CONSTRUCTION OF NOMOGRAMS DESCRIBING THE EFFECT OF DIFFERENT VARIABLES ON THE BEHAVIOR OF A KCl/POLYMER DRILLING FLUID

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ABSTRACT

144 tests were conducted on KCl/polymer drilling fluid samples in which mud temperature, mud density, viscosifier polymer's concentration, and fluid-loss reducer's concentration were varied and the physical and rheological properties were measured at each case.

The collected data have been used to study the effect of these variables on the fluid lost property of the mud and to construct four nomograms that relate the theological properties (plastic viscosity, yield point,10 second and 10-minute gels) to mud temperature, density and viscosifier polymers concentration.

The remits proved that Pac/starch polymer combination is the major factor that governs the nitration values of this mud.

The constructed nomograms are helpful in predicting the rheological properties of this type or muds by knowing mud density, XC-polymer concentration and buttonhole temperature.

INTRODUCTION

KCL/polymer drilling fluids are widely used for shale drilling because they provide high levels of shale inhibition and they minimize cuttings disitegration, which will result in achieving wellborn stability.[1,2,3]

When testing drilling fluids, the theological parameters measured at ambient temperatures should be adjusted to estimate subsurface temperature [4]. In addition, the effect of some important variables such as, mud density and the concentration of different mud constituents, on the physical and rheological properties of the mud must be taken into consideration in order to have a successful drilling operation.

In this study, an inhibitive KCl/polymer drilling fluid which is composed of (4 ppb bentonite, 0.5 ppb XC-polymer, 1 ppb Pac polymer, 4 ppb starch, 0.3 ppb KOH, 0.4 ppb preservative, 14 ppb K.C1 and 75 ppb barite) and was suggested by Terzi (1998)[5] is tested under variable conditions of temperature, density and polymer's concentration.

Temperatures of 50, 100, 150 and 200°F; and densities of9,10,ll and 12 ppg (corresponding to 1.08,1.2,1.32 and 1.44 Kg/m^3 respectively) were used. Different XC-polymer concentrations were used (0.25, 0.5 and 0.75 ppb), and the Pac/starch combination used were 0.5 /2, 1/4 and 1.5/6 ppb.

The collected data were used for the construction nomograms for rheological behavior of the mud.

EXPERIMENTAL WORK

Apparatus and equipment

A. Calibrated multi speed Fann VG-35 S viscometer. An IMCO Thermocup was provided to the Fann VG in order to avoid the cooling of the mud sample.
B. The standard Baroid Mud Balance.
C. The standard Hamilton Beach Mixer.
D. The Baroid Filter Press which was provided with a heat jacket to avoid the cooling of the mud sample.

Effect of different variables on the behavior of the mud

The mud was formulated and tested under variable conditions of temperature, density, and polymer concentration. The identification of the formulated samples of this mud is presented in Table (1). The physical and rheological properties of the mud measured at different temperatures, densities, and polymers concentrations are presented in Table (2). To simplify the nomograms, fluid loss was handled separately. Figures (1, 2, 3, and 4) shows the effect of mud density, XC polymer concentration, and Pac/starch concentration on the API fluid loss of the mud at temperatures of 50, 100,150, and 200 °F respectively. These Figures suggest the followings:

1. XC concentration does not affect the fluid loss values. It may cause a very slight decrease or increase in the fluid loss but with no definite trend. This is in good agreement with the fact that XC polymer is a roam viscosifier and not a filtration loss controller.
2. The density increase (caused by the uniform barite particles) will cause a slight decrease in the fluid loss values if there is adequate Pac/starch concentration in the mud (the 1/4 ppb and 1.5/6 ppb concentrations). In the case of inadequate Pac/starch concentration (the 0.5/2 ppb concentration), the density increase will cause a slight decrease in the fluid loss al the low-density range (9 and 10 ppg values), then a sharp increase at the higher (11 and 12 ppg) values.
3. The temperature increase will cause a gradual slight increase in the fluid loss values (almost for every case). This may be attributed to the reduction in the filtrate viscosity. Also the rise in temperature may affect filtrate volume through changes in the electrochemical equilibria which govern the degree of flocculation and aggregation, thus altering the permeability of the filter cake. Finally, chemical degradation of some of the mud components is expected at temperatures of 200 °F and more. This will lead to further increase in the filtration values.
4. At each density, temperature, and XC concentration; the major factor that governs the filtration values was found to be the Pac/Starch concentration- The lower concentration of 0.5/2 ppb is inadequate of achieving reasonable low fluid loss values. While the higher concentration of 1.5/6 ppb, provides the lowest fluid loss values. However, the intermediate concentration of 1/4 ppb, provides fluid loss values very close to the lowest levels. Therefore, it could be considered the optimum economic concentration, and will be used as the fluid-loss reducer concentration in the mud for the construction nomogram. Figure (5) shows the expected ranges of fluid loss values of the mud at different temperatures, densities, and XC polymer concentrations when Pac/strach concentration is taken as 1/4 ppb respectively.

Construction of the nomograms

To construct the nomograms for the rheological behavior of the mud, the rheological properties of PV, YP, 10 sec. Gel, and 10 min. Gel were each plotted against mud density for a fixed temperature and different XC polymer concentrations. Then four nomograms were prepared as shown in Figs. (6,7, 8, and 9). These nomograms shows the relationship between mud density, XC concentration, PV, YP, 10 sec. Gel, and 10 min. Gel at temperatures of 50,100,150, and 200°F and a Pac/Starch concentration of 1/4 ppb. These nomograms could be helpful in predicting the rheological properties of PV, YP, 10 sec. Gel, and 10 min. Gel for the mud by knowing the mud density, XC concentration, and the bottomhole temperature. Also, the theological properties could be predicted in cases when the muds density or the XC polymer concentration are desired to increase or to reduce, in addition to the increase of bottomhole temperature when the drilling continues deeper.

The limitations of the nomograms, is the fact that they do not take into account the change in the rheo logical properties (usually an increase) when the drilled formation cuttings become part of the circulating system (i-e. the dispersion of the cuttings). However, being very inhibitive in nature, and with optimized drilling practices, the mud should handle the drilled cuttings with minimum dispersion and disintegration, thus, minimizing the rheological properties changes from those measures in the laboratory.In addition, the pseudoplastic parameters (n and k) can not be obtained from these nomograms.

The flow model that best fit the Mud's behavior

A computer program that utilizes Farm VG readings to obtain the flow model that best fit the data, was used to obtain the flow model of the mud at different densities, temperatures, and XC-polymer concentration. The results are presented in Table (3). The results show that power law model is the best model to describe the behavior of the mud under most normal application conditions (41 sample results). Casson model was found to describe the behavior of the mud only under conditions of extreme temperature (200°F) and very low XC-polymer concentration (0.25 ppb), as is evident in the results of samples N29, T29, and V29.

CONCLUSIONS

1. 144 test runs performed on an inhibitive KCl/polymer drilling fluid proved that Pac/starch combination is the major factor that governs the filtration values of the mud.
2. The concentration of 1/4 ppb, could be considered the optimum economic concentration.
3. Four nomograms were constructed which correlates the mud density, temperature, XC-polymer concentration; to the rheological parameters of plastic viscosity, yield point, initial gel strength and 10-minutes gel strength. These nomograms could be helpful in predicting the rheological properties of the mud by knowing the mud density, XC concentration, and the bottomhole temperature. Also, the rheological properties could be predicted when the density or temperature changes or when the XC-polymer concentration is desired to increase or decrease.

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NOMENCLATURE

K	Power law consistency index (lb.S^n/100 ft^2)
N	Power law flow behavior index
PV	Plastic viscosity (cP)
T	Temperature (°F)
YP	Yield point (lb/100 ft^2)
Φ	Viscometer dial reading

ABBREVIATIONS

API	American Petroleum Institute
PAC	Polyanionic Collulose
ppb	Pounds per Barrel
ppg	Pounds per Gallon
XC-polymer	Xanthan Gum

SI METRIC CONVERSION FACTORS

cP	x 1.0E-03	= Pa.s
°F (°F-32/1.8)	x 3.04 E-01	= °C
ft	x 3.048E-01	= m
gal	x 3.785412E-03	= m^3
in	x 2.54E00	= cm
lb/100 sq.ft.	x 4.788026E-01	= Pa.s
ppg	x 1.198E02	= Kg/m^3

Table(1), The physical properties of mud, measured at different temperatures, densities, & polymer concentration.

