UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Pertama
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EKC 333 - Kejuruteraan Pemprosesan Gas dan Petroleum

Masa: [3 jam]

ARAHAN KEPADA CALON:

Sila pastikan kertas soalan ini mengandungi **LIMA BELAS (15)** muka surat dan **DUA PULUH (20)** lampiran bercetak sebelum anda mula menjawab soalan.

Kertas soalan ini mengandungi **TUJUH (7)** soalan dan dua bahagian iaitu Bahagian A dan Bahagian B.

Jawab **LIMA (5)** soalan sahaja. **TIGA** (3) soalan dari Bahagian A dan **DUA** (2) soalan dari Bahagian B

Soalan No. 4 dari Bahagian A adalah soalan **WAJIB**.

Soalan No. 4 mempunyai 25 soalan objektif. Bagi setiap jawapan yang **salah** akan **ditolak** 2 markah. Tandakan jawapan dalam buku jawapan anda.

SATU soalan di Bahagian B wajib dijawab dalam Bahasa Malaysia. Soalan-soalan lain boleh dijawab dalam Bahasa Inggeris.

Soalan terjemahan Bahasa Inggeris ditaip dalam bentuk tulisan Italic.

Data dan graf yang berkaitan dengan soalan di Bahagian B diberikan di lampiran.

BAHAGIAN A

1. Takrifkan istilah-istilah berikut (dengan ringkas).
Define the following terms (in brief)

[a] °API graviti *(°API gravity)*
[b] Faktor pencirian Watson *(Watson characterisation factor)*
[c] Lengkungan TBP *(TBP curve)*
[d] Gasolin asli *(natural gasoline)*
[e] Gas sekutu *(Associated gas)*
[f] Tekanan Wap Reid *(Reid vapor pressure)*
[g] Titik anilina *(Aniline point)*
[h] Takat kilat *(Flash point)*
[i] Kelikatan sejagat saybolt *(Saybolt universal viscosity)*
[j] "Topping"
[k] Hidrat gas *(Gas hydrate)*
[l] Nombor oktana penyelidikan *(Research octane number)* (RON)
[m] Takat tuang *(Pour point)*
[n] Minyak mentah terturun *(Reduced crude)*
[o] Salingan tengah *(Middle distillates)*
[p] titik didih purata min *(Mean average boiling point)*
[q] Nilai pemanasan kasar *(Gross Heating Value)*
[r] Penyulingan 15-5 *(15-5 Distillation)*
[s] Nombor setana *(Cetane Number)*
[t] Penyingkiran gas berasid *(Acid gas removal)*

(100 markah)

2. Jawab **Lima** soalan secara jelas dan ringkas. **Bezakan antara yang berikut:**
*Answer any **five** question. Differentiate between the followings:*
(Be specific and to the point)

[a] Pemecahan bermangkin lawan penghidropecahan
Catalytic Cracking vs. Hydrocracking

[b] Pembentuhan semula bermangkin lawan pengisomeran
Catalytic Reforming vs. Isomerisation

[c] Pengkokan terlengah lawan 'visbreaking'
Delayed Coking vs Visbreaking

[d] Mangkin zeolit lawan mangkin silika-alumina
Zeolite vs Silica Alumina Catalyst

[e] Minyak mentah paraffin lawan minyak mentah aromatik
Paraffinic vs Aromatic Crude

[f] Penyulingan atmosfera lawan penyulingan vakum
Atmospheric vs Vacuum Distillation

[g] Penyahlilinan bermangkin lawan penyahlilinan pelarut
Catalytic vs Solvent Dewaxing

(100 markah)

3. Lakarkan satu gambarajah aliran yang dipermudah untuk mana-mana **dua** proses, tunjukkan nilai-nilai pembolehubah dan parameter proses yang penting.
Draw a simplified flow diagram of any two processes showing the values of important process variables and parameters.

[a] Pengkokan lentur
Flexicoking

[b] Pemecahan bermangkin tiub penaik
Riser tube catalytic cracking

[c] Proses penghidropecahan dua peringkat
Two stage hydrocracking process

[d] Penukaran gas asli kepada ammonia
Natural gas conversion to ammonia

(100 markah)

4. Pilih jawapan **yang betul**. **Jawapan yang salah akan dipotong 50% markah**.
Pick up the correct answer. Wrong answer carries 50% negative marks.

