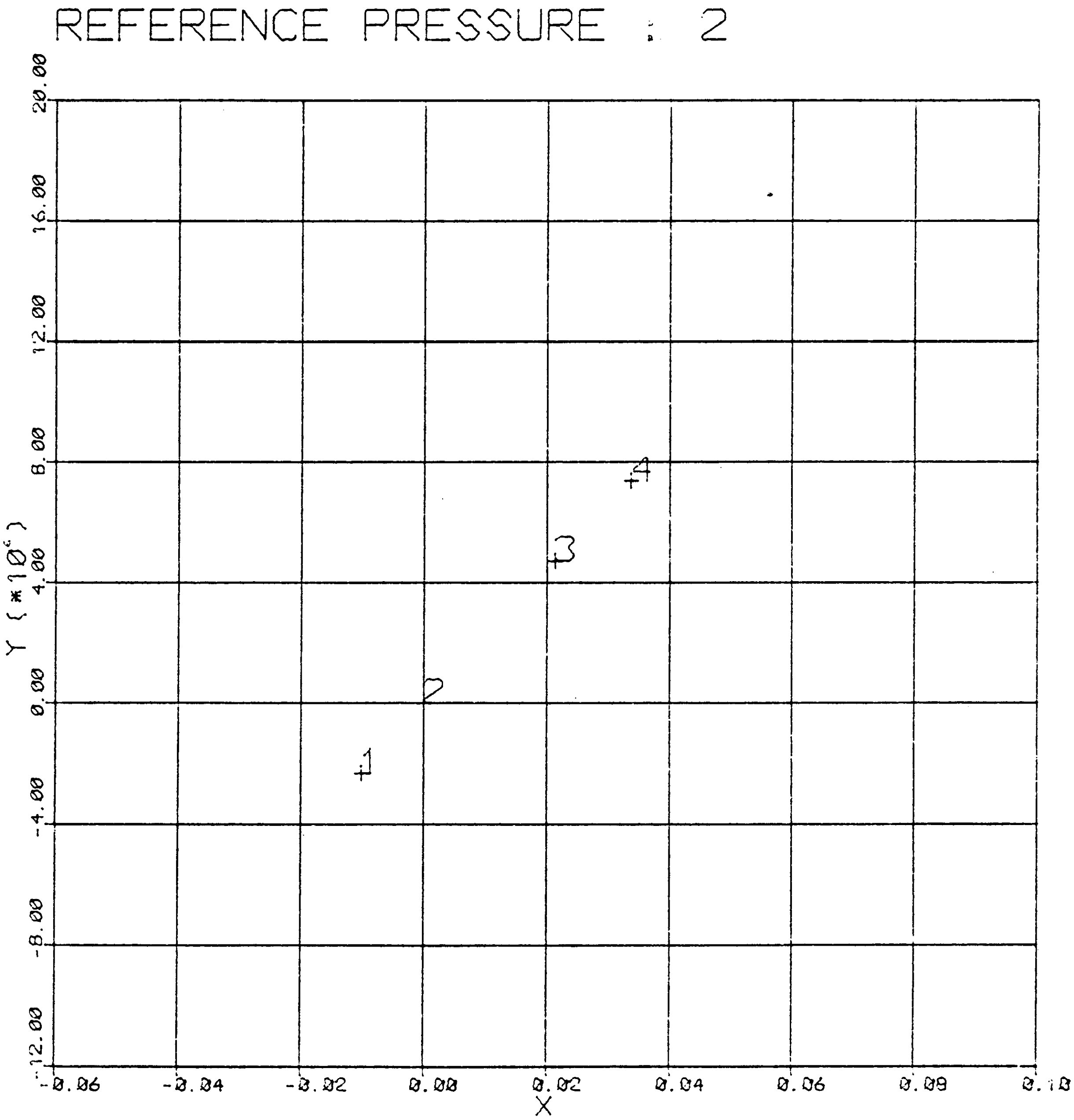

Figure 28. $(x_j - x_k)$ versus $(y_j - y_k)$ plot for the second reference pressure of Well No. 2.

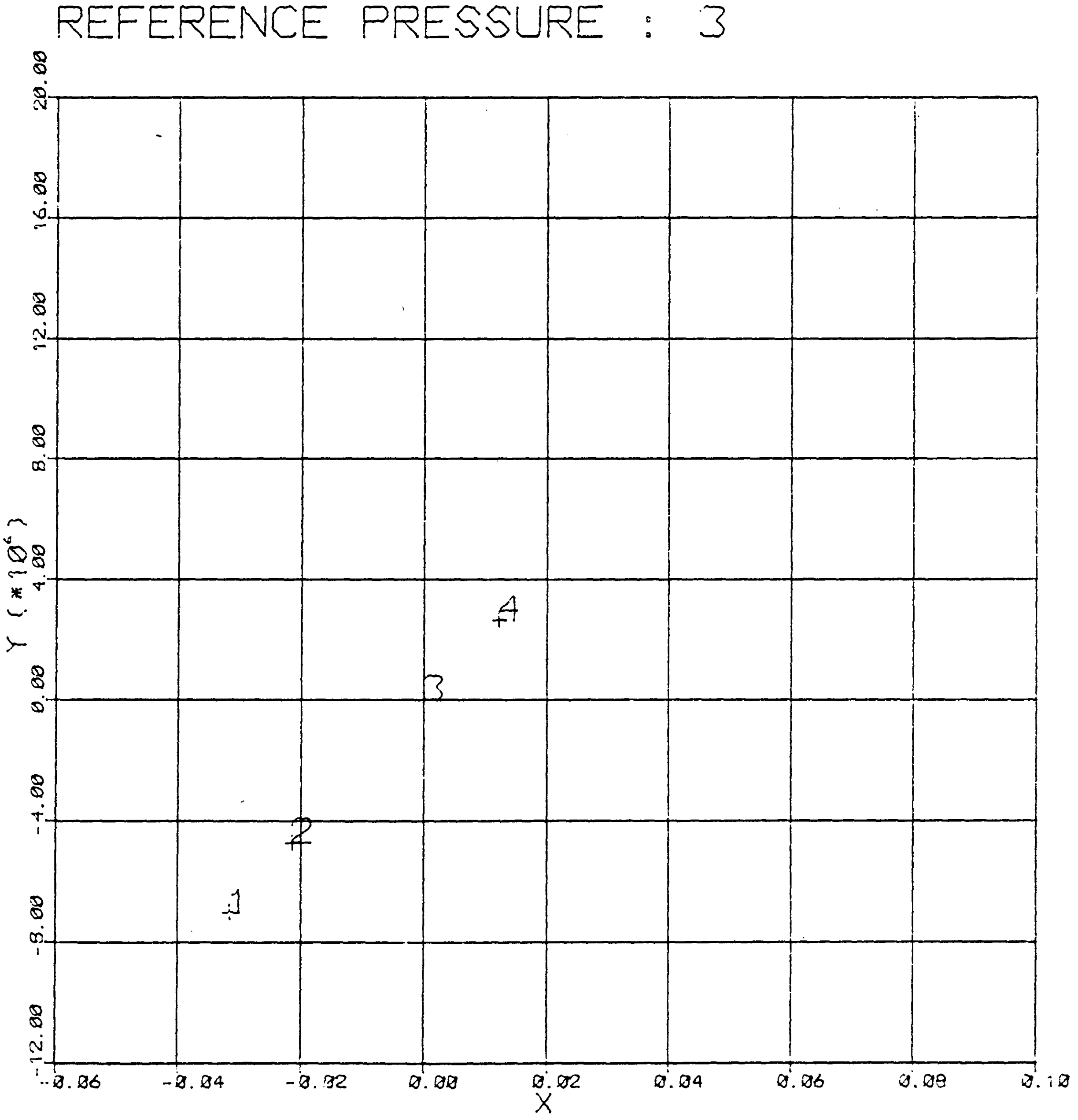

Figure 29. $(x_j - x_k)$ versus $(y_j - y_k)$ plot for the third reference pressure of Well No. 2.

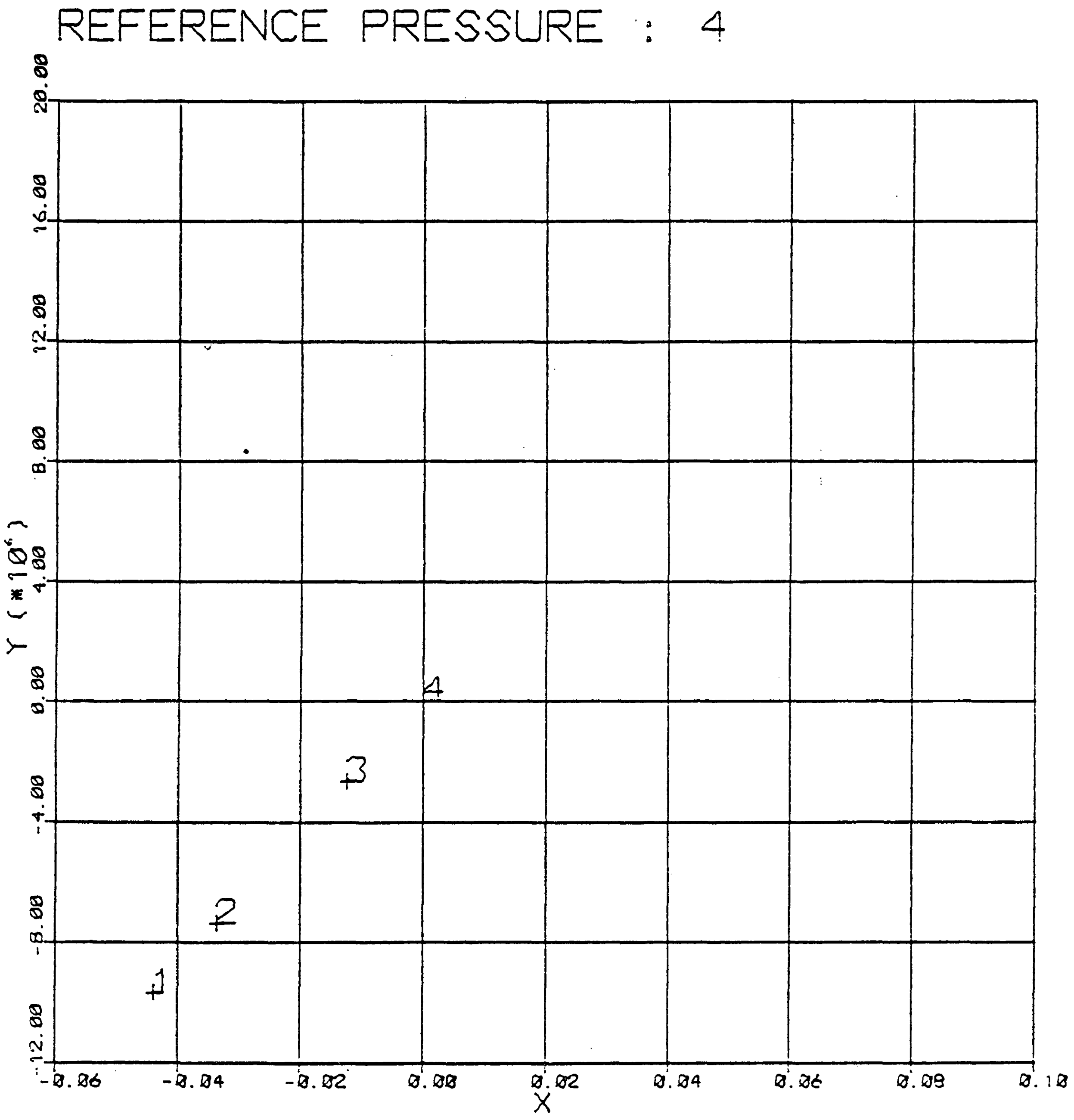

Figure 30 . $(x_j - x_k)$ versus $(y_j - j_k)$ plot for the fourth reference pressure of Well No. 2.

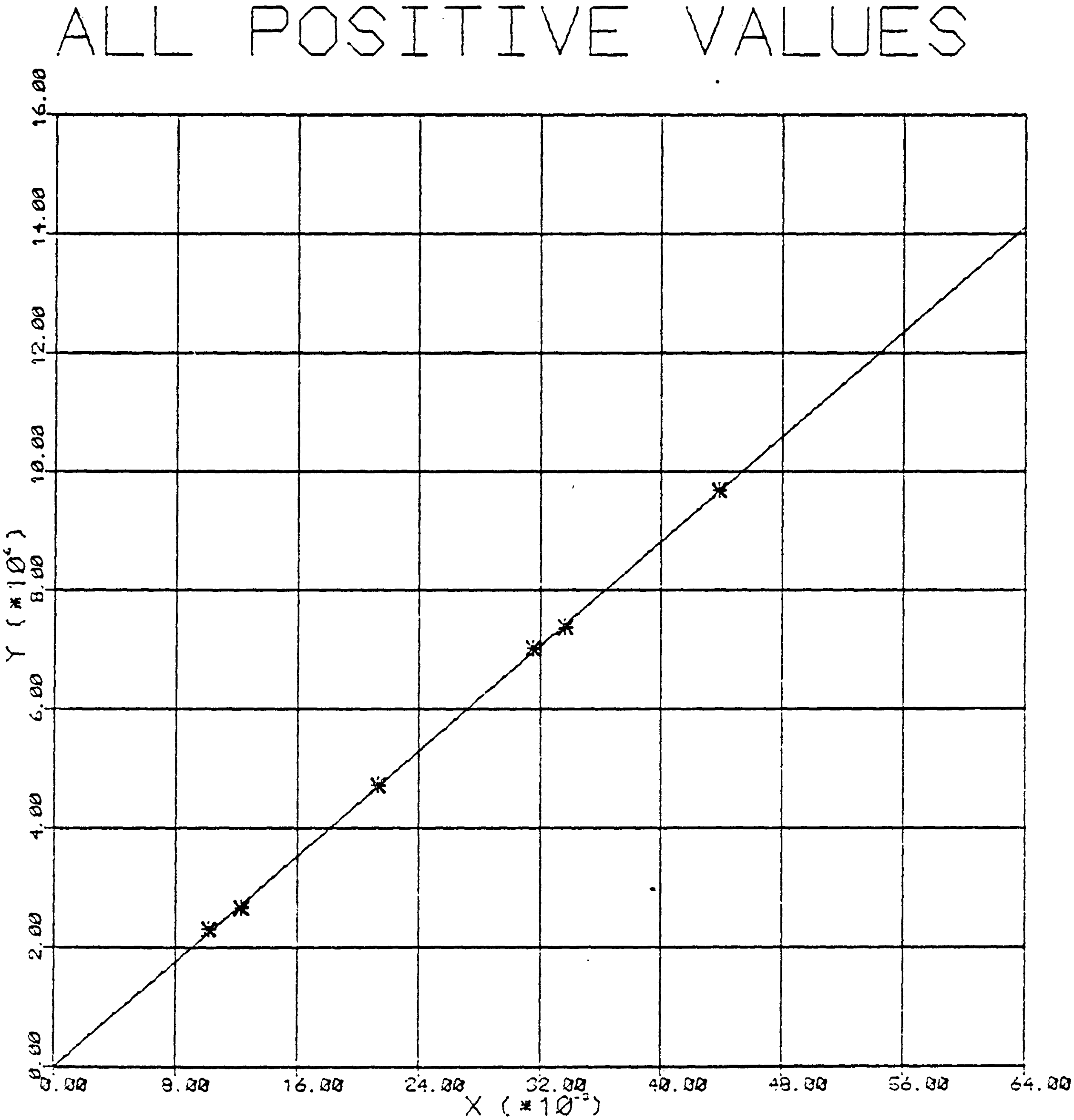

Figure 31. Calculation of oil in place of Well No. A2 by (x_j-x_k) vs. (y_j-y_k) plot.