Mud Code	Φ 600	Φ 300	Φ 200	Φ 100	Φ 6	Φ 3	10S Gel	10M Gel	PV	YP	AV	API F.L.	Cake mm.	Foam. Tend.	Bar. Setl.
N1	25	16	13	9	3	2	3	6	9	7	13	5.6	<0.5	N	N
N2	46	31	23	16	5	3	5	12	15	16	23	4.5	<0.5	N	N
N3	74	51	42	30	7	5	7	17	23	28	37	4	<0.5	S	N
N4	33	22	17	12	4	3	4	11	11	11	16	6	<0.5	N	N
N5	54	37	30	21	6	4.5	6	17	17	20	27	4.6	<0.5	N	N
N6	81	57	46	33	8	6	8	28	24	33	40	4.1	<0.5	S	N
N7	39	27	21	16	6	5	6	16	12	15	20	6	<0.5	N	N
N8	66	47	39	28	9	7	8	22	19	28	33	5.2	<0.5	N	N
N9	94	69	57	41	13	10	12	34	25	44	47	5	<0.5	S	N
N10	17	11	9	6	2	1	2	5	6	5	8	6.9	<0.5	N	N
N11	32	21	18	12	3	2	3	9	11	10	16	5.8	<0.5	N	N
N12	47	32	26	17	3.5	2.5	4	12	15	17	23	5.2	<0.5	S	N
N13	23	16.5	13	10	3.5	2.5	3	8	6.5	10	12	7.4	<0.5	N	N
N14	39	27	22	16	4	3	4	12	12	15	19	5.5	<0.5	N	N
N15	56	39	32	22	5	3	4.5	15	17	22	28	4.8	<0.5	S	N
N16	27	20	17	13	5	3.5	5	13	7	13	13	7.6	<0.5	N	N
N17	48	34	28	20	6	4	5.5	16	14	20	24	5.8	<0.5	N	N
N18	67	47	39	27	7	5	7	19	20	27	34	5.2	<0.5	S	N
N19	15	10	8	5	1.5	1	1.5	4	5	5	7	8	<0.5	N	N
N20	26.5	17.5	14	9	2	1.5	2	7	9	8.5	13	6.4	<0.5	N	N
N21	37	24	19	12	2.5	2	2.5	8.5	13	11	18	5.6	<0.5	S	N
N22	21	15	11	8	3	2	2.75	7.5	6	9	10	8.4	<0.5	N	N
N23	33	22.5	18	12	3.5	2	3.5	11	10.5	12	17	5.8	<0.5	N	N
N24	46	31	24	16	4	2.5	4	14	15	16	23	5	<0.5	S	N
N25	25	18.5	16	12	4	3	4	10	6.5	12	13	8.8	<0.5	N	N
N26	41	29	24	17	5	3.5	5	14	12	17	21	6.6	<0.5	N	N
N27	56	39	32	21	5.5	4	6	17	17	22	28	5.9	<0.5	S	N
N28	11	7.5	5.5	4	1.25	0.75	1.25	2.5	3.5	4	5	6.6	0.5	N	S
N29	22	14.5	10	6	1.75	1.25	1.75	5	7.5	7	11	7.5	<0.5	N	N
N30	32	20	14.5	8.5	2.25	1.5	2.25	6	12	8	16	6.8	<0.5	S	N
N31	18.5	13.5	10.5	7.5	2.75	2	2.5	6	5	8.5	9	9.4	<0.5	N	N
N32	28	19	15	10	3	2	2.75	7	9	10	14	7.1	<0.5	N	N
N33	36.5	24	18.5	11.5	3	2.25	3	9	12.5	11.5	18	5.5	<0.5	S	N
N34	24	18	15	11	3.5	2.5	3.5	8	6	12	12	9.2	<0.5	N	N
N35	34	23.5	19	13	3.75	2.5	4	9	10.5	13	17	7.2	<0.5	N	N
N36	45	30.5	23	14.5	4	2.75	4	10	14.5	16	23	6.2	<0.5	S	N
T1	30	20	15	9	3	2	3	7	10	10	15	5.4	0.5	N	N
T2	52	36	30	20	6	4	6	16	16	20	26	3.6	<0.5	N	N
T3	79	55	46	31	8	6	8	25	24	31	40	3.4	<0.5	S	N
T4	37	25	19	13	4	3	4.5	12	12	13	18	5.8	<0.5	N	N
T5	62	44	34	23	7	5	7	22	18	26	31	3.6	<0.5	N	N
T6	87	62	49	34	9	7	9	32	25	37	43	3.4	<0.5	S	N
T7	44	31	25	17	7	5	7	18	13	18	22	6	<0.5	N	N
T8	72	51.5	43	30	10	7	9.5	27	20.5	31	36	3.8	<0.5	N	N
T9	102	74	61	43	13	9	13	37	28	46	51	3.6	<0.5	S	N
T10	20	13.52	10	7	2	1	2	5	6.5	7	10	6.8	0.5	N	N
T11	36	24	20	13	3	2	3	9	12	12	18	5.1	<0.5	N	N
T12	54	36	29	19	4	3	4	12	18	18	27	4.6	<0.5	N	N

Table (2) The identification of the formulated samples of mud with variable density, temperature, & polymer concentrations.