[a] Unsur utama gas asli ialah:
The main constituent of natural gas is:

[i] CH_4
[ii] CO
[iii] C_2H_2
[iv] C_2H_6

[b] Minyak mentah masam bermaksud
Sour crude means

[i] minyak mentah bergalas asfalt
asphalt bearing crude
[ii] minyak mentah mengandungi sebatian sulfur
crude containing sulphur compounds
[iii] minyak mentah berlilin
waxy crude
[iv] minyak mentah mengandungi sebatian nitrogen
crude containing nitrogen compounds

[c] Nombor oktana gasolin ialah pengukuran ke atas:
Octane number of gasoline is a measure of its

[i] Kecenderungan ketukan
knocking tendency
[ii] Kelengahan pencucuhan
ignition delay
[iii] Titik asap
smoke point
[iv] Suhu pencucuhan
ignition temperature

[d] Minyak tanah mesti mempunyai
Kerosene should have

[i] titik asap yang rendah
low smoke point
[ii] titik asap yang tinggi
high smoke point
[iii] kandungan aromatik yang tinggi
high aromatics content
[iv] kandungan parafin yang rendah
low paraffins content

[e] Indeks kelikatan
Viscosity index

[i] ialah pengukuran takat kilat
is a measure of flash point
[ii] ialah pengukuran perubahan kelikatan dengan suhu
is the measure of variation of viscosity with temperature
[iii] untuk minyak pelincir mesti/sepatutnya rendah
of a lubricating oil should be low
[iv] tiada jawapan
none of these

[f] Takat kilat suatu minyak diukur dengan:
Flash point of an oil is measured by:

[i] Radas Pensky Martens
Pensky Martens Apparatus
[ii] Meter likat Saybolt
Saybolt viscometer
[iii] Meter kalori bom
Bomb calorimeter
[iv] Radas Conardson
Conardson apparatus

[g] Mangkin yang digunakan dalam pemecahan bermangkin ialah:
Catalyst used in catalytic cracking is:

[i] Gel silika (Silica gel)
[ii] Silika-alumina (Silica alumina)
[iii] Vandium pentaoksida (Vandium pentaoxide)
[iv] Nikel (Nickel)

[h] Suapan untuk pembentukan semula secara amnya ialah:
Feed for reforming is generally

[i] nafta atau gasolin larian terus
naphtha or straight run gasoline
[ii] minyak mentah tertuntun
reduced crude
[iii] minyak gas vakum
vacuum gas oil
[iv] minyak gas atmosfera
atmospheric gas oil

[i] Kelikatan tinggi minyak pelincir selalunya menunjukkan
Higher viscosity of lubricating oil usually signifies

[i] RVP yang rendah
lower RVP
[ii] Nombor asid yang tinggi
higher acid number
[iii] Takat kilat dan takat nyala yang tinggi
higher flash point and fire point
[iv] Takat kilat dan takat nyala yang rendah
lower flash point and fire point

[j] Takat kilat gasolin motor adalah sekitar
Flash point of motor gasoline may be around

(a) 30°F
(b) 110°F
(c) 240°F
(d) 310°F

[k] Nombor cetana diesel yang digunakan di dalam lori berkemungkinan:
Cetane number of diesel used in trucks may be

(a) 5
(b) 14
(c) 35
(d) 85

[l] Namakan hidrokarbon yang mempunyai kestabilan pengoksidaan yang paling buruk.
Name the hydrocarbon having poorest oxidation stability

[i] Naftana (*Naphthene*)
[ii] Aromatik (*Aromatics*)
[iii] Olefin (*Olefin*)
[iv] Parafin (*Paraffin*)

[m] Minyak mentah berasaskan parafin jika dibandingkan dengan minyak mentah berasaskan asfalt memberi
Paraffin base crude as compared to asphalt base crude gives

[i] hasil gasolin larian terus yang tinggi
higher yield of straight run gasoline
[ii] Gasolin bernombor oktana tinggi
higher octane number gasoline
[iii] indeks kelikatan minyak pelincir yang rendah
lower viscosity index lube oil
[iv] hasil minyak pelincir yang buruk
poorer yield of lube oil

[n] Penghalusan hidro ialah kaedah yang berkesan untuk
Hydrofining is the most effective method for

[i] pembaikan takat asap
improvement of smoke point
[ii] penyingkiran sulfur
removal of sulphur
[iii] pengurangan kehilangan pernafasan
reduction of breathing loss
[iv] tiada jawapan
none of these

[o] 'Platforming' ialah:
Platforming is a

[i] proses lapisan bergerak
moving bed process
[ii] proses lapisan terbendalir
fluidised bed process
[iii] proses tak jana semula dan lapisan tetap
Non regenerative and fixed bed process
[iv] proses jana semula
regenerative process