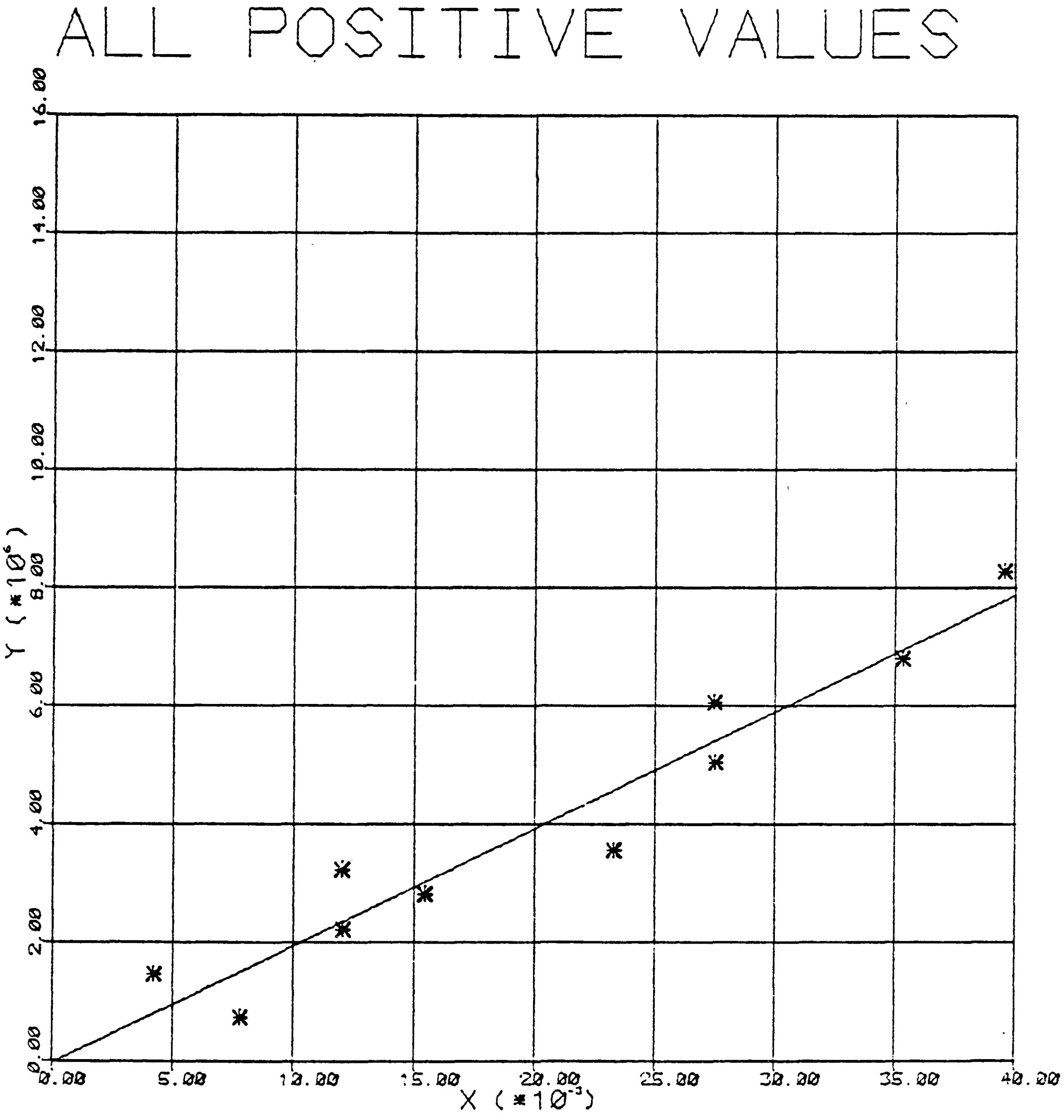

Figure 32. Calculation of oil in place of well No. A1 by $(x_j - x_k)$ plot versus $(y_j - y_k)$ plot.

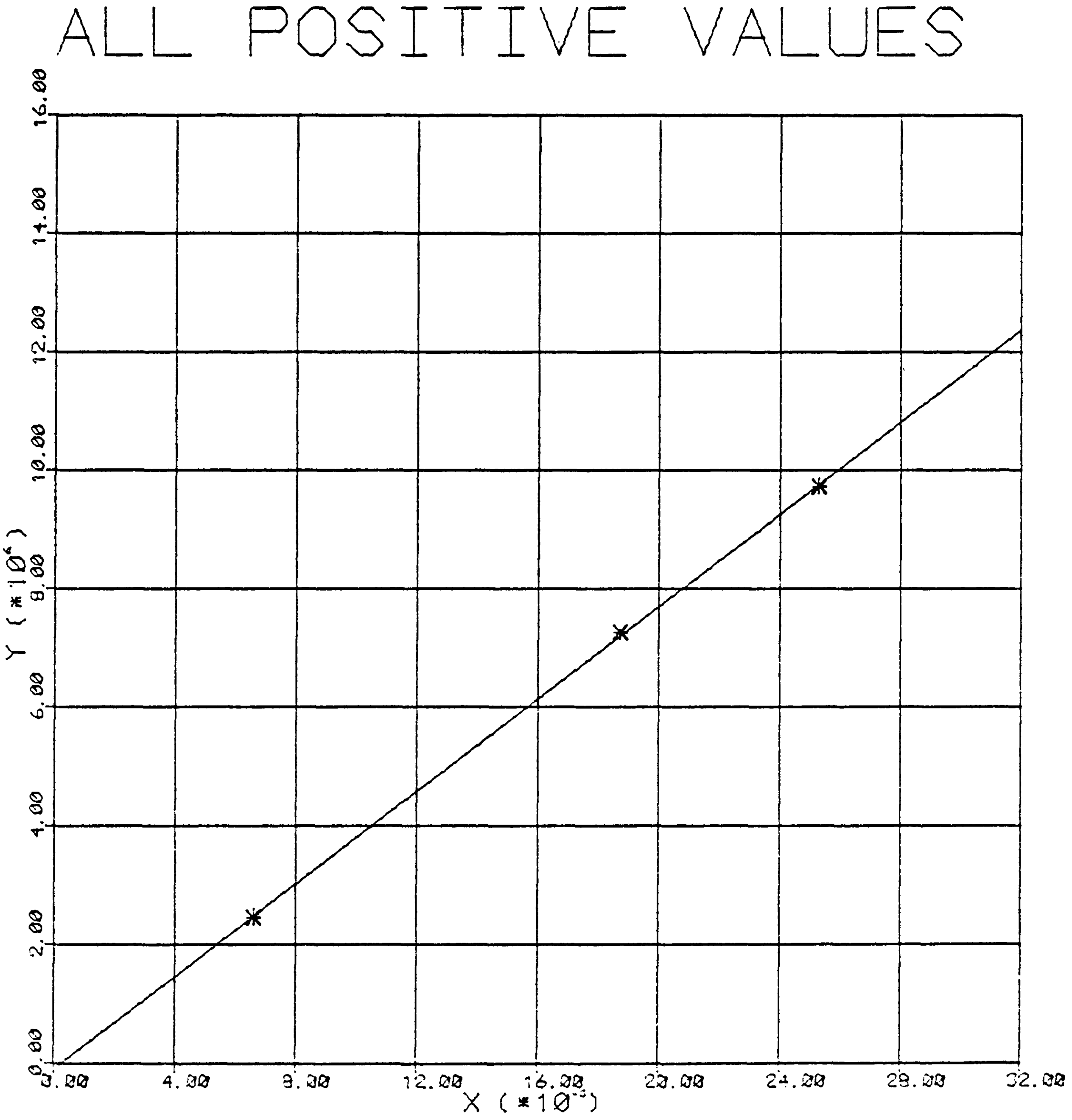

Figure 33. Calculation of oil in place of Well No. A3 by $(x_j - x_k)$ vs. $(y_j - y_k)$ plot.

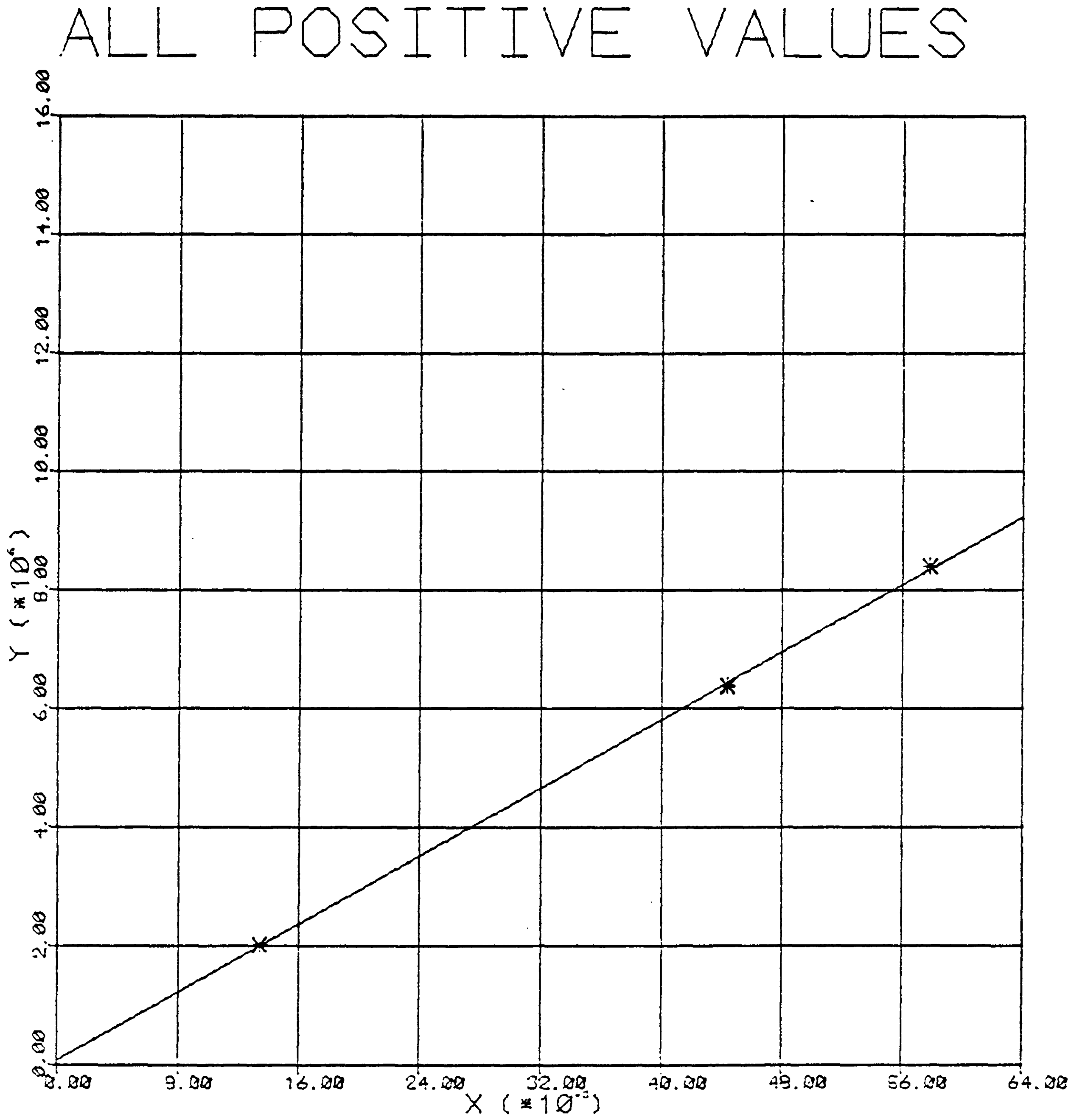

Figure 34. Calculation of oil in place of Well No. A4 by (x_j-x_k) vs. (y_j-y_k) plot.