Mud Code	Den. ppg	Temp F	XC Conc. ppb	Pac/S Conc. ppb	Mud Code	Den. ppg	Temp F	XC Conc. ppb	Pac/S Conc. ppb	Mud Code	Den. ppg	Temp F	XC Conc. ppb	Pac/S Conc. ppb
N1	9	50	0.25	0.5/2	T13	10	100	0.5	0.5/2	E25	11	150	0.75	0.5/2
N2	9	50	0.25	1/4	T14	10	100	0.5	1/4	E26	11	150	0.75	1/4
N3	9	50	0.25	1.5/6	T15	10	100	0.5	1.5/6	E27	11	150	0.75	1.5/6
N4	9	50	0.5	0.5/2	T16	10	100	0.75	0.5/2	E28	11	200	0.25	0.5/2
N5	9	50	0.5	1/4	T17	10	100	0.75	1/4	E29	11	200	0.25	1/4
N6	9	50	0.5	1.5/6	T18	10	100	0.75	1.5/6	E30	11	200	0.25	1.5/6
N7	9	50	0.75	0.5/2	T19	10	150	0.25	0.5/2	E31	11	200	0.5	0.5/2
N8	9	50	0.75	1/4	T20	10	150	0.25	1/4	E32	11	200	0.5	1/4
N9	9	50	0.75	1.5/6	T21	10	150	0.25	1.5/6	E33	11	200	0.5	1.5/6
N10	9	100	0.25	0.5/2	T22	10	150	0.5	0.5/2	E34	11	200	0.75	0.5/2
N11	9	100	0.25	1/4	T23	10	150	0.5	1/4	E35	11	200	0.75	1/4
N12	9	100	0.25	1.5/6	T24	10	150	0.5	1.5/6	E36	11	200	0.75	1.5/6
N13	9	100	0.5	0.5/2	T25	10	150	0.75	0.5/2	V1	12	50	0.25	0.5/2
N14	9	100	0.5	1/4	T26	10	150	0.75	1/4	V2	12	50	0.25	1/4
N15	9	100	0.5	1.5/6	T27	10	150	0.75	1.5/6	V3	12	50	0.25	1.5/6
N16	9	100	0.75	0.5/2	T28	10	200	0.25	0.5/2	V4	12	50	0.5	0.5/2
N17	9	100	0.75	1/4	T29	10	200	0.25	1/4	V5	12	50	0.5	1/4
N18	9	100	0.75	1.5/6	T30	10	200	0.25	1.5/6	V6	12	50	0.5	1.5/6
N19	9	150	0.25	0.5/2	T31	10	200	0.5	0.5/2	V7	12	50	0.75	0.5/2
N20	9	150	0.25	1/4	T32	10	200	0.5	1/4	V8	12	50	0.75	1/4
N21	9	150	0.25	1.5/6	T33	10	200	0.5	1.5/6	V9	12	50	0.75	1.5/6
N22	9	150	0.5	0.5/2	T34	10	200	0.75	0.5/2	V10	12	100	0.25	0.5/2
N23	9	150	0.5	1/4	T35	10	200	0.75	1/4	V11	12	100	0.25	1/4
N24	9	150	0.5	1.5/6	T36	10	200	0.75	1.5/6	V12	12	100	0.25	1.5/6
N25	9	150	0.75	0.5/2	E1	11	50	0.25	0.5/2	V13	12	100	0.5	0.5/2
N26	9	150	0.75	1/4	E2	11	50	0.25	1/4	V14	12	100	0.5	1/4
N27	9	150	0.75	1.5/6	E3	11	50	0.25	1.5/6	V15	12	100	0.5	1.5/6
N28	9	200	0.25	0.5/2	E4	11	50	0.5	0.5/2	V16	12	100	0.75	0.5/2
N29	9	200	0.25	1/4	E5	11	50	0.5	1/4	V17	12	100	0.75	1/4
N30	9	200	0.25	1.5/6	E6	11	50	0.5	1.5/6	V18	12	100	0.75	1.5/6
N31	9	200	0.5	0.5/2	E7	11	50	0.75	0.5/2	V19	12	150	0.25	0.5/2
N32	9	200	0.5	1/4	E8	11	50	0.75	1/4	V20	12	150	0.25	1/4
N33	9	200	0.5	1.5/6	E9	11	50	0.75	1.5/6	V21	12	150	0.25	1.5/6
N34	9	200	0.75	0.5/2	E10	11	100	0.25	0.5/2	V22	12	150	0.5	0.5/2
N35	9	200	0.75	1/4	E11	11	100	0.25	1/4	V23	12	150	0.5	1/4
N36	9	200	0.75	1.5/6	E12	11	100	0.25	1.5/6	V24	12	150	0.5	1.5/6
T1	10	50	0.25	0.5/2	E13	11	100	0.5	0.5/2	V25	12	150	0.75	0.5/2
T2	10	50	0.25	1/4	E14	11	100	0.5	1/4	V26	12	150	0.75	1/4
T3	10	50	0.25	1.5/6	E15	11	100	0.5	1.5/6	V27	12	150	0.75	1.5/6
T4	10	50	0.5	0.5/2	E16	11	100	0.75	0.5/2	V28	12	200	0.25	0.5/2
T5	10	50	0.5	1/4	E17	11	100	0.75	1/4	V29	12	200	0.25	1/4
T6	10	50	0.5	1.5/6	E18	11	100	0.75	1.5/6	V30	12	200	0.25	1.5/6
T7	10	50	0.75	0.5/2	E19	11	150	0.25	0.5/2	V31	12	200	0.5	0.5/2
T8	10	50	0.75	1/4	E20	11	150	0.25	1/4	V32	12	200	0.5	1/4
T9	10	50	0.75	1.5/6	E21	11	150	0.25	1.5/6	V33	12	200	0.5	1.5/6
T10	10	100	0.25	0.5/2	E22	11	150	0.5	0.5/2	V34	12	200	0.75	0.5/2
T11	10	100	0.25	1/4	E23	11	150	0.5	1/4	V35	12	200	0.75	1/4
T12	10	100	0.25	1.5/6	E24	11	150	0.5	1.5/6	V36	12	200	0.75	1.5/6

Table (2) Continued…

Mud Code	Φ 600	Φ 300	Φ 200	Φ 100	Φ 6	Φ 3	10S Gel	10M Gel	PV	YP	AV	API F.L.	Cake mm.	Foam. Tend.	Bar. Setl.
T13	27	19	15	11	3	2	3.5	9	8	11	13	6.6	<0.5	N	N
T14	43	30	23	16	4	2.5	4.5	13	13	17	21	4.5	<0.5	N	N
T15	60	42	31	21	5	3.5	5	16	18	24	30	4	<0.5	S	N
T16	32	23	19	14	5	4	5.5	14	9	14	16	6.4	<0.5	N	N
T17	52	37	30	21	6	4.5	6	17	15	22	26	4.9	<0.5	N	N
T18	73	52	42	29	7.5	5.5	7	21	21	31	36	4.4	<0.5	S	N
T19	16.5	11	8	5	1.5	1	1.75	4	5.5	5.5	8	7.2	<0.5	N	S
T20	30	20.5	15	9	2	1.5	2.25	7.5	9.5	11	15	5.3	<0.5	N	N
T21	44	30	21	13	2.5	2	3	10	14	16	22	4.8	<0.5	S	N
T22	24	17	14.5	10	3	2	3	9	7	10	12	7.3	<0.5	N	N
T23	38	26.5	22	15	4	2.5	3.75	12	11.5	15	19	4.9	<0.5	N	N
T24	52	35	28	19	4	3	4.5	15	17	18	26	4.4	<0.5	S	N
T25	29	21	18	13.5	5	3.5	5	11.5	8	13	15	7.6	<0.5	N	N
T26	45	32	26	18	5.5	4	6	15	13	19	22	5.4	<0.5	N	N
T27	62	43	33	21.5	6	4.5	7	18	19	24	31	4.8	<0.5	S	N
T28	13.5	9	7	4.5	1.75	1	1.5	3	4.5	4.5	7	8.4	0.5	N	S
T29	24.5	16	12	7	2	1.5	2	5.5	8.5	7.5	12	6.4	<0.5	N	S
T30	36	23	16	10	2.5	1.752	2.5	7	13	10	18	5.0	<0.5	S	N
T31	21.5	15.5	12.5	8.5	3	2.5	2.5	6.5	6	9.5	11	9.0	<0.5	N	N
T32	31.5	21.5	17	11	3.5	2.5	3.25	8	10	11.5	16	6.2	<0.5	N	N
T33	43	29	21.5	13.5	3.75	2.75	4	9.5	14	15	22	5.0	<0.5	S	N
T34	26.5	19	15.5	11	3.75	2.75	4	8.5	7.5	11.5	14	9.2	<0.5	N	N
T35	37.5	26	21	14	4.25	3.25	4.25	10	11.5	14.5	19	7.1	<0.5	N	N
T36	49	33.5	26	17	4.5	3.5	4.5	11	15.5	18	25	5.8	<0.5	S	N
E1	33	22	17	11	4	3	4	9	11	11	17	6.8	0.5	N	N
E2	61	42	32	20	6	4	6.5	18	19	23	30	4.1	<0.5	N	N
E3	89	61	47	30	8	4.5	9	28	28	33	44	3.6	<0.5	S	N
E4	44	30	23	15	5	4	5	14	14	16	22	6.4	<0.5	N	S
E5	75	52.5	43	29	8	6	8	25	22.5	30	38	3.6	<0.5	N	N
E6	107	75	63	43	10	7	11	35	32	43	54	3.0	<0.5	S	N
E7	57	40	32	22	8	6	8	20	17	23	29	6.4	<0.5	N	N
E8	89	64	51	35	11	8	11.5	30	25	39	45	3.4	<0.5	N	N
E9	122	87	70	49	13	9	14	41	35	52	61	2.8	<0.5	S	N
E10	24	16	12	7	2	1.5	2	6	8	8	12	7.2	0.5	N	S
E11	42	28	22	13	4	2.5	4	11	14	14	21	4.5	<0.5	N	N
E12	60	40	32	20	5	3	5	16	20	20	30	3.8	<0.5	N	N
E13	31	22	17	12	4	3	4	12	9	13	15	7.0	<0.5	N	N
E14	53	37	30	20	6	4	5.5	16	16	21	27	4.1	<0.5	N	N
E15	73	51	43	29	7	4.5	6.5	24	22	29	37	3.4	<0.5	N	N
E16	40	29	25	18	6	4	6	15	11	18	20	7.3	<0.5	N	N
E17	61	44	37	26	7	5	7	20	17	27	30	5.0	<0.5	N	N
E18	82	59	48	33	8	6	8	25	23	36	41	4.2	<0.5	N	N
E19	20	13	10.5	7	2	1.5	2	4	7	6	10	7.7	<0.5	N	S
E20	34	23.5	17	11	3	2	2.75	8	10.5	13	17	4.7	<0.5	N	N
E21	48	33	23	14	3.5	2.5	3.5	11	15	18	24	4.0	<0.5	S	N
E22	27	19.5	15.5	11	3.5	2.5	3.5	10	7.5	12	14	8.0	<0.5	N	N
E23	42	29	23	15	4	3	4	12.5	13	15	21	4.5	<0.5	N	N
E24	55	37	29	19	4.5	3.5	5	15.5	18	19	28	3.8	<0.5	S	N

Table (2) Continued...