[p] Faktor pencirian minyak mentah dihitung sebagai 12.5. Ini bermakna ia adalah:
The characterisation factor of crude oil is calculated as 12.5. It means that, it is:

[i] berparafin *(paraffinic)*
[ii] bernaftina *(naphthenic)*
[iii] pertengahan *(intermediate)*
[iv] tiada jawapan *(none of these)*

[q] Yang manakah diantara berikut yang dikehendaki di dalam diesel dan minyak tanah tetapi tidak dikehendaki dalam gasolin?
Which of the following is desirable in diesel and kerosene but is undesirable in gasoline?

[i] aromatik *(aromatics)*
[ii] merkaptan *(mercaptans)*
[iii] parafin *(paraffins)*
[iv] asid naftanik*(naphthenic acid)*

[r] Sebuah loji penapis yang terlibat dalam "topping", pemeringkatan atmosfera dan pembentukan semula bermangkin dikenali sebagai
A refinery which involves topping, atmospheric fractionation and catalytic reforming is known as

[i] loji penapis minyak pelincir *(Lube oil refining)*
[ii] loji penapis 'topping' *(Topping refinery)*
[iii] loji penapis pemecahan rendah *(Low cracking refinery)*
[iv] loji penapis bersepadu *(Integrated refinery)*

[s] Sejumlah air yang besar daripada gas asli disingkirkan melalui:
Large amounts of water from natural gas is removed by:

[i] penjerapan *(adsorption)*
[ii] penyerapan/pelucutan *(absorption/stripping)*
[iii] pengewapan kilat *(flash vaporisation)*
[iv] tiada jawapan *(none of the above)*

[t] Nilai kalori (kcal/Nm^3) gas asli ialah sekitar:
The calorific value (kcal/Nm^3) of natural gas is about

[i] 2,500
[ii] 10,000
[iii] 35,000
[iv] 25,000

[u] Tindakbalas yang manakah tidak dikehendaki dalam pengeluaran gasolin pembentukan semula bermangkin?
Which of the following reaction is undesirable in the production of catalytically reformed gasoline?

[i] penyahhidrogenan naftena
dehydrogeneration of naphthene
[ii] penyahhidrogenan parafin rendah
dehydrogeneration of lower paraffin
[iii] penyahhidrosiklisasi parafin tinggi
dehydrocyclisation of higher paraffins
[iv] pengisomeran parafin
Isomerisation of paraffins

[v] Tekanan (kg/cm^2) dan suhu (°C) yang dikekalkan di dalam penyahgaram elektrik untuk minyak mentah masing-masing ialah:
The pressure (kg/cm^2) and temperature (°C) maintained in electrical desalters for crude oil are respectively

[i] 10 dan 120 (*10 and 120*
[ii] 1 dan 200 (*1 and 200*)
[iii] 50 dan 250 (*50 and 250*)
[iv] 10 dan 300 (*10 and 300*)

[w] Peningkatan nombor/jumlah atom karbon dan hidrogen di dalam molekul hidrokarbon, ketumpatan hasil-hasil petroleum akan:
With increase in the number of carbon and hydrogen atoms in hydrocarbon molecules, the density of petroleum products

[i] menurun/berkurangan *(decreases)*
[ii] menaik/bertambah *(increases)*
[iii] tetap sama *(remains same)*
[iv] tidak boleh dijangkakan melalui data ini *(unpredictable from the data)*

[x] Yang mana satukah mempunyai graviti °API yang maksimum?
Which has the maximum °API gravity of all?

[i] Diesel
[ii] Petrol
[iii] Minyak tanah *(kerosene)*
[iv] Minyak relau *(furnace oil)*

[y] 95% (isipadu) daripada gas petroleum cecair (LPG) pada tekanan 760 mm Hg akan sejat pada
95% (by volume) of liquified petroleum gas (LPG) at 760 mm Hg pressure will evaporate at

[i] 2°C
[ii] 30°C
[iii] -40°C
[iv] 55°C

(100 markah)

BAHAGIAN B

5. [a] Minyak mentah sedang diproses di dalam menara penyulingan minyak mentah atmosfera untuk memisahkan kepada beberapa pecahan. Analisis TBP minyak mentah diberi di dalam Jadual 1. Sediakan satu imbangan bahan yang lengkap di penyuling atmosfera minyak mentah untuk spesifikasi pecahan minyak mentah sebagai:

Crude oil is being processed in the atmospheric crude distillation tower for separation into various fractions. The crude TBP analysis is given in Table 1. Make a complete material balance around an atmospheric crude still for crude oil fraction specifications as:

	IBP (°F)	**EP (°F)**
Gasolin LSR *(LSR gasoline)*	90	180
Nafta *(Naphtha)*	190	380
Minyak tanah *(Kerosene)*	380	520
Minyak gas ringan *(Light Gas Oil)*	520	610
Minyak gas atmosfera *(Atmospheric Gas Oil)*	610	800
Minyak gas vakum (VGO) *(Vacuum Gas Oil) (VGO)*	800	1050

Andaikan kadar suapan 100,000 BP CD minyak mentah kepada penyuling atmosfera minyak mentah. Sediakan imbangan kepada paun terdekat.
Assume a 100,000 BP CD crude oil feed rate to the atmospheric crude still. Make the balances to the nearest pounds.

(80 markah)

[b] Sediakan imbangan jisim sulfur untuk suapan dan keluaran kepada paun terdekat.
Make sulphur weight balances for the feed and the products to the nearest pound.

(20 markah)

Table 1: Crude Petroleum Analysis

GENERAL CHARACTERISTICS

Gravity, specific, 0.834 Gravity, °API, 38.2 Pour point, °F., below 5
Sulfur, percent, 0.24 Color, brownish green
Viscosity, Saybolt Universal at 100°F, 43 sec Nitrogen, percent, 0.000

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

STAGE 1-Distillation at atmospheric pressure, 751 mm. Hg
First drop, 106°F

Fraction No	Cut temp. °F	Percent	Sum. percent	Sp. gr., 60/60°F	°API 60°F	C.I.	Refractive index no at 20°C	Specific diapersion	S.U. visc., 100°F	Cloud test, °F
1.....	122									
2.....	167	1.7	1.7	0.666	81.0					
3.....	212	3.2	4.9	.701	70.4	12	1.38738	127.2		
4.....	257	6.2	11.1	.724	63.9	14	1.40466	128.3		
5.....	302	5.9	17.0	.742	59.2	15	1.41441	122.9		
6.....	347	7.6	24.6	.762	54.2	18	1.42379	132.2		
7.....	392	6.8	31.4	.778	50.4	19	1.43298	128.6		
8.....	437	5.7	37.1	.795	46.5	22	1.44101	125.8		
9.....	482	7.1	44.2	.809	43.4	23	1.44869	130.9		
10.....	527	7.4	51.6	.826	39.8	26	1.45727	134.7		

STAGE 2-Distillation continued at 40 mm. Hg

11.....	392	4.5	56.1	0.844	36.2	31	1.46666	136.0	41	10
12.....	437	6.2	62.3	.854	34.2	32	1.47114	139.4	47	25
13.....	482	5.1	67.4	.866	31.9	34	1.47746	141.3	59	45
14.....	527	4.8	72.2	.884	28.6	40	1.48359	147.2	84	60
15.....	572	5.5	77.7	.894	26.8	41	1.49112	142.5	155	75
Residuum		21.6	99.3	.951	17.2					

Carbon residue, Conradson: Residuum, 8.3 percent; crude, 2.0 percent

APPROXIMATE SUMMARY

	Percent	Sp. gr.	°API	Viscosity
Light gasoline.....	4.9	0.689	73.9	
Total gasoline and naphtha.....	31.4	0.743	58.9	
Kerosine distillate.....	12.8	.803	44.7	
Gas oil.....	16.5	.839	37.2	
Nonviscous lubricating distillate.....	10.3	.857-886	33.6-28.2	50-100
Medium lubricating distillate.....	6.7	.886-889	28.2-25.9	100-200
Viscous lubricating distillate.....	-	-	-	Above 200
Residuum.....	21.6	.951	17.3	
Distillation loss.....	.7			

6. [a] Untuk stok suapan pemecah bermangkin 27.0°API dengan julat didih daripada 650°F kepada 900°F dan kandungan sulfur 1.2% berdasarkan berat, sediakan imbangan keseluruhan berat dan isipadu bahan untuk kadar suapan 10,000 BPD bila beroperasi pada aras penukaran 65% dan operasi sekali lalu dengan mangkin zeolit.

For a 27.0°API catalytic cracker feed stock with a boiling range of 650 to 900°F and a sulfur content of 1.2% by wt, make an overall weight and volume material balance for 10,000 BPD feed rate when operating at a 65% conversion level and a once through operation with a zeolite catalyst.