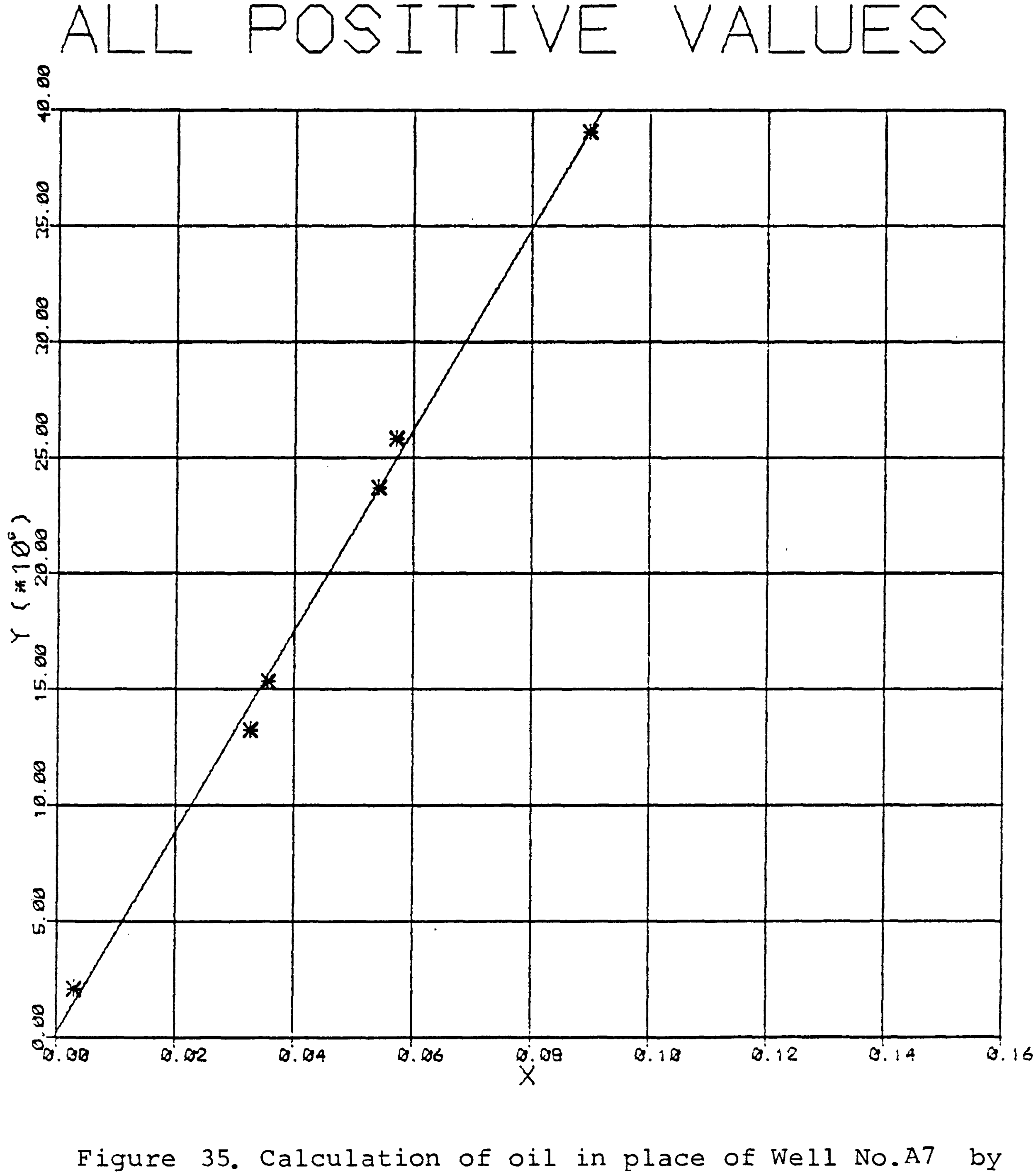

Figure 35. Calculation of oil in place of Well No. A7 by $(x_j - x_k)$ vs. $(y_j - y_k)$ plot.

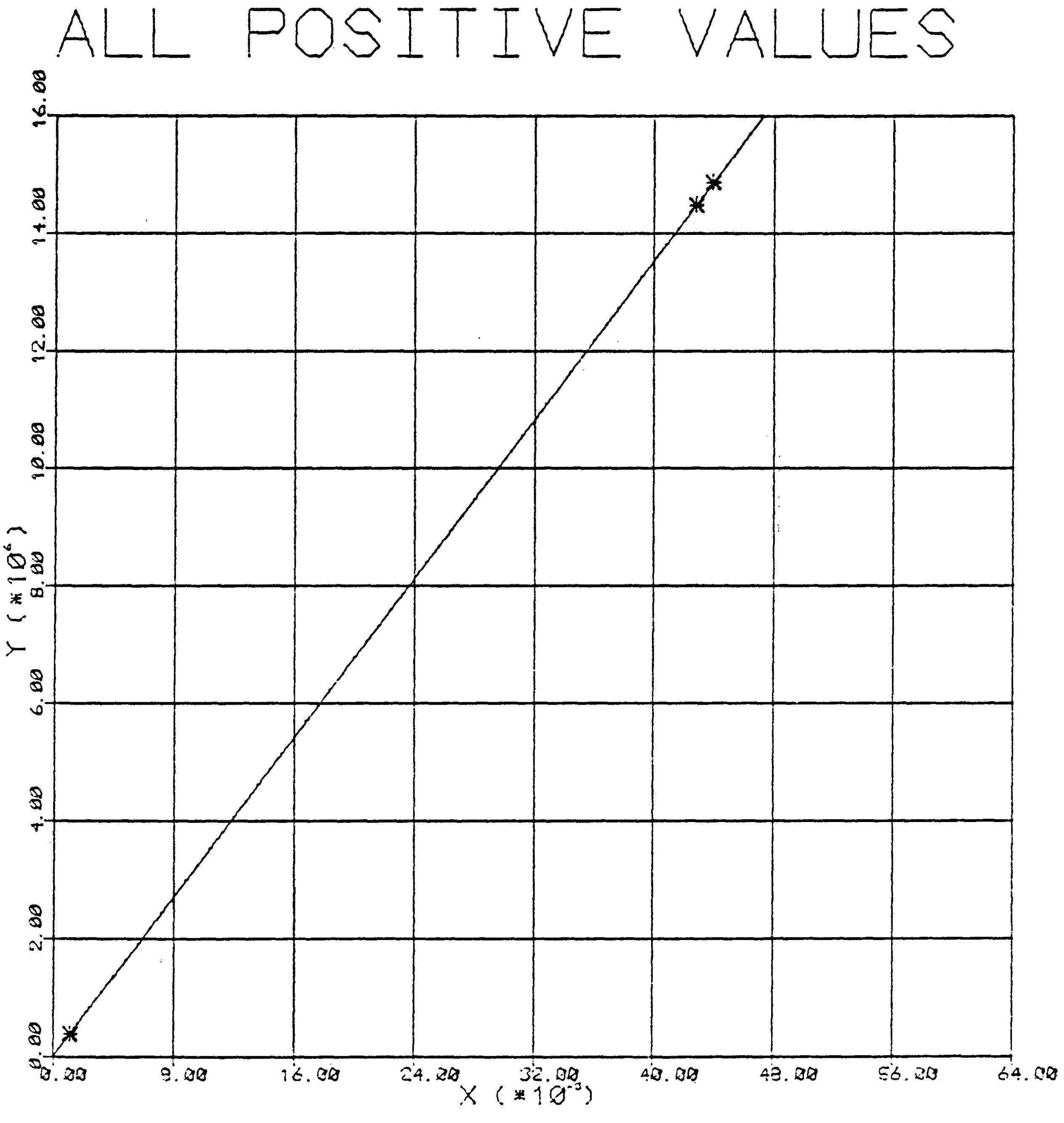

Figure 36. Calculation of oil in place of Well No. A8 by $(x_j - x_k)$ vs. $(y_j - y_k)$ plot.

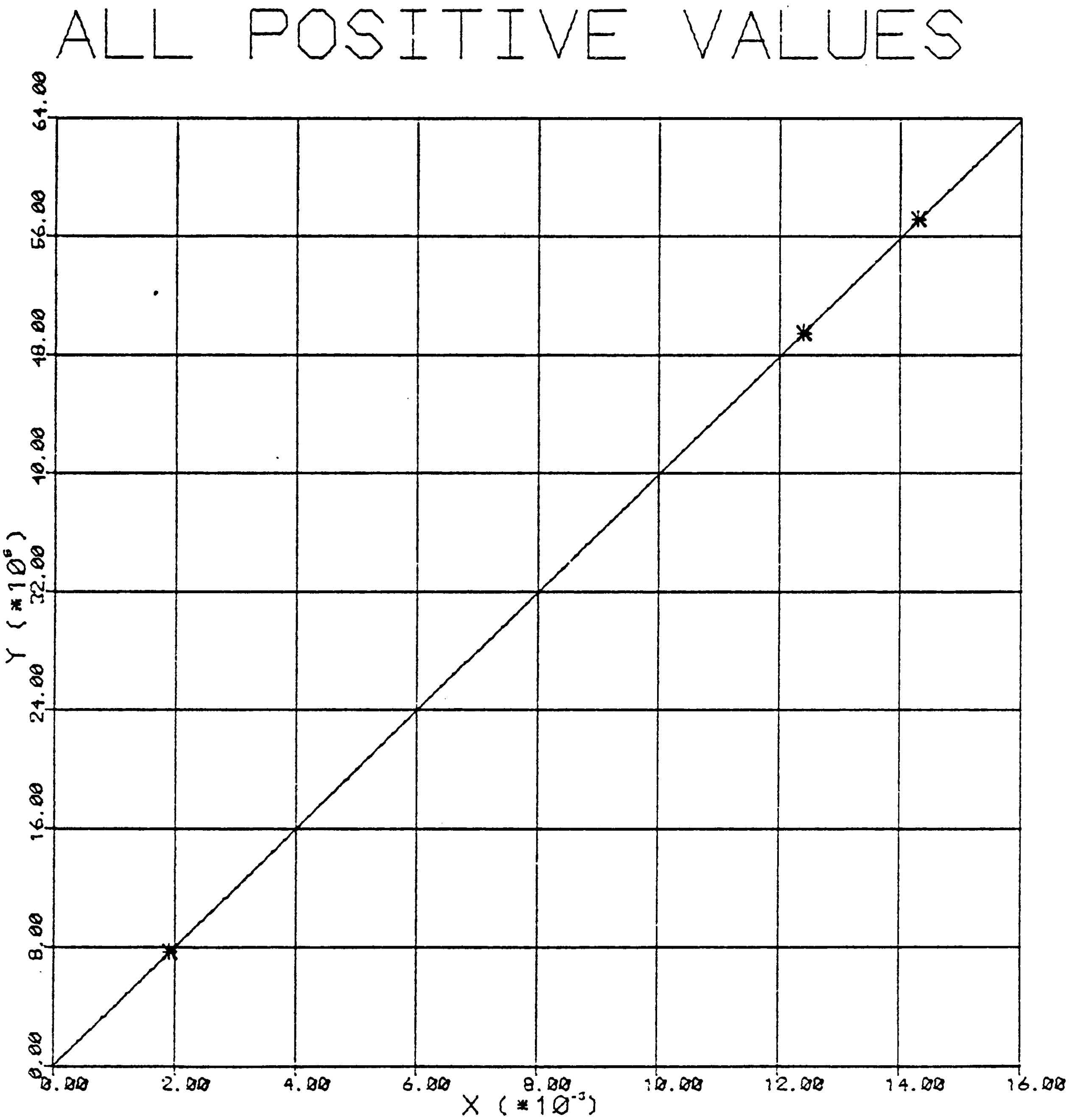

Figure 37. Calculation of oil in place of Well No. A9 by (x_j-x_k) vs. (y_j-y_k) plot.

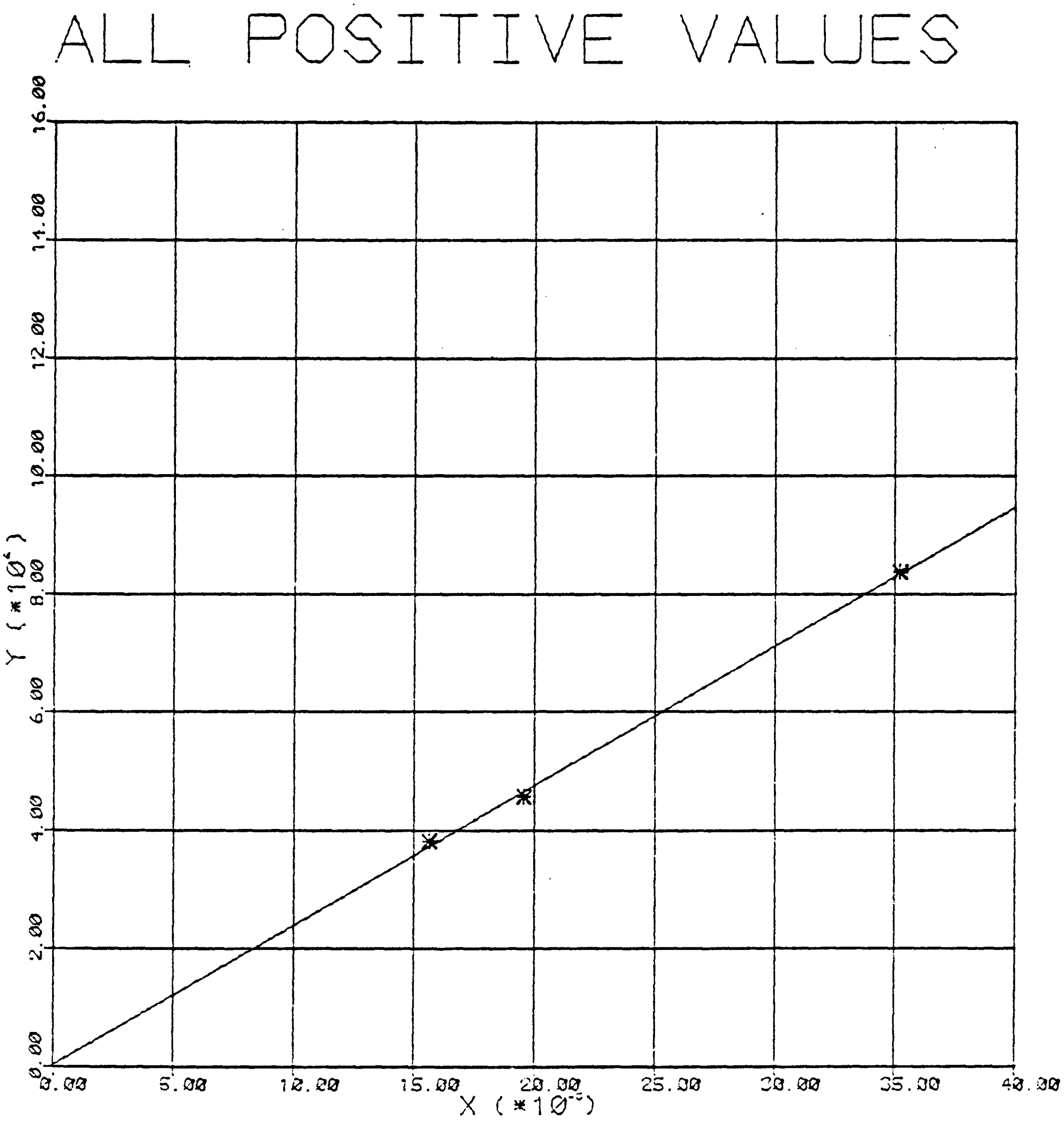

Figure 38. Calculation of oil in place of Well No.All by (x_j-x_k) vs. (y_j-y_k) plot.