Mud Code	Φ 600	Φ 300	Φ 200	Φ 100	Φ 6	Φ 3	10S Gel	10M Gel	PV	YP	AV	API F.L.	Cake mm.	Foam. Tend.	Bar. Sett.
E25	34	24	20.5	15	6	4.5	5.5	14	10	14	17	7.6	<0.5	N	N
E26	51	36	30	20	6	4.5	6.5	16.5	15	21	26	5.2	<0.5	N	N
E27	68	47	39	25	6.5	4.5	7.5	19	21	26	34	4.5	<0.5	S	N
E28	16	10.5	8	5	1.5	1	1.75	3.5	5.5	5	8	8.0	0.5	N	S
E29	27	17.5	12	7.5	2	1.25	2.25	6	9.5	8	14	5.8	<0.5	N	S
E30	37.5	24	16	9.5	2.5	1.5	2.5	7	13.5	10.5	19	4.4	<0.5	S	N
E31	23	16.5	12.5	9	2.5	2	2.75	6.5	6.5	10	12	8.4	<0.5	N	N
E32	35	24	18	12	3	2.25	3.5	8.25	11	13	18	5.4	<0.5	N	N
E33	46	31	23	14	3.5	2.5	4	10	15	16	23	4.0	<0.5	S	N
E34	29	21	17.5	12.5	4.25	3	4.75	9	8	13	15	7.8	<0.5	N	N
E35	41	28.5	22	14	4.25	3	4.75	10.5	12.5	16	21	6.0	<0.5	N	N
E36	53	36	26.5	16	4.5	3.25	5	11.5	17	19	27	4.8	<0.5	S	N
V1	41	27	20	13	4	3	4	10	14	13	22	9.4	0.75	N	S
V2	75	51	38	25	7	5	7	21	24	27	38	3.5	0.5	N	N
V3	106	72	56	37	9	6	10	33	34	38	53	2.8	0.5	N	N
V4	60	42	31	21	6	5	6	17	18	24	30	8.4	0.5	N	N
V5	92	64	50	34	9	7	9.5	28	28	36	46	3.7	0.5	N	N
V6	124	86	69	47	12	9	13	39	38	48	62	3.0	0.5	N	N
V7	70	50	40	29	11	9	11	23	20	30	35	6.8	0.5	N	N
V8	109	77	61	44	13	11	13	35	32	45	55	2.7	0.5	N	N
V9	147	103	82	58	15	12	15	49	42	61	73	2.4	0.5	N	N
V10	29	19	14	9	2.5	1.5	2.5	6	10	9	14	9.6	1.0	N	S
V11	51	34	26	17	4	2.5	4.5	14	17	17	26	4.3	0.5	N	N
V12	72	49	38	25	5	3.5	5	22	23	26	36	3.6	<0.5	N	N
V13	40	28	21	14	4	3	4	12	12	16	20	8.6	<0.5	N	N
V14	61.5	43	34	23	6	5	6.5	20	18.5	24.5	31	4.3	<0.5	N	N
V15	84	58	46	32	8	6	7	27	26	32	42	3.8	<0.5	N	N
V16	49	35	29	21	7	5	7.5	17	14	21	24	7.8	<0.5	N	S
V17	74	53	43	30	9	7	8	25	21	32	37	4.5	<0.5	N	N
V18	98	71	56	39	10	8	9	33	27	44	49	4.0	<0.5	S	N
V19	24	16	10	6.5	2	1.5	2	4	8	8	12	10.4	0.5	N	S
V20	40	27	19	12	3	2.5	3	8.5	12.5	14	20	4.5	<0.5	N	N
V21	56	38	27	16	4	3	3.5	12	18	20	28	3.8	<0.5	S	N
V22	31	22	17	11	3.5	2.5	3.5	10.5	9	13	15	8.8	<0.5	N	N
V23	47	32.5	25	16	4.5	3	4.25	13.5	14.5	18	23	4.6	<0.5	N	N
V24	62	41.5	32.5	21	5	4	5	16.5	20.5	21	31	3.9	<0.5	S	N
V25	37	26	20	15	5	3.5	6	15	11	15	18	8.6	<0.5	N	N
V26	57	40	31	22	6	4.5	7	18.5	17	23	29	4.7	<0.5	N	N
V27	76	52	41	28	7	5.5	8	22	24	28	38	4.1	<0.5	N	N
V28	18	11.5	8.5	5.5	1.75	1.25	2	3.5	6.5	5	9	11.0	0.75	N	S
V29	30	19.5	14	8.5	2.25	1.75	2.5	6	10.5	9	15	5.6	<0.5	N	S
V30	41.5	27	19	11	2.75	2	2.753	7.5	14.5	12.5	21	4.2	<0.5	S	N
V31	25.5	18	13.5	9.5	3	2.25	3	7	7.5	10.5	13	10.0	0.5	N	N
V32	39	27	20	13	4	3	4	8.5	12	15	20	5.0	<0.5	N	N
V33	53	35	26	16	4.5	3.5	4.5	10.5	18	17	27	3.8	<0.5	S	N
V34	33	24.5	19	13.5	5	4	5	10	8.5	16	17	9.4	<0.5	N	N
V35	46	32	25	17	5.5	4.25	5.25	11	14	18	23	6.2	<0.5	N	N
V36	59	39.5	30	20	6	4.5	5.5	12	19.5	20	30	4.4	<0.5	S	N

Table (3) Selection of best flow model for mud at different densities, temperatures, & XC concentration. (Pac/starch concentration fixed at ¼ ppb)