(70 markah)

[b] Hitungkan nisbah mangkin kepada minyak untuk keadaan unit pemecah mangkin di bawah:

Calculate the catalyst to oil ratio for the following conditions of catalytic cracker unit.

Karbon atas mangkin telah guna *(Carbon on spent catalyst):*	1.5 berat %
Karbon atas mangkin jana semula: *(Carbon on regenerated catalyst):*	0.80 berat %
Udara dari peniup *(Air from blower):*	155,000 lb/hr
Suapan hidrokarbon ke reaktor : *(Hydrocarbon feed to reactor):*	295,000 lb/hr

Analisis gas serombong (Orsat), % isipadu
Flue gas analysis (Orsat), Vol %

CO	12.0
CO_2	6.0
O_2	0.7
N_2	81.3

(30 markah)

7. [a] Gas daripada Medan Duyong (Malaysia) dilaporkan mempunyai komponen-komponen dan peratus isipadu campuran seperti berikut. Apakah graviti tentu gas tersebut.

Gas from the Duyong field (Malaysia) is reported to have the following components and volume percent compositions. What is the specific gravity of gas

Komponen (*Component*)	**Peratus** (*Percent*)	**Berat Mol** (*Mol. wt*)
Metana (*Methane*)	87.09	16
Etana (*Ethane*)	4.42	30
Propana (*Propane*)	1.60	44
Isobutana (*Isobutane*)	0.40	58
n-butana (*n-butane*)	0.5	58
Pentana (*Pentanes*)	0.46	72
Heksana (*Hexanes*)	0.29	86
Heptana (*Heptanes*)	0.06	100
Nitrogen	4.76	28
Karbon dioksida (*Carbon dioxide*)	0.40	44

(30 markah)

[b] Hitungkan kuasa kuda adiabatik teori yang diperlukan untuk memampatkan 1 MM cf/hari gas asli 0.6 graviti pada 100 psia dan 70°F kepada 1800 psia. Penyejuk saling tukar menyejukkan gas ke 70°F. Apakah beban haba ke atas penyejuk saling tukar dan apakah suhu terakhir gas? Anda boleh gunakan gambarajah H-S untuk menyelesaikan masalah ini.

Calculate the adiabatic theoretical horsepower required to compress 1 MM cf/day of 0.6 gravity natural gas at 100 psia and 70°F to 1800 psia. Intercoolers cool the gas to 70°F. What is the heat load on the intercoolers and what is the final gas temperature? You can use the H-S diagram to solve the problem.

(70 markah)