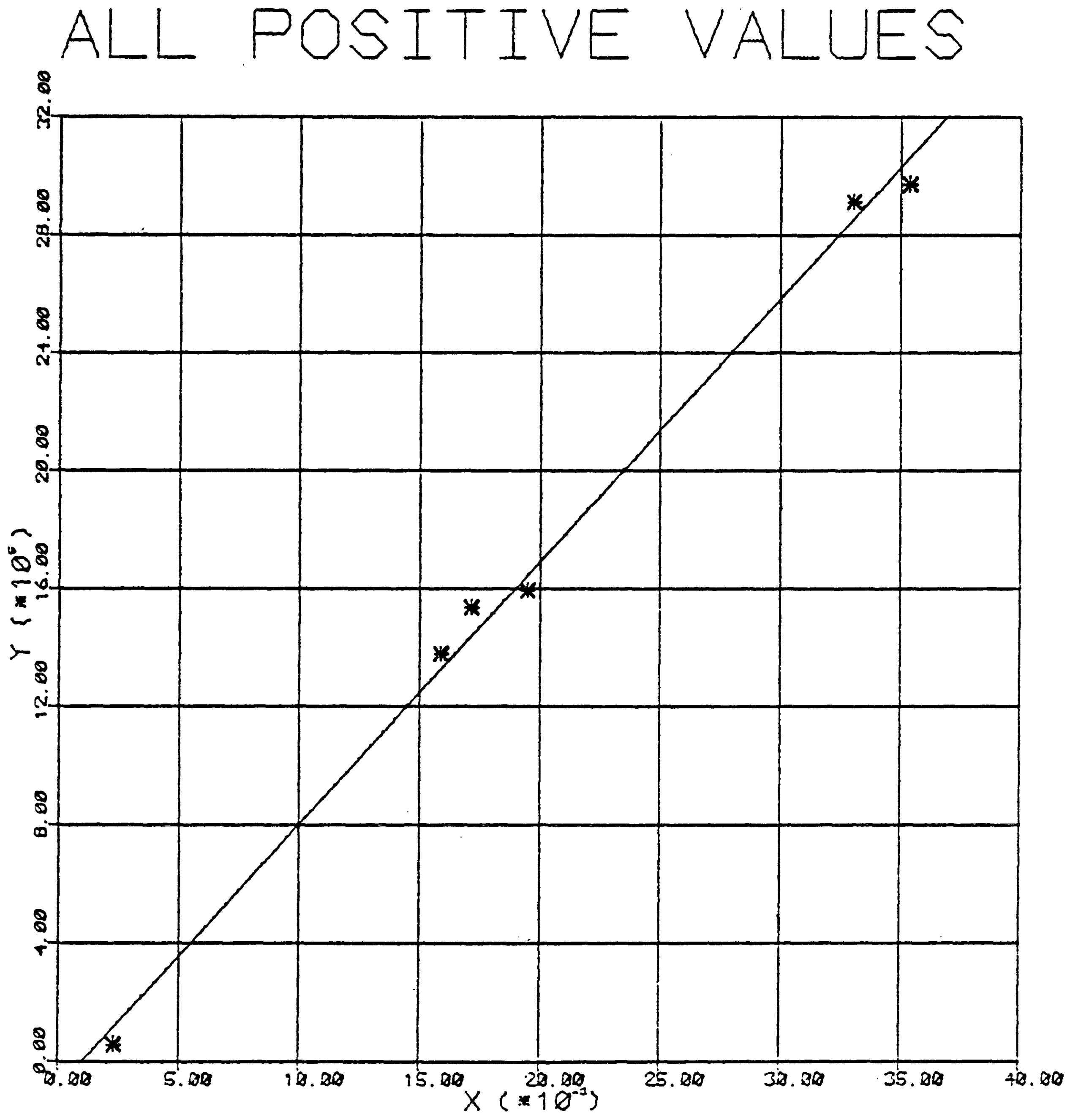

Figure 39. Calculations of oil in place of Well No. A12 by (x_j-x_k) versus (y_j-y_k) plot.

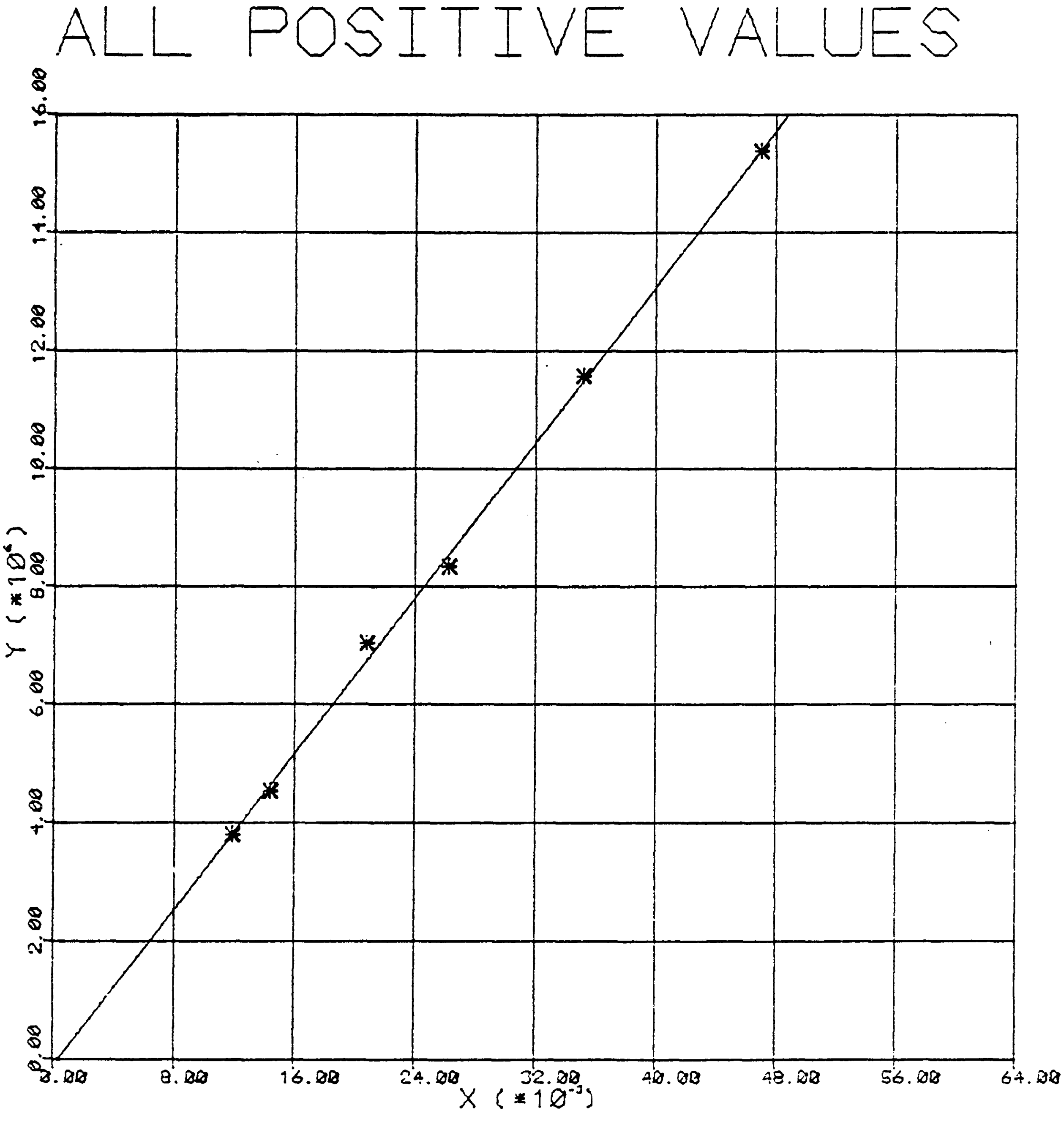

Figure 40. Calculations of oil in place of Well No. A13 by (x_j-x_k) versus (y_j-y_k) plot.

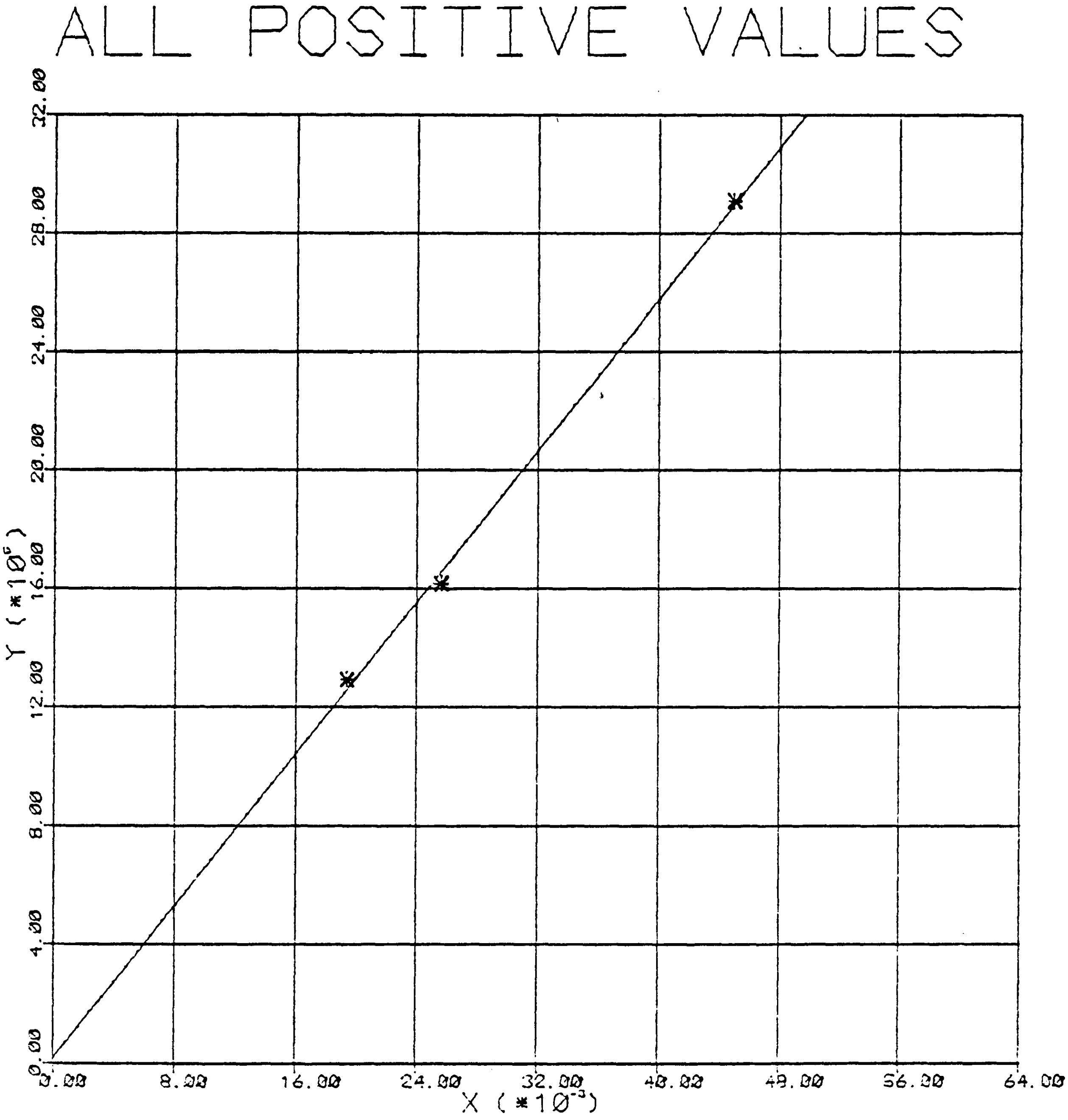

Figure 41. Calculation of oil in place of Well No.A14 by (x_j-x_k) vs. (y_j-y_k) plot.

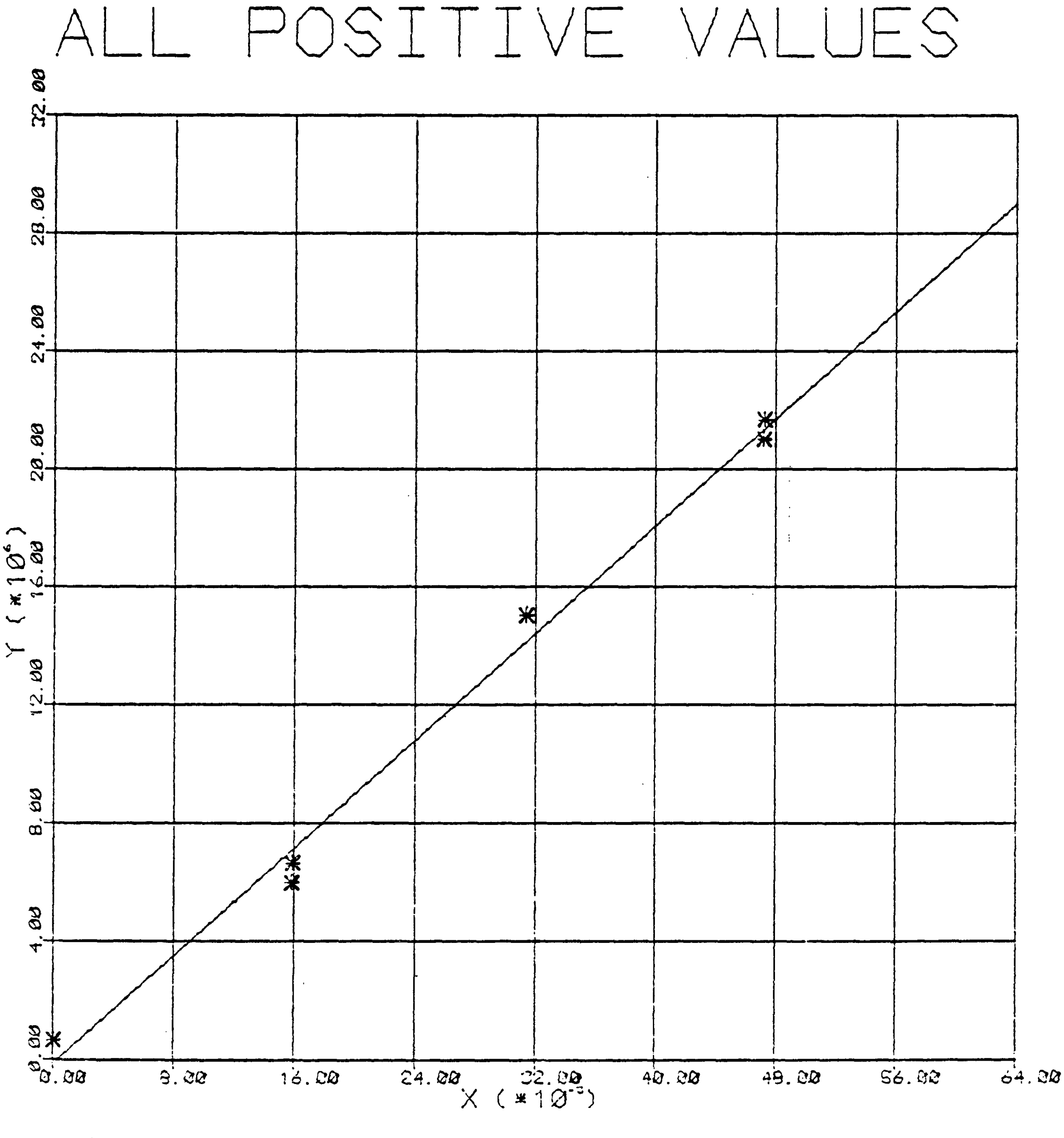

Figure 42. Calculation of oil in place of Well No. A15 by $(x_j - x_k)$ vs. $(y_j - y_k)$ plot.