Mud Code	AAPE						Best Model
	Bingham Plastic	Power Law	Modified P.L.	Robertson & Stiff	Modified Rob.&Stiff	Casson	
N2	120	7.52	****	23.20	****	10.65	P.L.
N5	104	2.83	****	22.40	****	10.63	P.L.
N8	92.6	2.69	****	21.30	****	10.66	P.L.
N11	112	2.71	****	21.20	****	13.38	P.L.
N14	120	1.62	****	21.30	****	13.68	P.L.
N17	113	2.61	****	20.20	****	13.00	P.L.
N20	142	3.34	****	23.44	****	11.80	P.L.
N23	133	5.47	****	21.10	****	13.67	P.L.
N26	112	1.83	****	20.60	****	12.80	P.L.
N29	144	10.22	****	29.27	****	5.37	Casson
N32	115	4.61	****	22.90	****	9.63	P.L.
N35	120	3.15	****	21.61	****	11.80	P.L.
T2	113	3.28	****	21.60	****	11.86	P.L.
T5	127	4.41	****	23.50	****	9.90	P.L.
T8	100	2.95	****	20.60	****	11.30	P.L.
T11	141	1.95	****	21.90	****	14.27	P.L.
T14	162	3.40	****	21.80	****	13.90	P.L.
T17	113	2.23	****	22.00	****	12.10	P.L.
T20	197	6.27	****	26.30	****	9.65	P.L.
T23	137	2.80	****	20.50	****	15.00	P.L.
T26	112	2.66	****	21.80	****	11.30	P.L.
T29	126	8.10	****	27.80	****	5.10	Casson
T32	108	5.30	****	24.00	****	7.90	P.L.
T35	107	4.10	****	23.40	****	9.40	P.L.
E2	140	5.86	****	24.80	****	8.90	P.L.
E5	121	2.50	****	22.70	****	12.00	P.L.
E8	117	3.50	****	22.40	****	10.70	P.L.
E11	131	6.80	****	24.70	****	9.40	P.L.
E14	122	3.60	****	21.90	****	11.40	P.L.
E17	128	0.70	****	20.90	****	15.20	P.L.
E20	162	6.00	****	25.50	****	8.90	P.L.
E23	133	3.80	****	23.80	****	10.80	P.L.
E26	111	2.80	****	22.70	****	11.36	P.L.
E29	156	8.70	****	27.40	****	7.10	Casson
E32	148	4.90	****	24.90	****	10.00	P.L.
E35	131	5.40	****	24.60	****	8.63	P.L.
V2	133	5.70	****	25.30	****	8.10	P.L.
V5	129	4.30	****	23.90	****	10.80	P.L.
V8	101	5.30	****	23.50	****	9.80	P.L.
V11	162	3.80	****	22.90	****	12.00	P.L.
V14	127	5.23	****	24.30	****	10.90	P.L.
V17	111	3.20	****	22.40	****	11.20	P.L.
V20	154	9.70	****	28.50	****	5.90	Casson
V23	146	4.65	****	24.00	****	10.10	P.L.
V26	126	3.40	****	23.10	****	11.20	P.L.
V29	134	9.20	****	28.50	****	4.10	Casson
V32	126	6.93	****	26.10	****	6.70	Casson
V35	102	5.37	****	24.10	****	7.70	P.L.

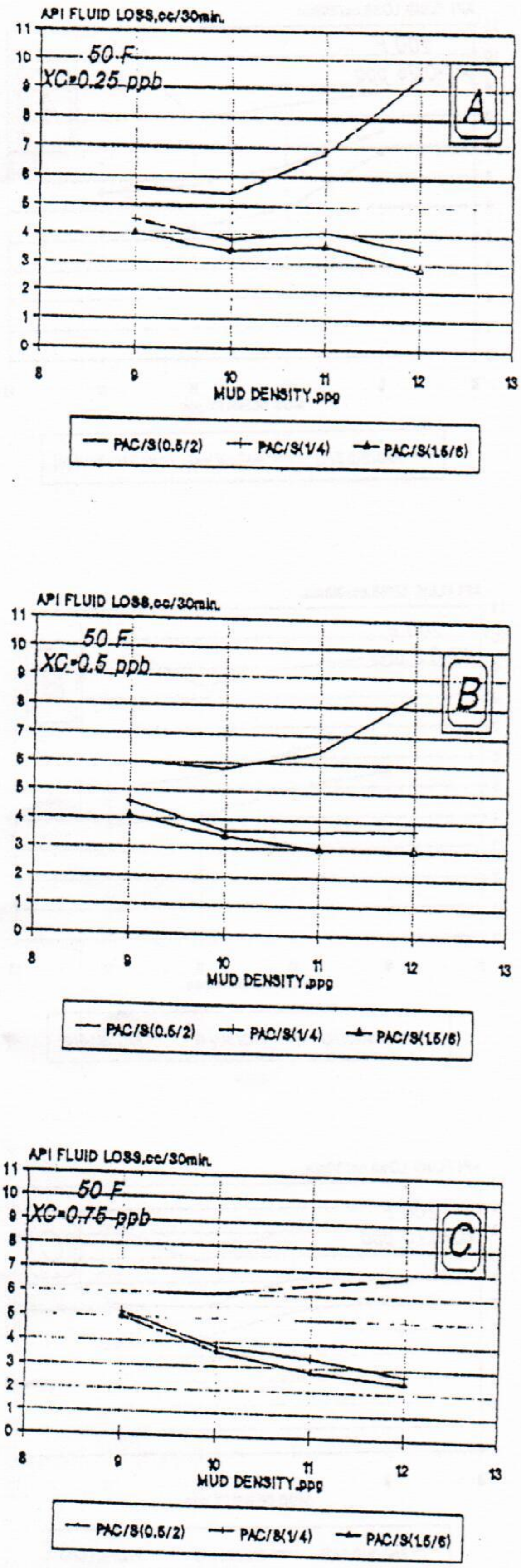

Fig. (1) Effect of density, XC conct. PAC/STARCH Conct.on the API fluid loss of mud (at 50°F)

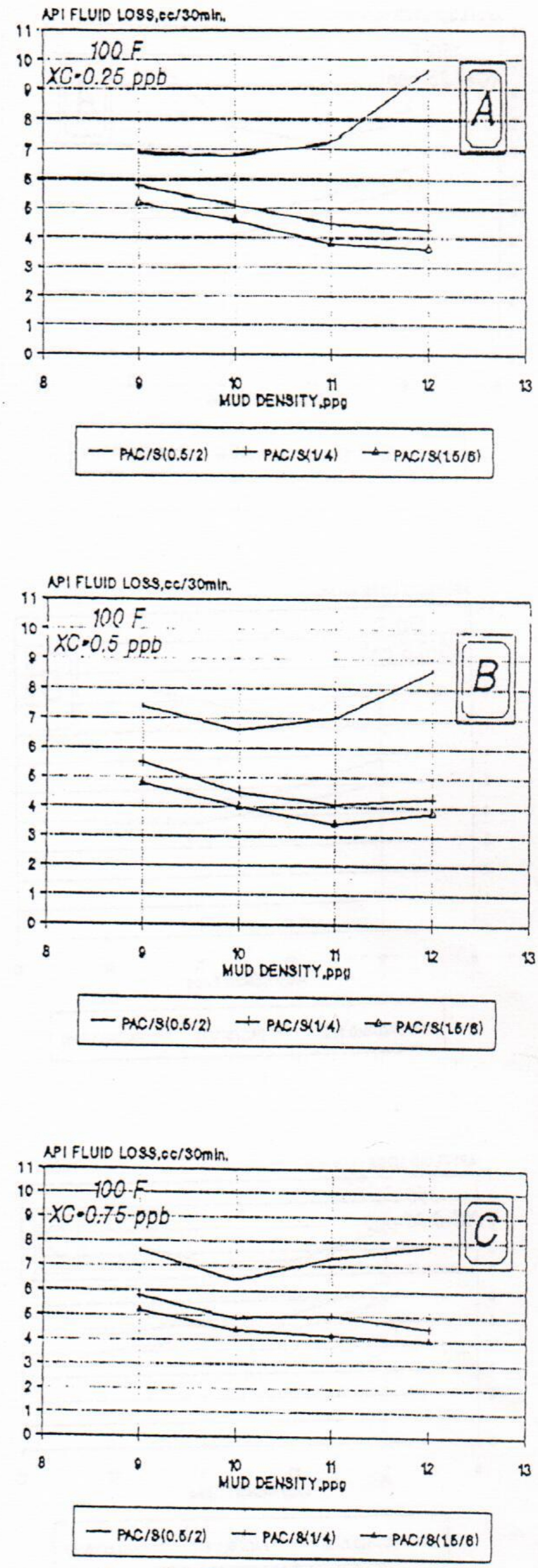

Fig. (2) Effect of density, XC Conct. PAC/starch conct. On the API fluid loss of mud (at 100°F)