oooOooo

TABLE B.1

Density Conversion Table

Specific gravity 60/60° F	Density in vacuo °API	lb/bbl	lb/gal	lb/hr* from bbl/day	Specific gravity 60/60° F	Density in vacuo °API	lb/bbl	lb/gal	lb/hr* from bbl/day
1.165	-10.0	407.8	9.71	16.99	1.092	-2.0	382.6	9.11	15.94
1.163	-9.8	407.1	9.69	16.95	1.090	-1.8	382.0	9.09	15.92
1.161	-9.6	406.5	9.68	16.94	1.089	-1.6	381.4	9.08	15.89
1.159	-9.4	405.8	9.66	16.91	1.087	-1.4	380.8	9.07	15.87
1.157	-9.2	405.1	9.65	16.88	1.085	-1.2	380.3	9.05	15.85
1.155	-9.0	404.5	9.63	16.85	1.084	-1.0	379.7	9.04	15.82
1.153	-8.8	403.8	9.61	16.82	1.082	-0.8	379.1	9.03	15.80
1.151	-8.6	403.2	9.60	16.80	1.080	-0.6	378.5	9.01	15.77
1.149	-8.4	402.5	9.58	16.77	1.079	-0.4	377.9	9.00	15.75
1.147	-8.2	401.9	9.57	16.74	1.077	-0.2	377.4	8.98	15.72
1.145	-8.0	401.2	9.55	16.72	1.076	0.0	376.8	8.97	15.70
1.143	-7.8	400.6	9.54	16.69	1.074	.2	376.2	8.96	15.67
1.142	-7.6	399.9	9.52	16.66	1.073	.4	375.6	8.94	15.65
1.140	-7.4	399.3	9.51	16.64	1.071	.6	375.1	8.93	15.63
1.138	-7.2	398.6	9.49	16.61	1.070	.8	374.5	8.92	15.60
1.136	-7.0	398.0	9.48	16.58	1.068	1.0	373.9	8.90	15.53
1.134	-6.8	397.3	9.46	16.55	1.066	.2	373.4	8.89	15.56
1.132	-6.6	396.7	9.45	16.53	1.065	.4	372.8	8.88	15.53
1.131	-6.4	396.1	9.43	16.50	1.063	.6	372.3	8.86	15.51
1.129	-6.2	395.4	9.42	16.47	1.062	.8	371.7	8.85	15.49
1.127	-6.0	394.8	9.40	16.45	1.060	2.0	371.1	8.84	15.46
1.125	-5.8	394.2	9.39	16.42	1.053	.2	370.6	8.82	15.44
1.123	-5.6	393.6	9.37	16.40	1.057	.4	370.0	8.81	15.42
1.122	-5.4	392.9	9.36	16.37	1.055	.6	369.5	8.80	15.40
1.120	-5.2	392.3	9.34	16.35	1.054	.8	368.9	8.78	15.37
1.118	-5.0	391.7	9.33	16.32	1.052	3.0	368.4	8.77	15.35
1.116	-4.8	391.1	9.31	16.30	1.051	.2	367.8	8.76	15.32
1.115	-4.6	390.5	9.30	16.27	1.049	.4	367.3	8.75	15.30
1.113	-4.4	389.8	9.28	16.25	1.047	.6	366.8	8.73	15.28
1.111	-4.2	389.2	9.27	16.22	1.046	.8	366.2	8.72	15.26
1.109	-4.0	388.6	9.25	16.19	1.044	4.0	365.7	8.71	15.24
1.108	-3.8	388.0	9.24	16.17	1.043	.2	365.1	8.69	15.21
1.106	-3.6	387.4	9.22	16.14	1.041	.4	364.6	8.68	15.19
1.104	-3.4	386.8	9.21	16.12	1.040	.6	364.0	8.67	15.17
1.102	-3.2	386.2	9.19	16.09	1.038	.8	363.5	8.66	15.15
1.101	-3.0	385.6	9.18	16.07	1.037	5.0	363.0	8.64	15.12
1.099	-2.8	385.0	9.16	16.04	1.035	.2	362.4	8.63	15.10
1.097	-2.6	384.4	9.15	16.02	1.034	.4	361.9	8.62	15.08
1.096	-2.4	383.8	9.14	15.99	1.032	.6	361.4	8.60	15.06
1.094	-2.2	383.2	9.12	15.97	1.031	.8	360.9	8.59	15.04

TABLE B.1 (Continued)

Specific gravity 60/60°F	Density in vacuo °API	lb/bbl	lb/gal	lb/hr* from bbl/day	Specific gravity 60/60°F	Density in vacuo °API	lb/bbl	lb/gal	lb/hr* from bbl/day
1.029	6.0	360.3	8.58	15.01	0.973	14.0	340.5	8.11	14.19
1.028	.2	359.8	8.57	14.99	0.971	.2	340.1	8.10	14.17
1.026	.4	359.3	8.55	14.97	0.970	.4	339.6	8.09	14.15
1.025	.6	358.8	8.54	14.95	0.969	.6	339.1	8.08	14.13
1.023	.8	358.3	8.53	14.93	0.967	.8	338.7	8.06	14.11
1.022	7.0	357.7	8.52	14.90	0.966	15.0	338.2	8.05	14.09
1.020	.2	357.2	8.51	14.88	0.965	.2	337.8	8.04	14.07
1.019	.4	356.7	8.49	14.86	0.963	.4	337.3	8.03	14.05
1.017	.6	356.2	8.48	14.84	0.962	.6	336.8	8.02	14.03
1.016	.8	355.7	8.47	14.82	0.961	.8	336.4	8.01	14.02
1.014	8.0	355.2	8.46	14.80	0.959	16.0	335.9	8.00	14.00
1.013	.2	354.7	8.44	14.78	0.958	.2	335.5	7.99	13.98
1.011	.4	354.2	8.43	14.76	0.957	.4	335.0	7.98	13.96
1.010	.6	353.7	8.42	14.74	0.955	.6	334.6	7.96	13.94
1.009	.8	353.2	8.41	14.72	0.954	.8	334.1	7.95	13.92
1.007	9.0	352.7	8.40	14.70	0.953	17.0	333.7	7.94	13.90
1.006	.2	352.2	8.38	14.67	0.952	.2	333.2	7.93	13.88
1.004	.4	351.7	8.37	14.65	0.950	.4	332.8	7.92	13.87
1.003	.6	351.2	8.36	14.63	0.949	.6	332.3	7.91	13.85
1.001	.8	350.7	8.35	14.61	0.948	.8	331.9	7.90	13.83
1.000	10.0	350.2	8.34	14.59	0.947	18.0	331.4	7.89	13.81
0.999	10.2	349.7	8.33	14.57	0.945	.2	331.0	7.88	13.79
0.997	10.4	349.2	8.31	14.55	0.944	.4	330.5	7.87	13.77
0.996	10.6	348.7	8.30	14.53	0.943	.6	330.1	7.86	13.75
0.994	10.8	348.2	8.29	14.51	0.942	.8	329.7	7.85	13.74
0.993	11.0	347.7	8.28	14.49	0.940	19.0	329.2	7.84	13.72
0.992	.2	347.2	8.27	14.47	0.939	.2	328.0	7.83	13.70
0.990	.4	346.7	8.26	14.45	0.938	.4	328.4	7.82	13.68
0.989	.6	346.2	8.24	14.43	0.937	.6	327.9	7.81	13.66
0.987	.8	345.8	8.23	14.41	0.935	.8	327.5	7.80	13.65
0.986	12.0	345.3	8.22	14.39	0.934	20.0	327.1	7.79	13.63
0.985	.2	344.8	8.21	14.37	0.933	.2	326.6	7.78	13.61
0.983	.4	344.3	8.20	14.35	0.932	.4	326.2	7.77	13.59
0.982	.6	343.8	8.19	14.33	0.930	.6	325.8	7.76	13.57
0.981	.8	343.4	8.18	14.31	0.929	.8	325.3	7.75	13.55
0.979	13.0	342.9	8.16	14.29	0.928	21.0	324.9	7.74	13.54
0.978	.2	342.4	8.15	14.27	0.927	.2	324.5	7.73	13.52
0.977	.4	341.9	8.14	14.25	0.925	.4	324.0	7.72	13.50
0.975	.6	341.5	8.13	14.23	0.924	.6	323.6	7.71	13.48
0.974	.8	341.0	8.12	14.21	0.923	.8	323.2	7.70	13.47