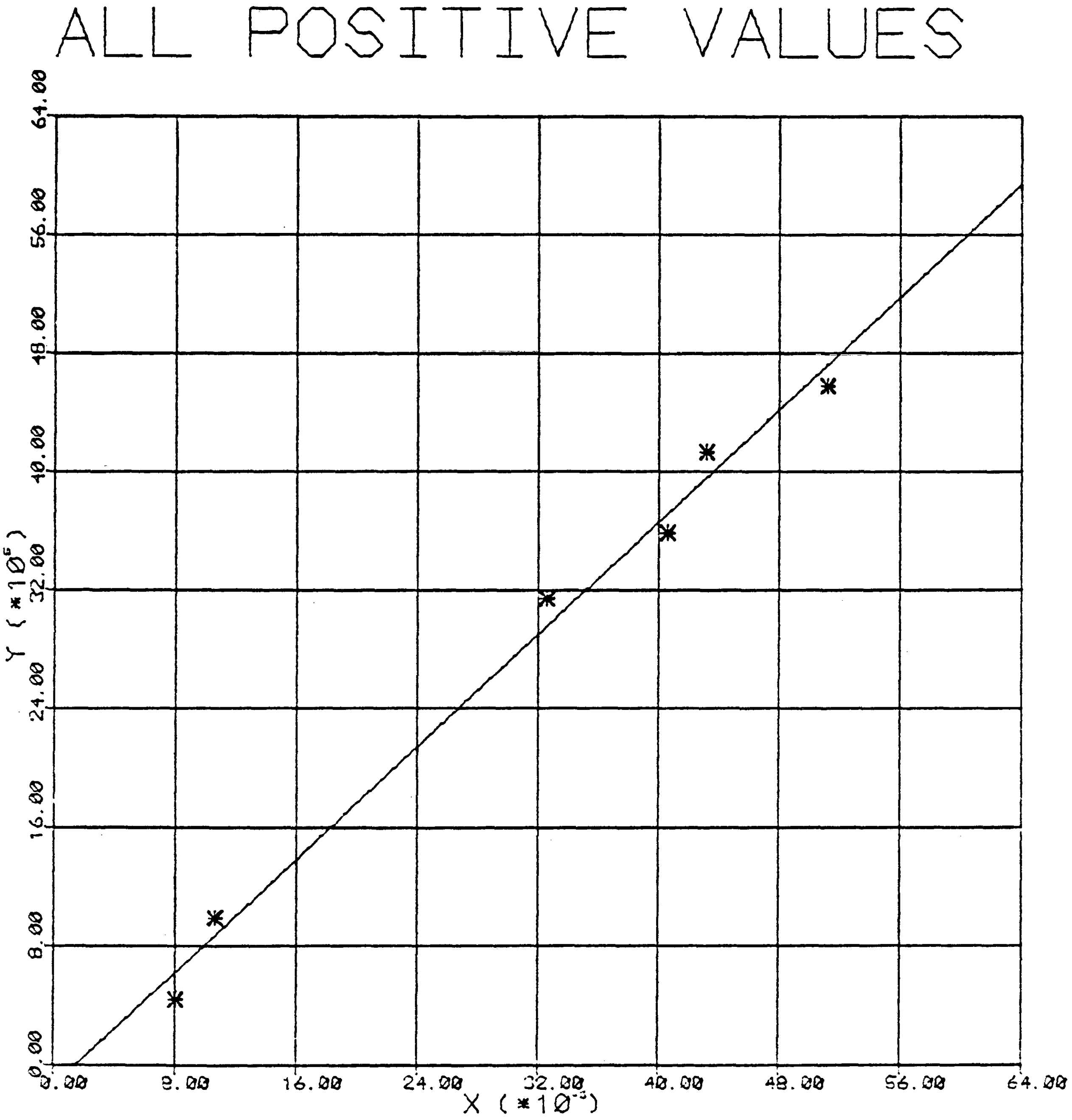

Figure 43. Calculation of oil in place of Well No. A16 by $(x_j - x_k)$ vs. $(y_j - y_k)$ plot.

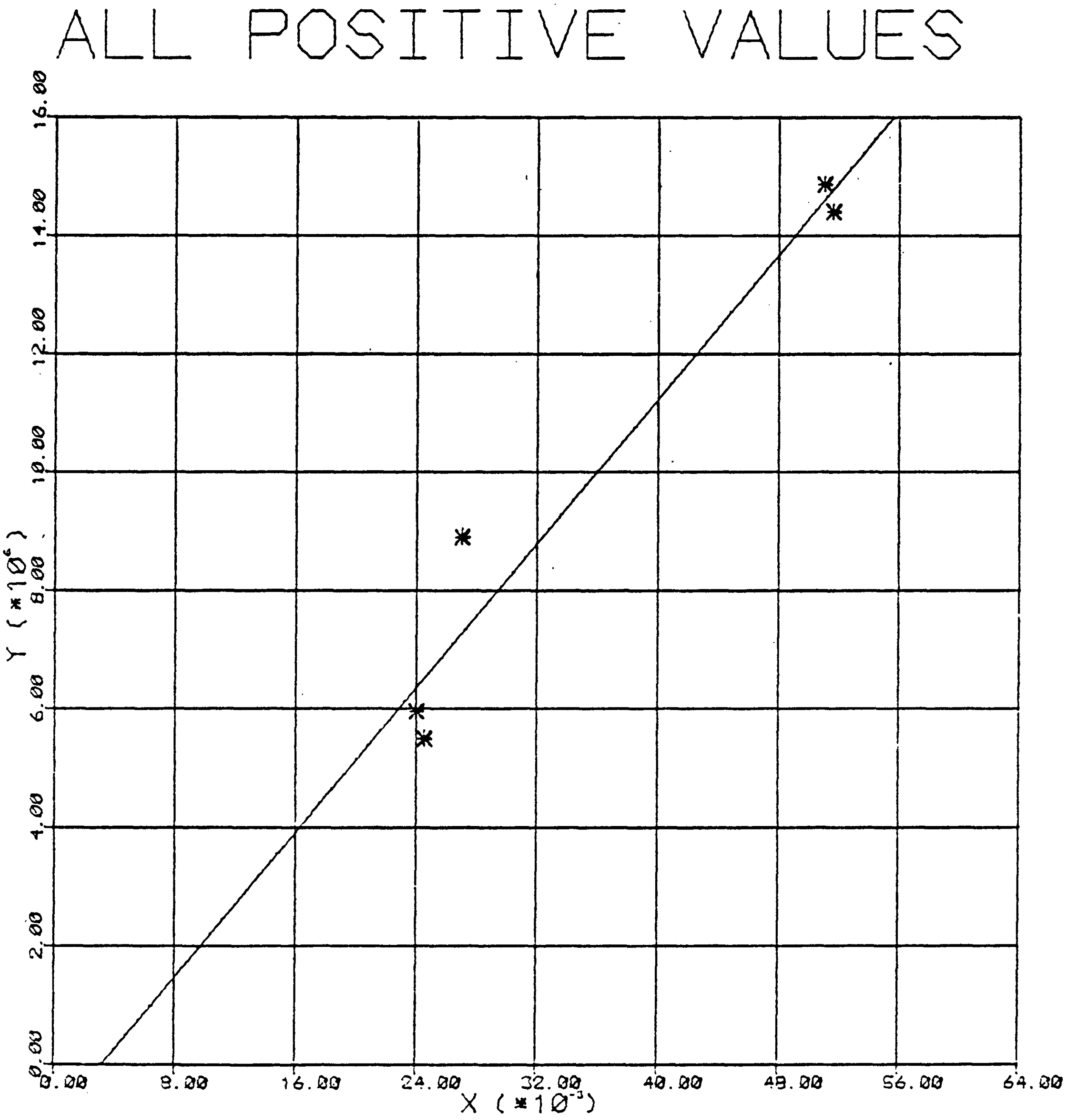

Figure 44. Calculation of oil in place of Well No. A17 by (x_j-x_k) vs. (y_j-y_k) plot.

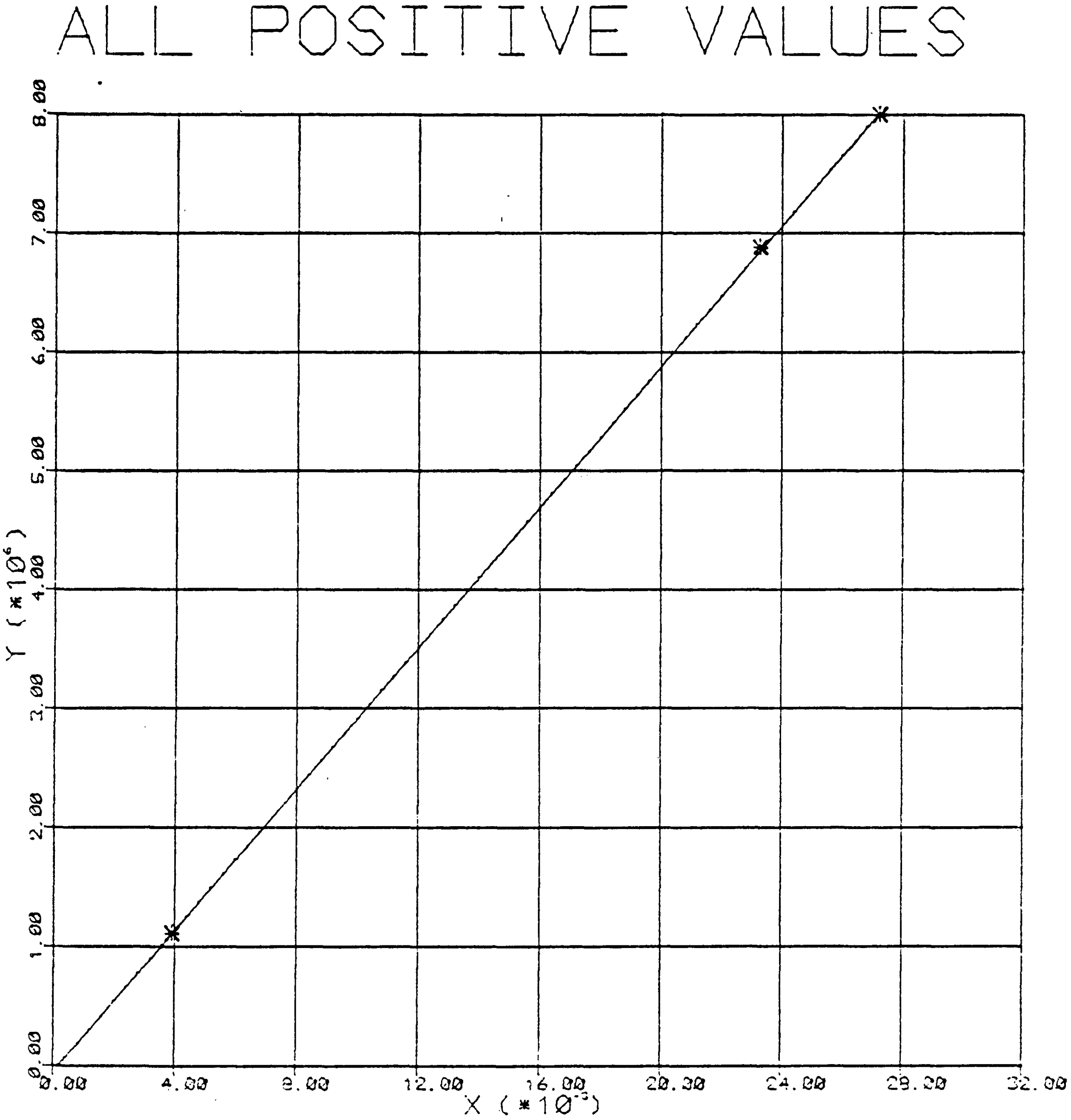

Figure 45 Calculation of oil in place of Well No. A18 by (x_j-x_k) vs. (y_j-y_k) plot.