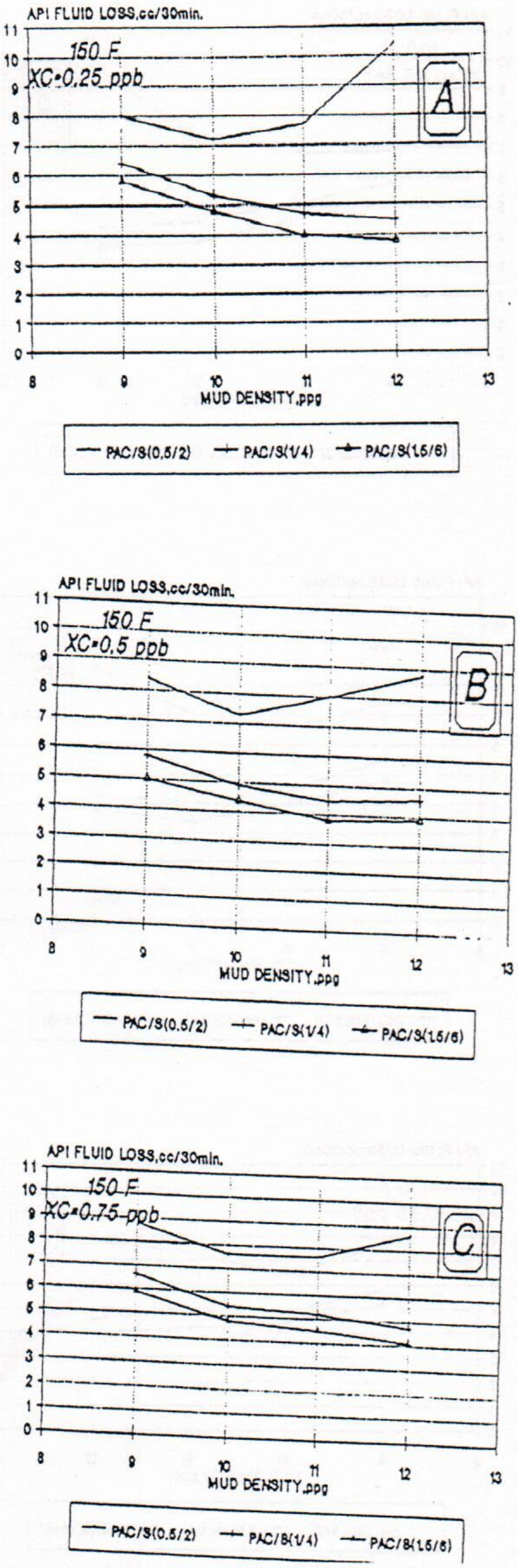

Fig. (3) Effect of density, XC conct PAC/starch conct on the API fluid loss of mud (at 150°F)

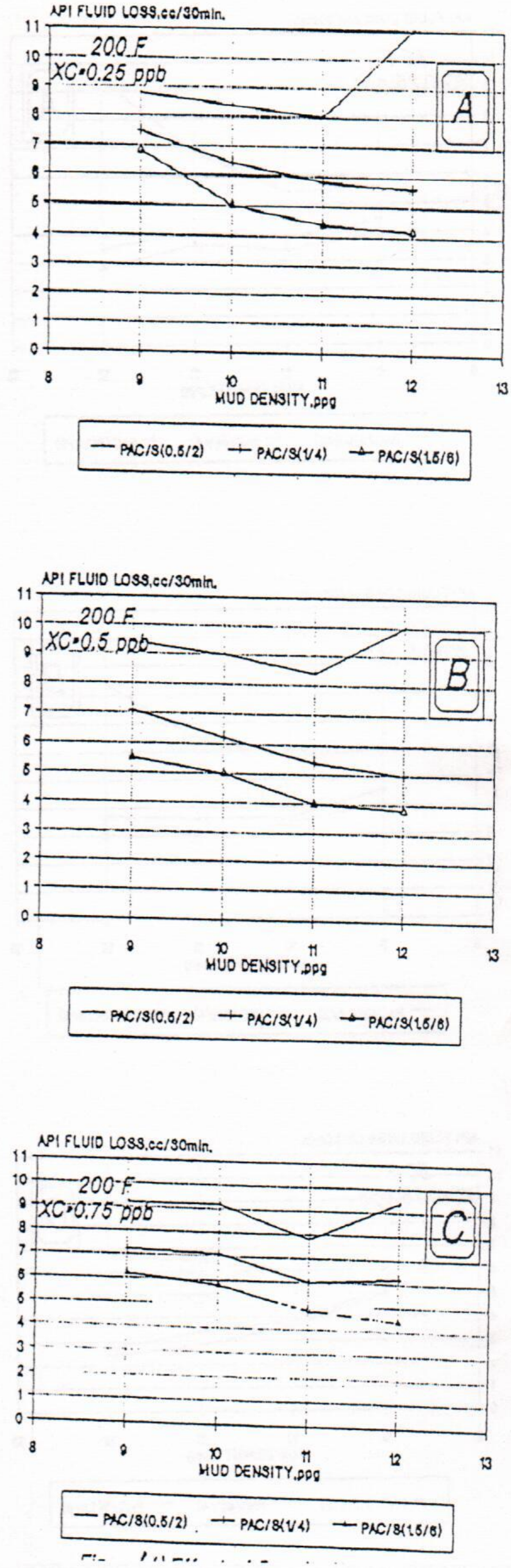

Fig. (4) Effect of density, XC conct PAC/starch conct on the API fluid loss of mud (at 200°F)

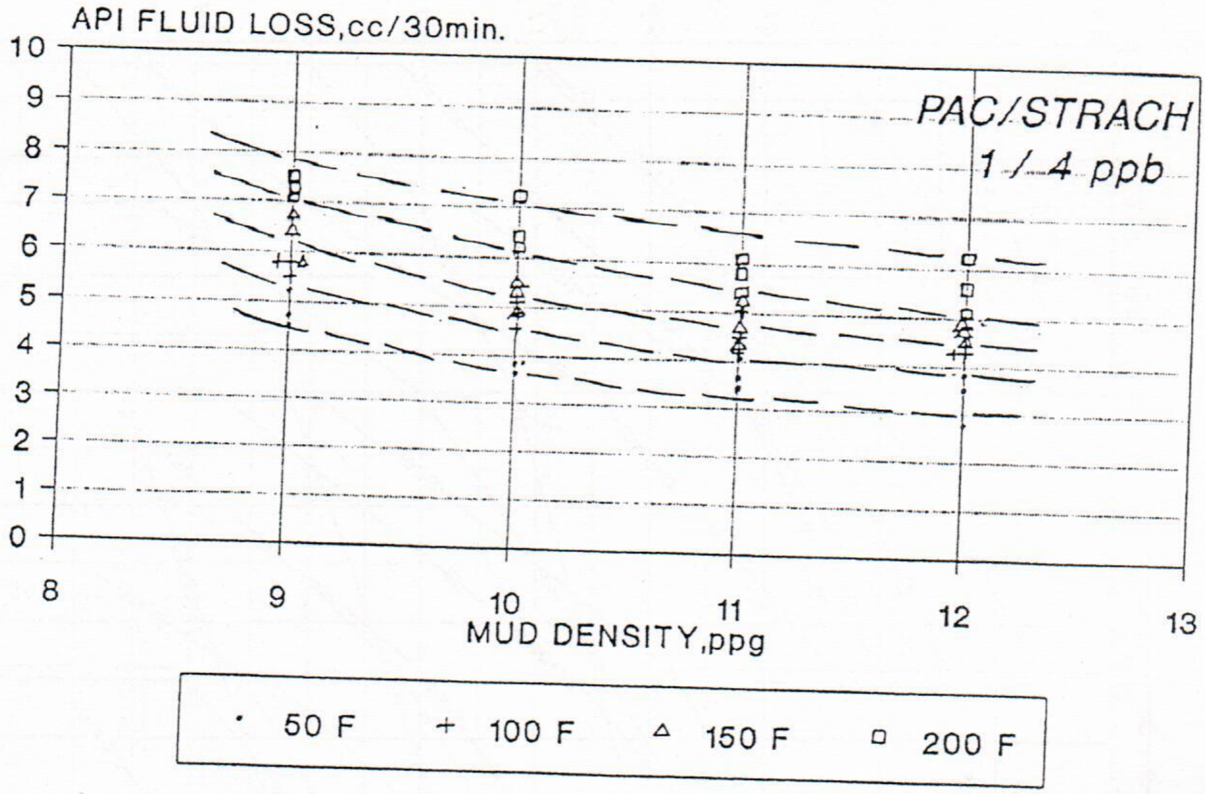

Fig. (5) The expected fluid loss of mud at various temperatures, densities, & XC polymer concentrations