TABLE B.1 (Continued)

Specific gravity 60/60° F	Density in vacuo °API	lb/bbl	lb/gal	lb/hr* from bbl/day	Specific gravity 60/60° F	Density in vacuo °API	lb/bbl	lb/gal	lb/hr* from bbl/day
0.922	22.0	322.8	7.69	13.45	0.876	30.0	306.8	7.30	12.78
0.921	.2	322.4	7.68	13.43	0.875	.2	306.4	7.30	12.77
0.919	.4	321.9	7.67	13.41	0.874	.4	306.0	7.29	12.75
0.918	.6	321.5	7.66	13.40	0.873	.6	305.7	7.28	12.74
0.917	.8	321.1	7.65	13.38	0.872	.8	305.3	7.27	12.72
0.916	23.0	320.7	7.64	13.36	0.871	31.0	304.9	7.26	12.70
0.915	.2	320.3	7.63	13.35	0.870	.2	304.5	7.25	12.69
0.914	.4	319.9	7.62	13.33	0.869	.4	304.2	7.24	12.67
0.912	.6	319.5	7.61	13.31	0.868	.6	303.8	7.23	12.66
0.911	.8	319.0	7.60	13.29	0.867	.8	303.4	7.22	12.64
0.910	24.0	318.6	7.59	13.27	0.865	32.0	303.0	7.21	12.62
0.909	.2	318.2	7.58	13.26	0.864	.2	302.7	7.20	12.61
0.908	.4	317.8	7.57	13.24	0.863	.4	302.3	7.19	12.60
0.907	.6	317.4	7.56	13.22	0.862	.6	301.9	7.19	12.58
0.905	.8	317.0	7.55	13.21	0.861	.8	301.6	7.18	12.57
0.904	25.0	316.6	7.54	13.19	0.860	33.0	301.2	7.17	12.55
0.903	.2	316.2	7.53	13.17	0.859	.2	300.8	7.16	12.53
0.902	.4	315.8	7.52	13.16	0.858	.4	300.5	7.15	12.52
0.901	.6	315.4	7.51	13.14	0.857	.6	300.1	7.14	12.50
0.900	.8	315.0	7.50	13.12	0.856	.8	299.7	7.14	12.49
0.898	26.0	314.6	7.49	13.11	0.855	34.0	299.4	7.13	12.47
0.897	.2	314.2	7.48	13.09	0.854	.2	299.0	7.12	12.46
0.896	.4	313.8	7.47	13.07	0.853	.4	298.7	7.11	12.45
0.895	.6	313.4	7.46	13.06	0.852	.6	298.3	7.10	12.43
0.894	.8	313.0	7.45	13.04	0.851	.8	297.9	7.09	12.41
0.893	27.0	312.6	7.44	13.02	0.850	35.0	297.6	7.09	12.40
0.892	.2	312.2	7.43	13.01	0.849	.2	297.2	7.08	12.38
0.891	.4	311.8	7.42	12.99	0.848	.4	296.9	7.07	12.37
0.889	.6	311.4	7.41	12.97	0.847	.6	296.5	7.06	12.35
0.888	.8	311.0	7.40	12.96	0.846	.8	296.2	7.05	12.34
0.887	28.0	310.6	7.40	12.95	0.845	36.0	295.8	7.04	12.32
0.886	.2	310.3	7.39	12.93	0.844	.2	295.4	7.04	12.31
0.885	.4	309.9	7.38	12.91	0.843	.4	295.1	7.03	12.30
0.884	.6	309.5	7.37	12.90	0.842	.6	294.8	7.02	12.28
0.883	.8	309.1	7.36	12.88	0.841	.8	294.4	7.01	12.27
0.882	29.0	308.7	7.35	12.86	0.840	37.0	294.0	7.00	12.25
0.881	.2	308.3	7.34	12.85	0.839	.2	293.7	6.99	12.24
0.879	.4	307.9	7.33	12.83	0.838	.4	293.4	6.99	12.21
0.878	.6	307.6	7.32	12.82	0.837	.6	293.0	6.98	12.21
0.877	.8	307.2	7.31	12.80	0.836	.8	292.7	6.97	12.20