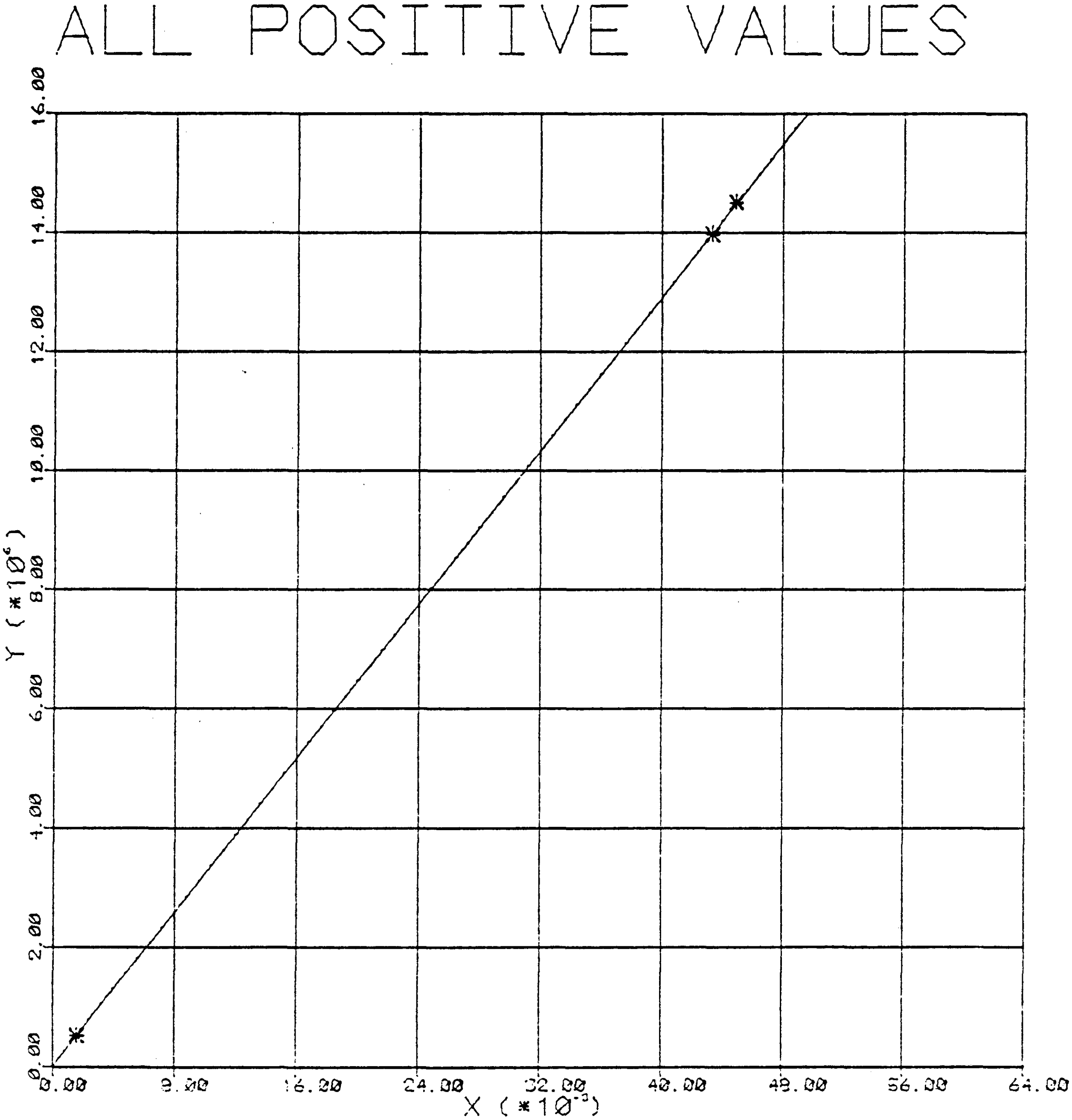

Figure 46 Calculation of oil in place of Well No.A20 by $(x_j - x_k)$ vs. $(y_j - y_k)$ plot.

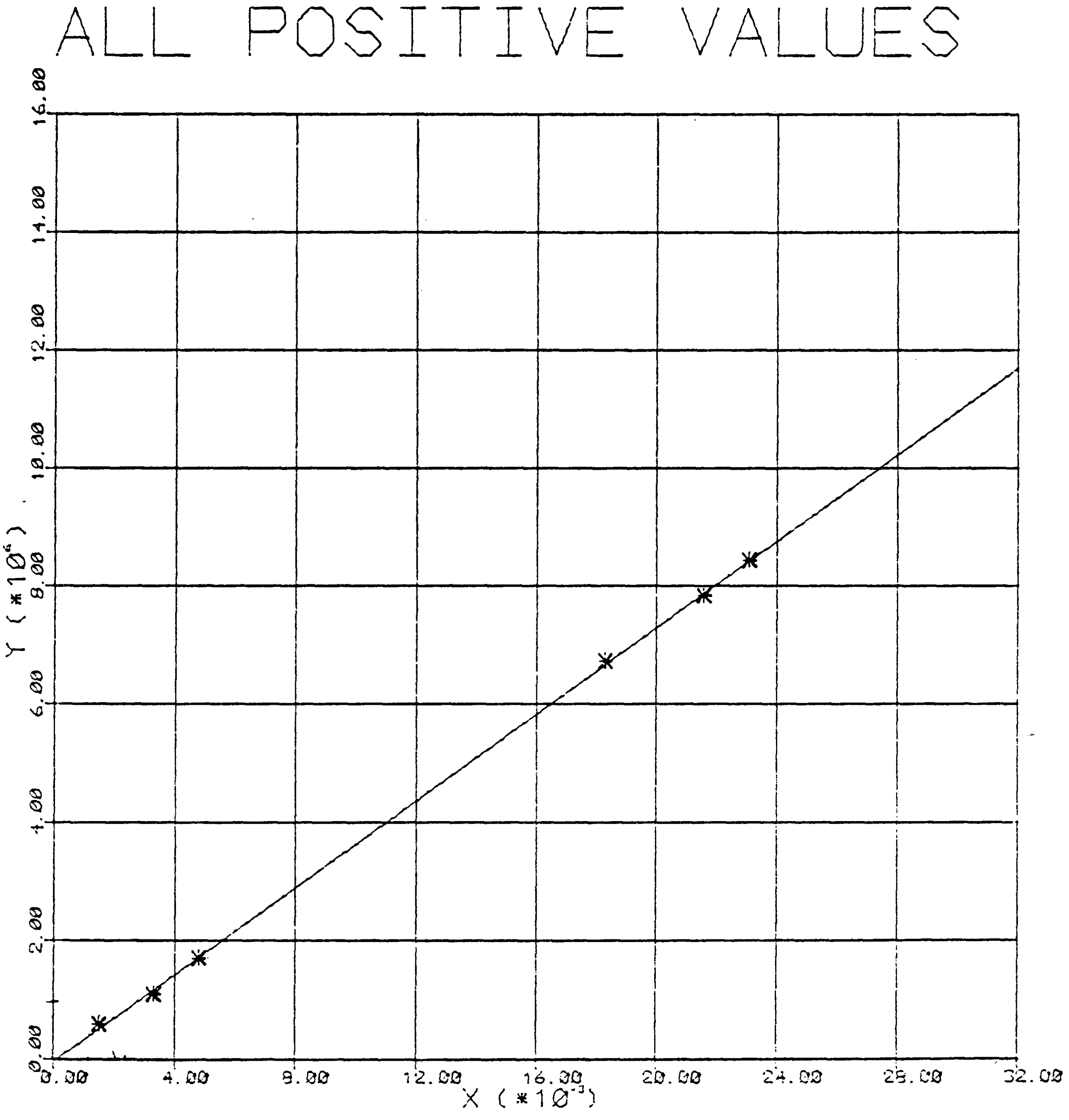

Figure 47. Calculation of oil in place of Well No.A21 by (x_j-x_k) vs. (y_j-y_k) plot.

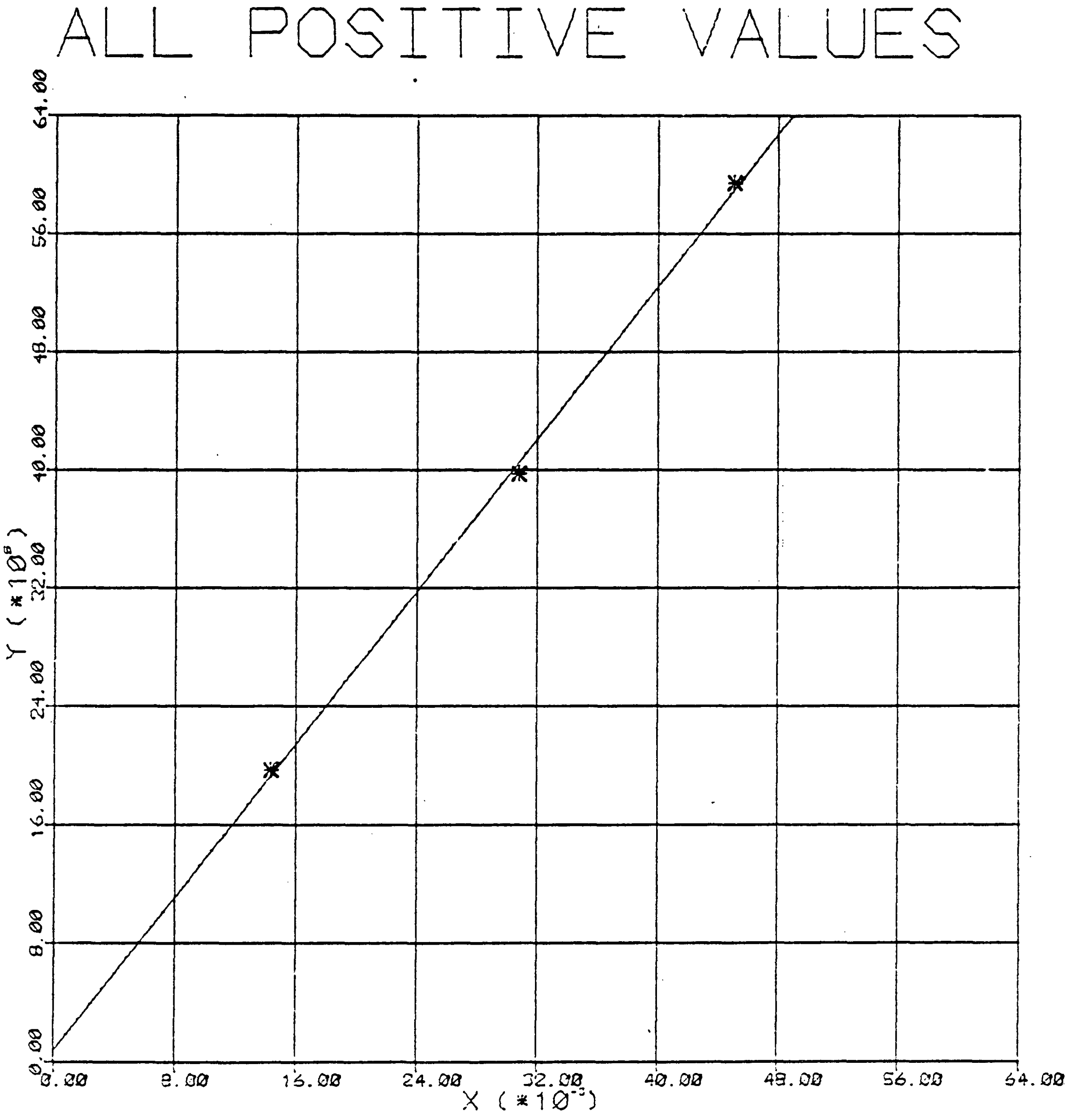

Figure 48. Calculation of oil in place of Well No. A22 by $(x_j - x_k)$ vs. $(y_j - y_k)$ plot.

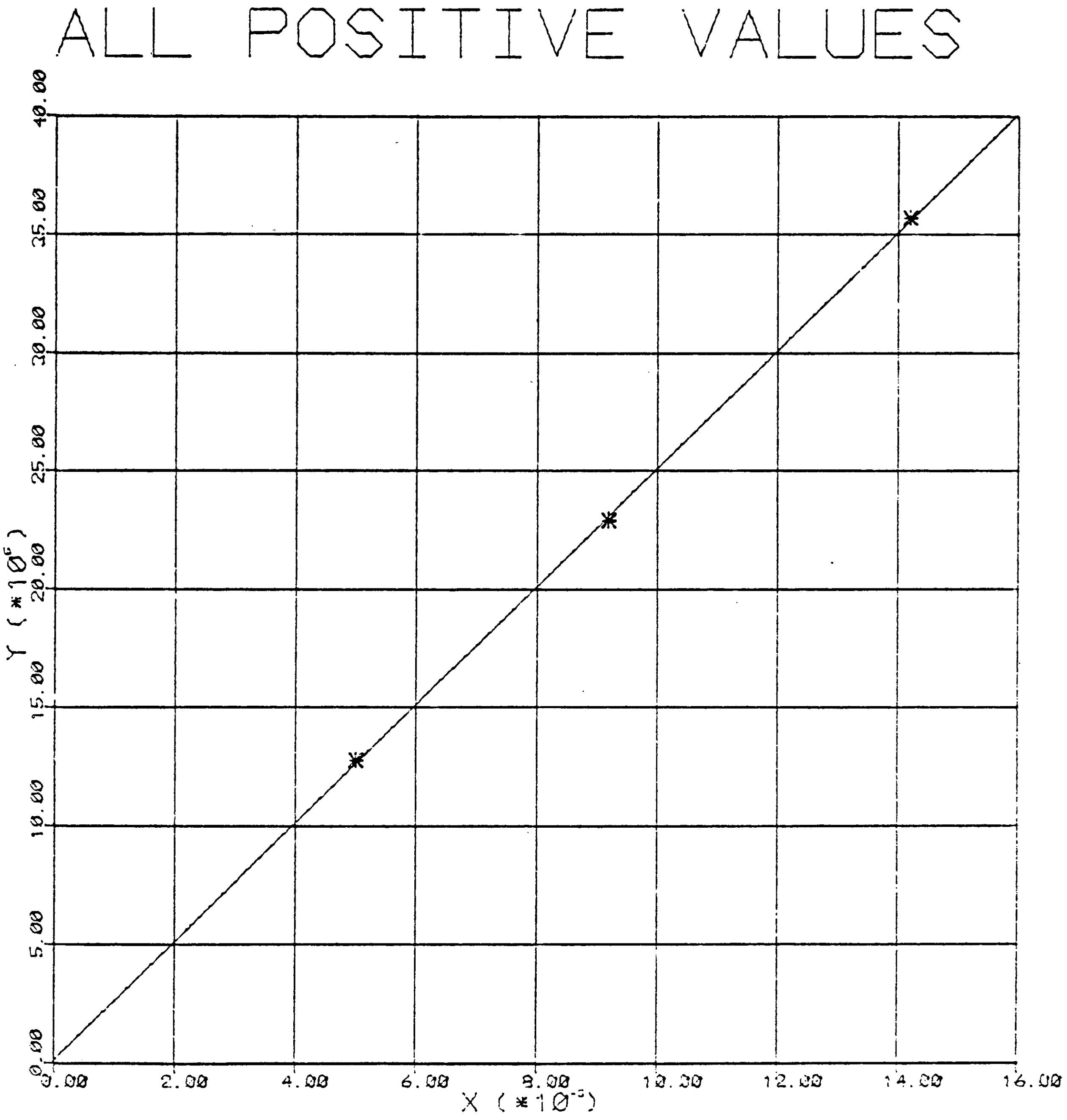

Figure 49. Calculation of oil in place of Well No. A25 by (x_j-x_k) vs. (y_j-y_k) plot.