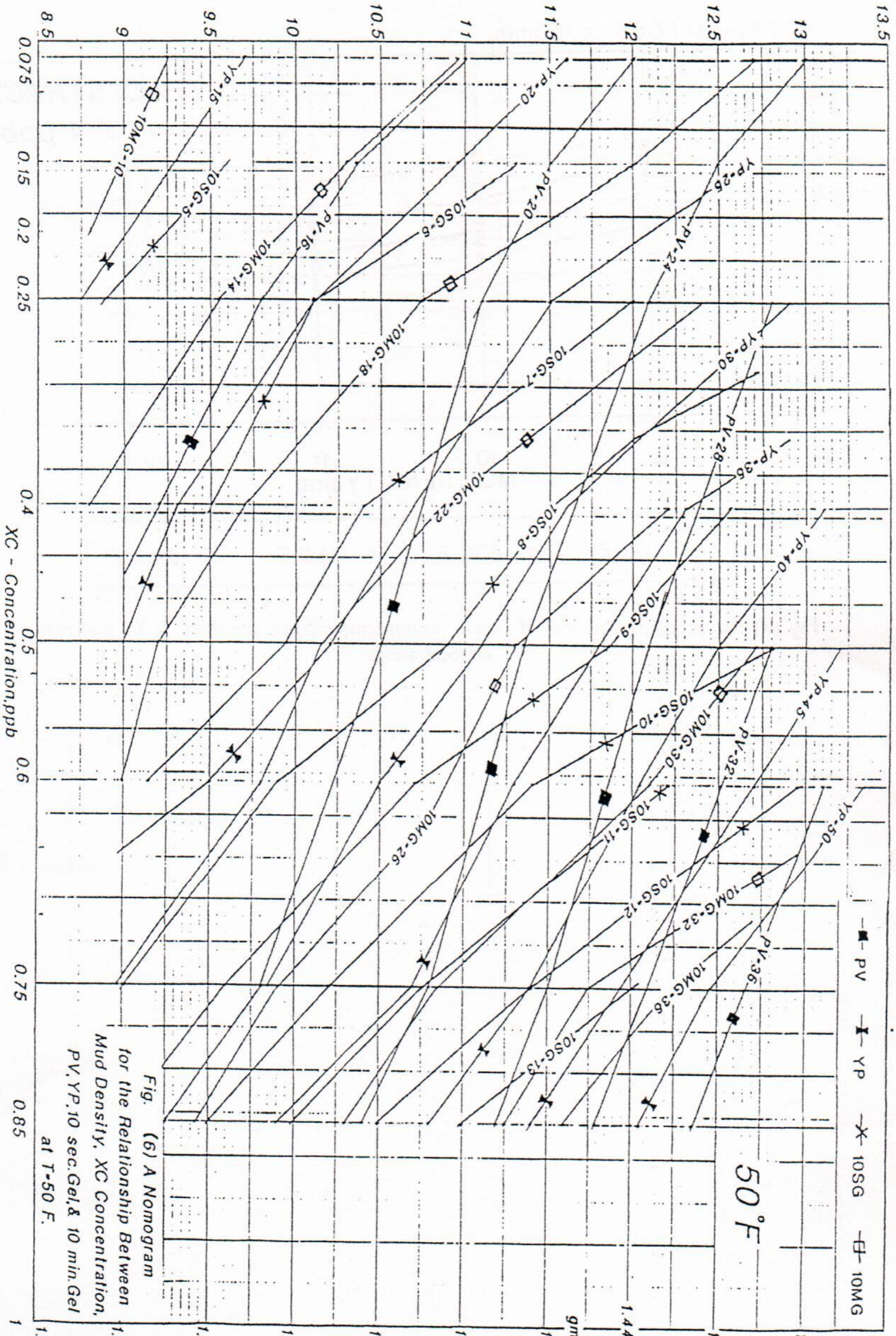

Fig. (6) A Nomogram for the Relationship Between Mud Density, XC Concentration, PV,YP,10 sec.Gel,& 10 min.Gel at T-50 F.

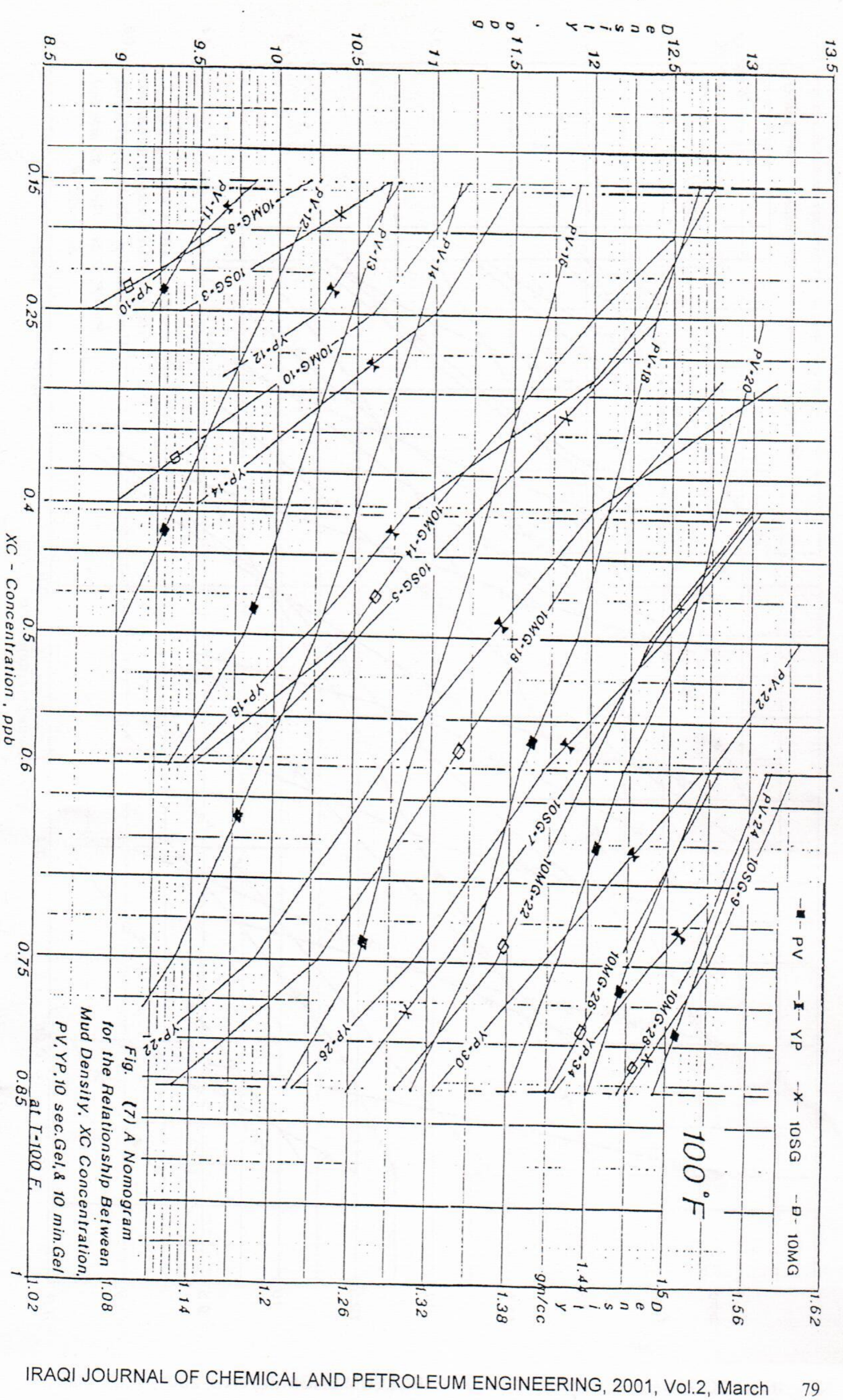

Fig. (7) A Nomogram for the Relationship Between Mud Density, XC Concentration, PV, YP, 10 sec.Gel, & 10 min.Gel at T-100 F.