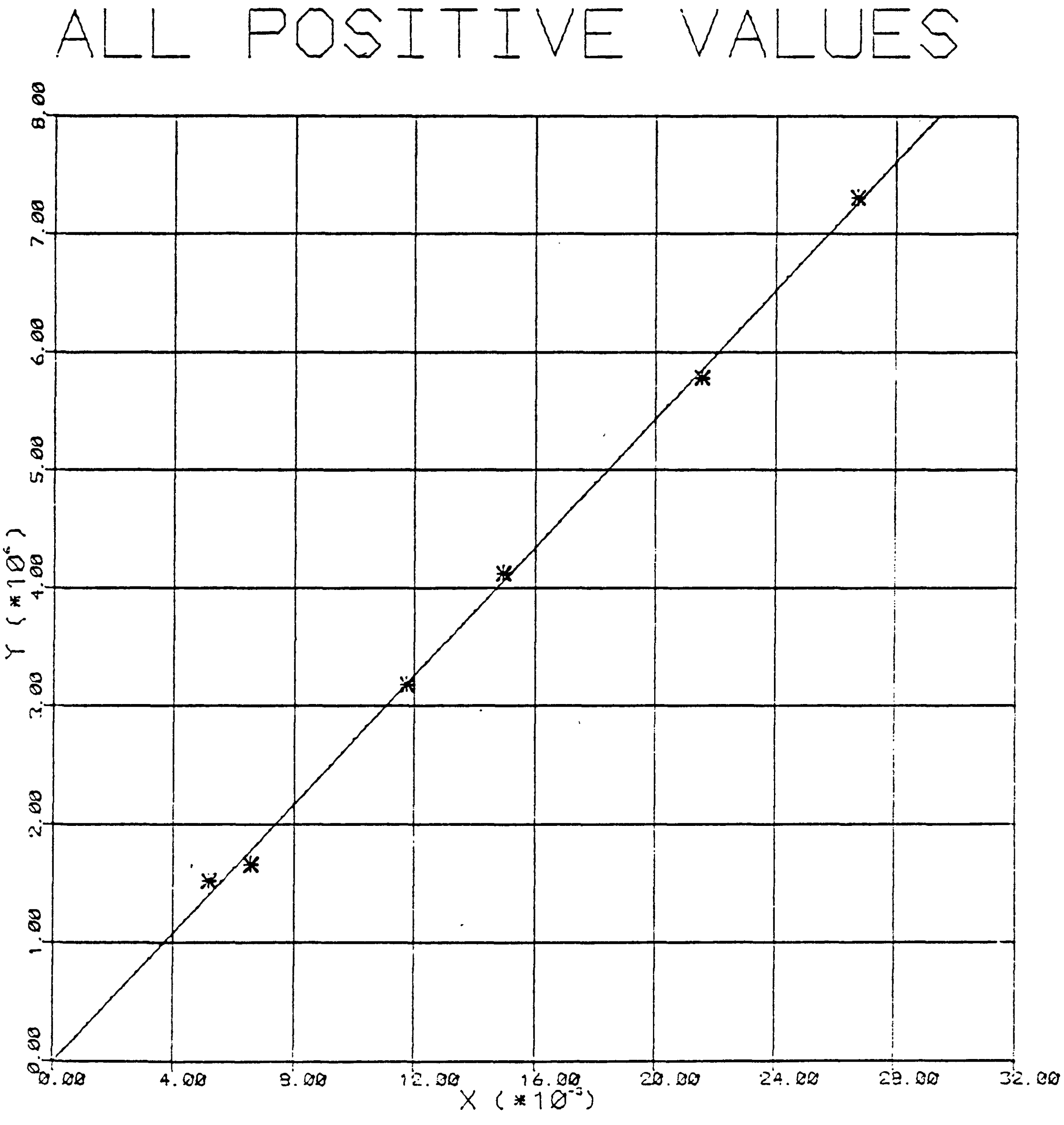

Figure 50. Calculation of oil in place of Well No. A26 by $(x_j - x_k)$ vs. $(y_j - y_k)$ plot.

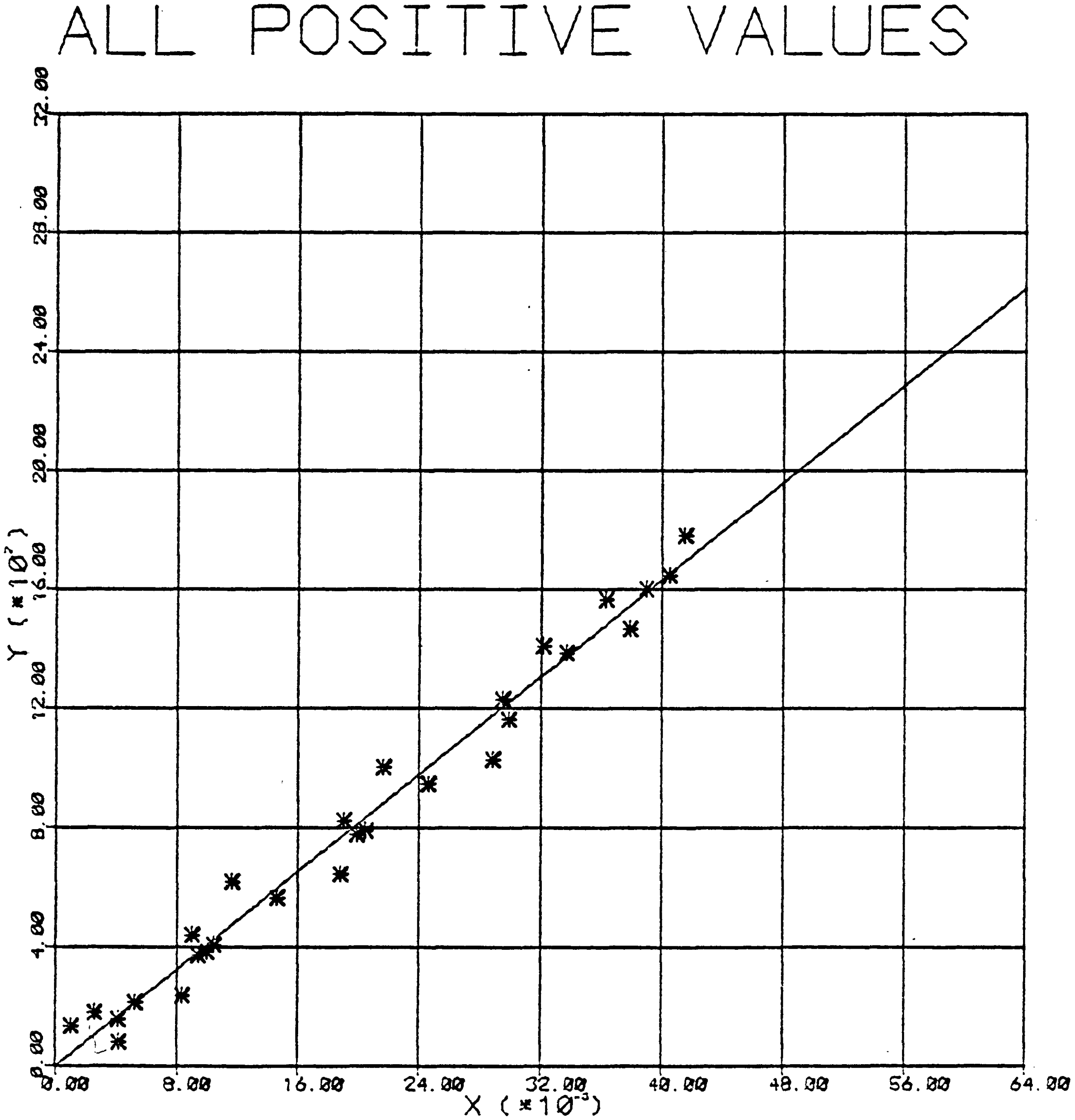

Fig. (51). Calculation of oil in place of the whole reservoir by (x_j-x_k) vs. (y_j-y_k) plot.