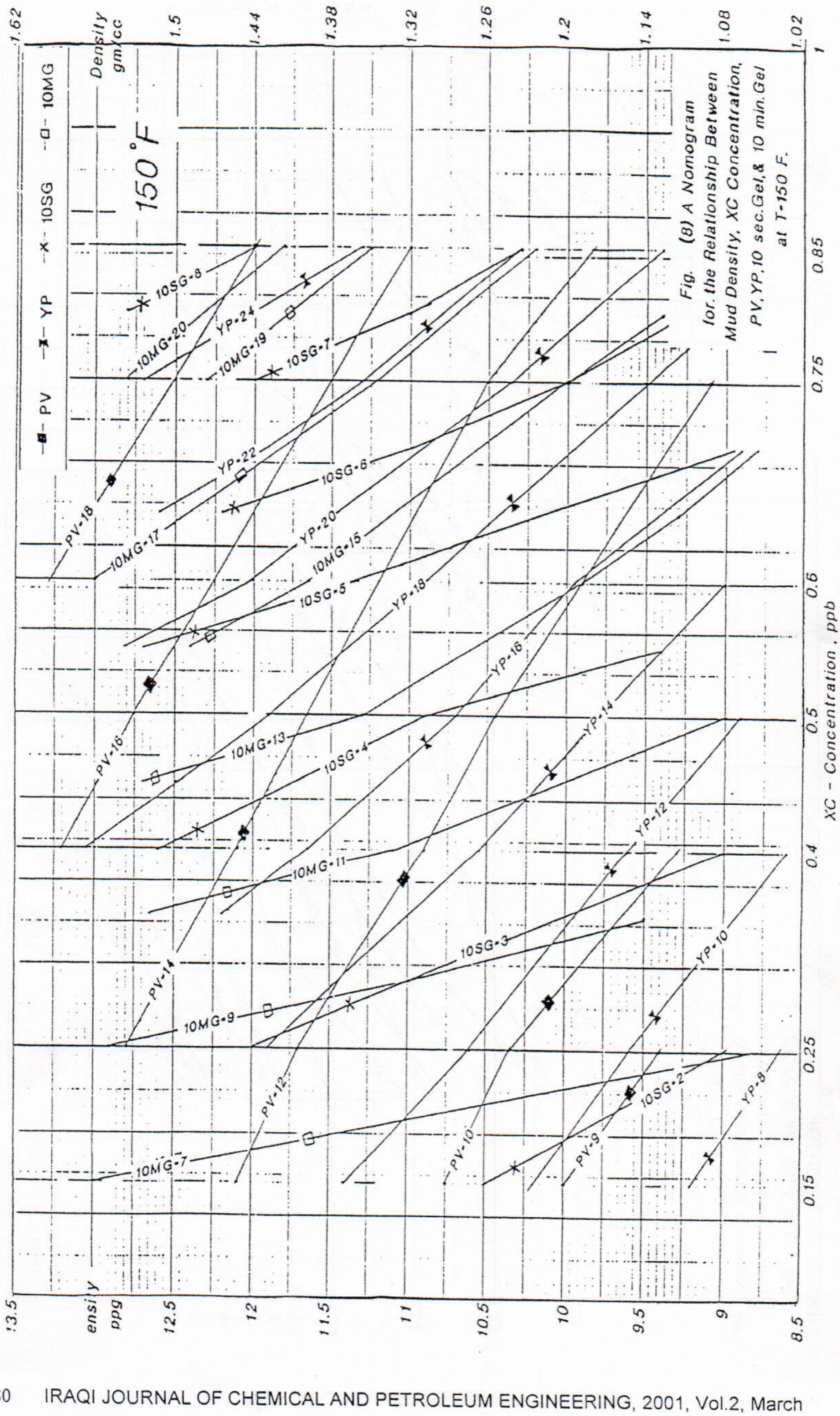

Fig. (8) A Nomogram for the Relationship Between Mud Density, XC Concentration, PV, YP, 10 sec.Gel, & 10 min.Gel at T-150 F.

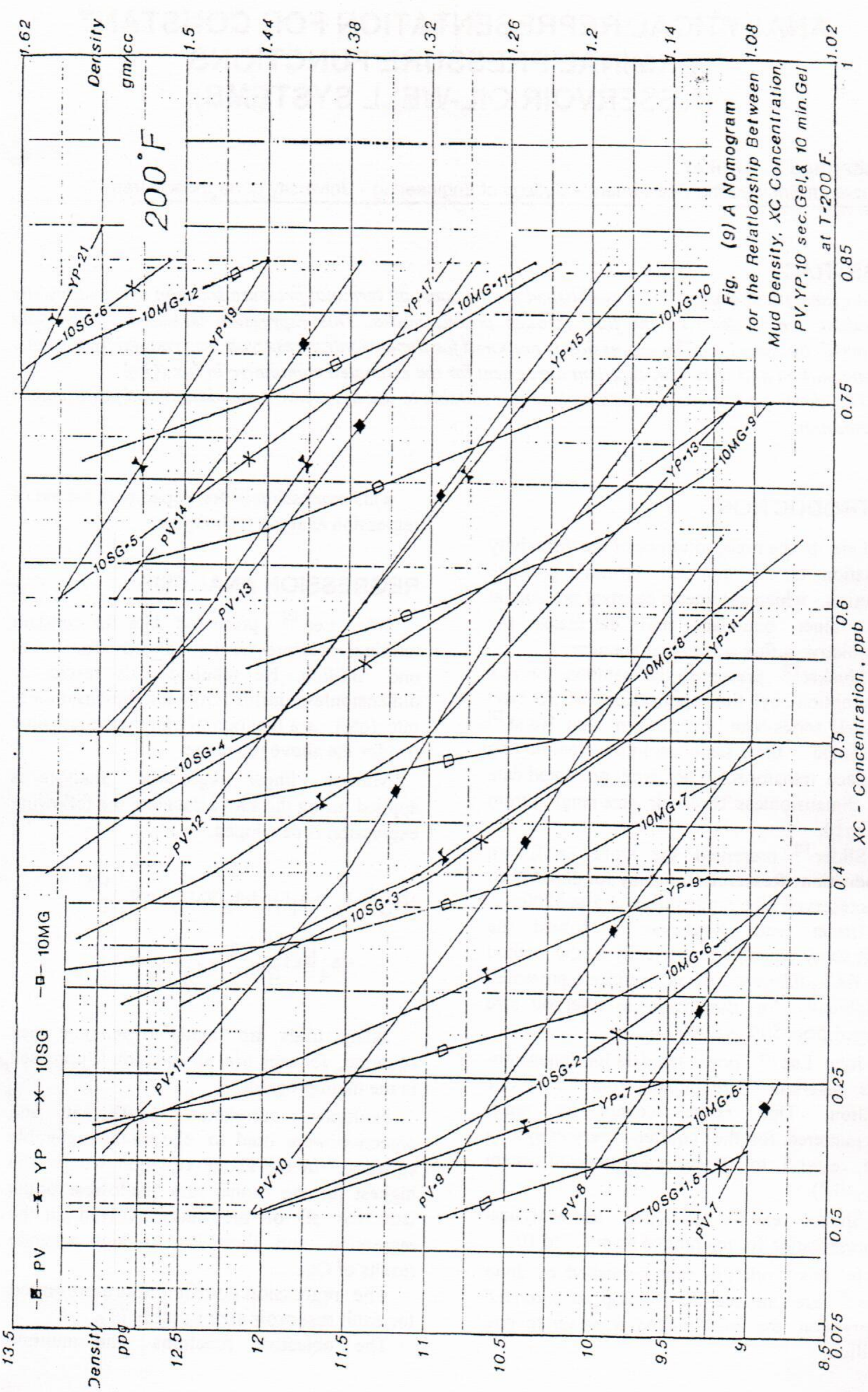

Fig. (9) A Nomogram for the Relationship Between Mud Density, XC Concentration, PV, YP, 10 sec. Gel, & 10 min. Gel at T-200 F.