COMPUTER PROGRAMS

```
C       THIS PROGRAM IS FOR USING THE
C       "SUBROUTINE FIT" TO ESTABLISH THE
C       VARIOUS RELATIONS BETWEEN THE
C       PHYSICAL PARAMETERS
C
C
        INTEGER OUT
        DIMENSION ARRAY (100,10),X(100),Y(100),B(6)
        DOUBLE PRECISION FILE
        DATA IN,OUT/2*4/

        WRITE (OUT,10)
10      FORMAT (' WHAT IS THE FILE NAME?')
        READ (IN,20) FILE
20      FORMAT (1A10)

        OPEN (UNIT = 1, FILE = FILE)

        DO 30 I = 1, 100
                READ (1,40,END=50) (ARRAY (I,J),J=1,10)
40              FORMAT (10G)
                WRITE (OUT,40) (ARRAY(I,J),J=1,10)
30      CONTINUE
50      CONTINUE
        N = I-1
120     CONTINUE

        WRITE(OUT,60)
60      FORMAT (' WHAT COLUMNS IS THE X AND Y DATA IN?')
        READ (IN,70) IX,IY
70      FORMAT (2G)

        WRITE (OUT,72)
72      FORMAT (' TYPE ''L'' FOR LOG  FIT',/,
        1' TYPE ''R'' FOR REAL FIT')
        READ (IN,75) ANS
75      FORMAT (1A1)

        NT= N
        DO 80 I = 1,N
                IF (ARRAY(I,IX) .EQ. -1.0 .OR. ARRAY(I,IY)
        1 .EQ. -1.0) NT = NT-1
                IF (ARRAY(I,IX) .EQ. -1.0 .OR. ARRAY (I,IY)
        1 .EQ. -1.0) GO TO 80

                IF (ANS .EQ. 'R') X(I-(N-NT)) = ARRAY (I,IX)
                IF (ANS .EQ. 'R') Y(I-(N-NT)) = ARRAY (I,IY)
                IF (ANS .EQ. 'L' .AND. ARRAY(I,IX) .EQ. 0.0)
        1       NT = NT-1
                IF (ANS .EQ. 'L' .AND. ARRAY(I,IX) .EQ.0.0)
        1       GO TO 80
                IF (ANS .EQ. 'L' .AND. ARRAY(I,IY) .EQ. 0.0)
        1       NT = NT-1
                IF (ANS .EQ. 'L' .AND. ARRAY(I,IY) .EQ. 0.0)
        1       GO TO 80
                IF (ANS .EQ. 'L') X(I-(N-NT)) = ALOG10(ARRAY (I,IX))
                IF (ANS .EQ. 'L') Y(I-(N-NT)) = ALOG10 (ARRAY (I,IY))
                WRITE (OUT,70) Y(I-(N-NT)),Y(I-(N-NT))
80      CONTINUE


        DO 90 K = 1,5
                CALL FIT (X,Y,NT,K,B,1,1,1,'LPT',SS0)
90      CONTINUE
```

```
      WRITE (OUT,100)
100   FORMAT (' IS A REGRESSION TO BE RUN ON MORE PAIRS?')
      READ (IN,110) ANS
110   FORMAT (1A1)
      IF (ANS .EQ. 'Y') GO TO 120
      STOP
      END
```

```
C        THIS PROGRAM IS TO FIND THE PHSICAL PROPERTIES
C        AT VARIOUS PRESSURES AND DEPTHES AND TO
C        CACULATE THE INTIAL RESSERVOIR PRESSURE
C        BY LEAST MEAN SQUARE FITTING OF THE
C        CUMULATIVE PRODUCTION (RES. BBLS.)
C        AND CRESSPONDING PRESSURE
C
C
         DOUBLE PRECISION IFILE,OFILE
         REAL D,P(100),NP(100),RC(100),PB,BT(100),X(100)
         1,B(2),BG(100),WP(100),RSB,RS,BOFBP,BODBP,Y(100)

         INTEGER I,J,OUT,IN,KOUNT,TTY,FILE

         DATA TTY,OUT,IN,FILE /4,1,16,12/

         WRITE (TTY,2)
2        FORMAT (' ENTER INPUT FILE.EXT')
         READ (TTY,4) IFILE
4        FORMAT (1A10)
         OPEN (UNIT=IN,ACCESS='SEQIN',FILE=IFILE)

         WRITE (OUT,10)
10       FORMAT (' ENTER MIDDLE PERFORATION DEPTH (FT)')
         READ (IN,20) D
20       FORMAT (G)

         WRITE (OUT,22)
22       FORMAT (' NUMBER OF PRESSURE READINGS')
         READ (IN,24) J
24       FORMAT (G)


C CALCULATE BUBBLE POINT PRESSURE
         PB = 5715.23+(.74516*(14250.0-D))-
         1(.21325E-3*((14250.0-D)**2))

C CALCULATE THE SOLUTION GAS OIL RATIO AT THE BUBBLE POINT

         RSB =  1299.92+.98532*(14250-D)
C CALCULATE BO FLASH AT BUBBLE POINT

                 BOFBP = 1.33963+(.51733E-03*(14250.0-D))

C CALCULATE BO DIFFERENTIAL A BUBBLE POINT

         BODBP = 1.52454+.574789E-3*RSB

         RSBD = .63297411E+3+(.10223560E+1*RSB)
         DO 30 I = 2,J+1
                 WRITE (OUT,40)
40               FORMAT (' ENTER PRESSURE (PSIA), OIL PRODUCTION
         1 (STB),CUMMULATIVE GOR (SCF/STB)',/,' WATER PRODU
         1CTION (BBLS)')
                 READ (IN,50) P(I),NP(I),RC(I),WP(I)
50               FORMAT (4G)

C CORRECT P

                 P(I) = (P(I)+(.233*(D-13800.0)))+14.73


C CALCULATE BG AT OR ABOVE THE BUBBLE POINT

                 IF (P(I) .GE. PB) BG(I) = 0.0
C CALCULATE BT AT THE BUBBLE POINT
```

```
                    IF (P(I) .EQ. PB) BT(I) = BOFBP
C SET RC EQUAL TO RSB ABOVE OR AT THE BUBBLE POINT

                    IF (P(I) .GE. PB) RC(I) = RSB


C CALCULATE BO DIFFERENTIAL AT PRESSURES ABOVE THE BUBBLE POINT

                    IF (P(I) .GT. PB) BT(I) = BODBP*(1.0-(4.54569
          1E-5*((P(I)-PB)**.92468)))

C CALCULATE BO FLASH AT ANY PRESSURE ABOVE THE BUBBLE POINT

                    IF (P(I) .GT. PB) BT(I) = BT(I)*(BOFBP/BODBP)

C CALCULATE X WHICH IS NP*BO AT OR ABOVE THE BUBBLE POINT

                    IF (P(I) .GE. PB) X(I-1) = NP(I)*BT(I)

C ENTER THE PRESSURES INTO A Y ARRAY

                    IF (P(I) .GE. PB) Y(I-1) = P(I)

C COUNT THE NUMBER OF DATA POINTS ABOVE THE BUBBLE POINT

                    IF (P(I) .GE. PB) KOUNT = I-1

C  JUMP OUT OF LOOP WHEN NO DATA IS LEFT

C                   IF (P(I) .GE. PB) WRITE (OUT,60)
C60                 FORMAT (' IS MORE DATA  TO BE ENTERED? (Y OR N)')

C                   IF (P(I) .GE. PB) READ (IN,70) ANS
C70                 FORMAT (1A1)


                    IF (P(I) .GE. PB .AND. ANS .EQ. 'N')
          1         GO TO 80
C CALCULATE BG BELOW THE BUBBLE POINT

                    IF (P(I) .LT. PB) BG(I) = 1.0/(-.37601
          1693E+01+(.57804478E-01*P(I))-(.21815831E-05*(P(I)**2)))

C CALCULATE THE BO PART OF BT BELOW THE BUBBLE POINT

                    IF (P(I) .LT. PB) BT(I) = BODBP*(1.0-(5.37118E-3*
          1((P(I)-PB)**.52793)))

C CALCUATE BO FLASH BELOW THE BUBBLE POINT

                    IF (P(I) .LT. PB) BT(I) = BT(I)*(BOFBP/BODBP)


C CALCULATE THE SOLUTION GAS OIL RATIO AT A PRESSURE BELOW
C THE BUBBLE POINT

                    IF (P(I) .LT. PB) RS = RSBD*(.403892376E-1+(.12817169*
          1(P(I)/PB))+(.76311158*((P(I)/PB)**2)))
```

```
C CALCUALTE BT BELOW THE BUBBLE POINT

                IF (P(I) .LT. PB) BT(I) =BT(I)+((RSBD-RS)*(BOFBP/BODBP)*
        1(BG(I)/5.6145))

C JUMP OUT OF THE LOOP WHEN NO DATA IS LEFT


C                IF (P(I) .LT. PB) WRITE (OUT,60)
C                IF (P(I) .LT. PB) READ (IN,70) ANS
C                IF (P(I) .LT. PB .AND. ANS .EQ. 'N')
C       1        GO TO 80
30      CONTINUE
80      CONTINUE

C FIT DATA TO FIND INTIAL PRESSURE

        CALL FIT (X,Y,KCUNT,1,B,1,1,1,'LPT',SSD)

        P(1) = B(1)

C ENTER VALUES OF NP,RC,BG, AND WP FOR A INTIAL RESERVOIR PRESSURE

        NP(1) = 0.0


        RC(1) = RSB

        BG(1) = 0.0

        WP(1) = 0.0

C  CALCULATE BT AT INTIAL RESERVOIR PRESSURE

        BT(1) = BODBP*(1.0-(4.54569E-5*((P(1)-PB)**.92463)))
        BT(1) = BT(1)*(BOFBP/BODBP)

C WRITE TO A DATA FILE

        WRITE (TTY,90)
90      FORMAT (' OUTPUT FILE.EXT')
        READ (TTY,95) OFILE
95      FORMAT (1A10)
        OPEN (UNIT=FILE,ACCESS='SEQOUT',FILE=OFILE)

        I = I-1
        WRITE (FILE,106) I
106     FORMAT (1G)
        DO 100 J = 1,I
                WRITE (FILE,110) P(J),NP(J),RC(J),BT(J)
        1,BG(J),WP(J)
110     FORMAT (6G)
100     CONTINUE

        STOP
        END
```

```
C       THIS PROGRAM IS TO CALCULATE OIL IN PLACE
C       USING THE MATERIAL BALANCE EQUATION AS AN
C       EQUATION OF STRAIGHT LINE USING THE METHOD
C       EXPLAINED IN THE TEXT AND MAKE THE PLOTS
C       FOR EACH PRESSURE DATA POINT AS REFERANCE
C
C

        REAL SWI,CF,CW,P(30),NP(30),RC(30),BT(30),BG(30),WP(30),
        1GKON,Y(30,30),X(30,30),YPOS(500),XPOS(500),XARRAY(4),
        2YARRAY(4),B(2),X1,Y1,X2,Y2

        INTEGER TTY,IN,OUT,NPRES,I,J,NPOS

        DOUBLE PRECISION IFILE,OFILE

        DATA XARRAY(1), YARRAY(1) /2*-1.0E30/
        DATA XARRAY(2), YARRAY(2) /2*1.0E30/


        DATA TTY,IN,OUT/4,2,1/

        WRITE (TTY,10)
10      FORMAT (' INPUT FILE.EXT')
        READ (TTY,20) IFILE
20      FORMAT (1A10)
        OPEN (UNIT=IN,ACCESS='SEQIN',FILE=IFILE)

        WRITE (TTY,30)
30      FORMAT(' OUTPUT FILE.EXT')
        READ (TTY,40) OFILE
40      FORMAT (1A10)
        OPEN (UNIT=OUT,ACCESS='SEQOUT',FILE=OFILE)

        READ (IN,50) SWI,CF,CW
50      FORMAT (3G)
        READ (IN,60) NPRES
60      FORMAT (G)
        READ (IN,70) (P(I),NP(I),RC(I),BT(I),BG(I),WP(I),I=1,NPRES)
70      FORMAT (6G)

        WRITE (OUT,80) OFILE,SWI,CF,CW
80      FORMAT (' INFORMATION FROM ',1A10,///,
        1' INTIAL WATER SATURATION (FRACTIONAL) : ',G,/,
        2' FORMATION COMPRESSIBILITY (1/PSIA) : ',G,/,
        3' WATER COMPRESSIBILITY (1/PSIA) : ',G)

        WRITE (OUT,90)
90      FORMAT (///,'     P (PSIA)',7X,'NP (STB)',7X,'RC (SCF/STB)',3X,
        1'BT (BBL/STB)',2X,'BG (SCF/STB)',3X,'WP (STB)',///)

        WRITE (OUT,70) (P(I),NP(I),RC(I),BT(I),BG(I),WP(I),I=1,NPRES)


        GKON = ((CW*SWI)+CF)/(1.0-SWI)
        DO 160 J = 1, NPRES
        WRITE (OUT,92) J
92      FORMAT (///,' REFERENCE PRESSURE: ',I2,/,' PRESSURE',7X,'DELTA
        1P',12X,'X',15X,'Y')
        DO 140 I = 1,NPRES
                FGAMMA = ((P(1)-P(I))*GKON)
                X(I,J) = (BT(I)-BT(1))+(BT(1)*FGAMMA)-X(J,1)
                Y(I,J) = NP(I)*((BT(I)+((((RCI-RCJ)/5.61))*BG(I))))
        1+WP(I)-Y(J,1)
155             CONTINUE
                DELP = P(J)-P(I)
                IF (X(I,J) .GT. XARRAY(1))
        1       XARRAY(1) = X(I,J)
```

```
               IF (X(I,J) .LT. XARRAY(2))
     1         XARRAY(2) = X(I,J)
               IF (Y(I,J) .GT. YARRAY(1))
     1         YARRAY(1) = Y(I,J)
               IF (Y(I,J) .LT. YARRAY(2))
     1         YARRAY(2) = Y(I,J)
               WRITE (OUT,150) P(I),DELP,X(I,J),Y(I,J)
150            FORMAT (4G)
140        CONTINUE
160        CONTINUE

           NPOS = 0
           DO 200 J = 1, NPRES
                IF (IPLOT(1) .NE. 0) STOP
                CALL PLOT (1.0,1.0,-3)
           NPEN = NEWPEN (2)
           CALL FACTOR (.7)
                CALL SYMBOL (0.0,8.5,.25,'REFERENCE PRESSURE :',0.0,20)
                CALL NUMBER (5.25,8.5,.25,FLOAT(J),0.0,-1)
                CALL SCALE (XARRAY,8.0,2)
                CALL SCALE (YARRAY,8.0,2)
                CALL AXIS (0.0,0.0,'X',-1,8.0,0.0,XARRAY(3),XARRAY(4))
                CALL AXIS (0.0,0.0,'Y',1,8.0,90.0,YARRAY(3),YARRAY(4))
                CALL GRID (0.0,0.0,1.0,1.0,8,8)
                DO 210 I = 1, NPRES
                     IF (X(I,J) .GT. 0.0 .AND. Y(I,J) .GT. 0.0)
           1NPOS = NPOS+1
                     IF (X(I,J) .GT. 0.0 .AND. Y(I,J) .GT. 0.0)
           1XPOS(NPOS) = X(I,J)
                     IF (X(I,J) .GT. 0.0 .AND. Y(I,J) .GT. 0.0)
           2YPOS(NPOS) = Y(I,J)
                     X(I,J) = (X(I,J)-XARRAY(3))/XARRAY(4)
                     Y(I,J) = (Y(I,J)-YARRAY(3))/YARRAY(4)
                     CALL SYMBOL (X(I,J),Y(I,J),.2,3,0.0,-1)
                     CALL NUMBER (X(I,J),Y(I,J),.2,FLOAT(I),0.0,-1)
210             CONTINUE
           CALL PLOT (0.0,0.0,99)
200        CONTINUE

           XARRAY(1) = 0.0
           YARRAY(1) = 0.0
           XARRAY(2) = 0.0
           YARRAY(2) = 0.0

           DO 220 I = 1,NPOS
                IF (XPOS(I) .GT. XARRAY(2))
           1 XARRAY(2) = XPOS(I)
                IF (YPOS(I) .GT. YARRAY(2))
           1 YARRAY(2) = YPOS(I)
220        CONTINUE

           CALL FIT(XPOS,YPOS,NPOS,1,8,1,1,1,OUT,SSD)

           IF (IPLOT(1) .NE. 0) STOP
           CALL PLOT (1.0,1.0,-3)
           NPEN = NEWPEN (2)
           CALL FACTOR (.7)
           CALL SYMBOL (0.0,8.5,.4,'ALL POSITIVE VALUES',0.0,19)
           CALL SCALE (XARRAY,8.0,2)
           CALL SCALE (YARRAY,8.0,2)
```

```
      CALL AXIS (0.0,0.0,'X',-1,8.0,0.0,XARRAY(3),XARRAY(4))
      CALL AXIS (0.0,0.0,'Y',1,8.0,90.0,YARRAY(3),YARRAY(4))
      CALL GRID (0.0,0.0,1.0,1.0,8,8)
      DO 300 I = 1,NPOS
              XPOS(I) = (XPOS(I)-XARRAY(3))/XARRAY(4)
              YPOS(I) = (YPOS(I)-YARRAY(3))/YARRAY(4)
              CALL SYMBOL (XPOS(I),YPOS(I),.2,11,0.0,-1)
300   CONTINUE

      CALL FIT (XPOS,YPOS,NPOS,1,8,0,0,0,OUT,SSD)
      CALL SUBWIN (0,J,0.0,0.0,8.0,8.0)

      X1 = 0.0
      Y1 = B(1)

      DO 230 I = 1,80
              X2 = FLOAT(I)/10.0
              Y2 = (B(2)*X2)+B(1)
              CALL DASHLN (X1,Y1,X2,Y2,0.0)
              X1 = X2
              Y1 = Y2
230   CONTINUE

      CALL PLOT (0.0,0.0,99)
      STOP
      END
```

FORTRAN FITTING SUBROUTINE

DATE: 20-JAN-76

SUBROUTINE FIT

Subroutine FIT is used to fit any number of observations of dependent and independent variables to a polynomial. The technique used is the method of LEAST SQUARES. By using this technique of fitting, the degree of the polynomial MUST NOT EXCEED 5 or there will be a substantial amount of error introduced into the resulting polynomial coefficients. Various print flags are used to obtain output of the table, coefficients and standard deviation that subroutine FIT calculates. There is also a provision for the specification of which output device is desired.

Calling sequence:

```
CALL FIT(X,Y,N,K,B,IT,IC,IS,ID,SSD)
```

Where:

X - The singular array for the independent variable dimensioned for N in the calling program.

Y - The singular array for the dependent variable dimensioned for N in the calling program.

N - The number of observations.

K - The degree of the fitted polynomial. Note: Should not exceed 5.

B - The array containing the resulting coefficients determined by FIT. This array should be dimensioned for K+1 in the calling program.

IT - The table print flag (0=No, 1=Yes).

IC - The coefficient print flag (0=No, 1=Yes).

IS - The sum of the squares of the deviations print flag (0=No, 1=Yes).

ID - The print device used for all output from FIT ('TTY' = Teletype, 'LPT' = Line printer or N, where N = the logical unit number.

SSD - The sum of the squares of the deviations of the computed Y from the experimental Y.

To use Subroutine FIT the user has two choices. Either the FORTRAN-10 compiler can be used to compile the calling program or the FORTRAN (F40) compiler can be used. The Subroutine itself is compiled using the FORTRAN-10 compiler. For a FORTRAN-10 user the following command should be used:

```
.EXECUTE/F10 MYPROG.FOR,LBY:FIT
```

FOR A FORTRAN (F40) user the following commands should be used:

```
.COMPILE MYPROG.FOR
.R LINK
*MYPROG,LBY:FIT/MIXFOR/GO
.START
```

The reason for the series of commands for a FORTRAN (F40) user is that each of the two different FORTRAN compilers generates different code (.REL files) and the linking loader (LINK-10) must be used with the /MIXFOR switch to resolve the use of routines generated by the two different compilers.

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