TABLE B.1 (Continued)

Specific gravity 60/60° F	Density in vacuo °API	lb/bbl	lb/gal	lb/hr* from bbl/day	Specific gravity 60/60° F	Density in vacuo °API	lb/bbl	lb/gal	lb/hr* from bbl/day
0.835	38.0	292.3	6.96	12.18	0.797	46.0	279.1	6.64	11.63
0.834	.2	292.0	6.95	12.17	0.796	.2	278.3	6.64	11.62
0.833	.4	291.6	6.94	12.15	0.795	.4	278.5	6.63	11.60
0.832	.6	291.3	6.94	12.14	0.795	.6	278.2	6.63	11.59
0.831	.8	291.0	6.93	12.13	0.794	.8	277.9	6.62	11.58
0.830	39.0	290.6	6.92	12.11	0.793	47.0	277.6	6.61	11.57
0.829	.2	290.3	6.91	12.10	0.792	.2	277.3	6.60	11.55
0.828	.4	290.0	6.90	12.08	0.791	.4	277.0	6.59	11.54
0.827	.6	289.6	6.89	12.07	0.790	.6	276.7	6.59	11.53
0.826	.8	289.2	6.89	12.06	0.789	.8	276.3	6.58	11.51
0.825	40.0	288.9	6.88	12.04	0.788	48.0	276.0	6.57	11.50
0.824	.2	288.6	6.87	12.02	0.787	.2	275.7	6.56	11.49
0.823	.4	288.2	6.86	12.01	0.787	.4	275.4	6.56	11.47
0.822	.6	287.9	6.85	12.00	0.786	.6	275.1	6.55	11.46
0.821	.8	287.6	6.84	11.98	0.785	.8	274.1	6.54	11.45
0.820	41.0	287.2	6.84	11.97	0.784	49.0	274.5	6.54	11.44
0.819	.2	286.9	6.83	11.95	0.783	.2	274.2	6.53	11.42
0.818	.4	286.6	6.82	11.94	0.782	.4	273.9	6.52	11.41
0.817	.6	286.2	6.81	11.92	0.781	.6	273.6	6.51	11.40
0.817	.8	285.9	6.81	11.91	0.781	.8	273.3	6.51	11.39
0.816	42.0	285.6	6.80	11.90	0.780	50.0	273.0	6.50	11.37
0.815	.2	285.3	6.79	11.89	0.779	.2	272.7	6.49	11.36
0.814	.4	284.9	6.79	11.87	0.778	.4	272.4	6.49	11.35
0.813	.6	284.6	6.78	11.86	0.777	.6	272.1	6.48	11.34
0.812	.8	284.3	6.77	11.85	0.776	.8	271.8	6.47	11.32
0.811	43.0	283.9	6.76	11.83	0.775	51.0	271.5	6.46	11.31
0.810	.2	283.6	6.75	11.82	0.775	.2	271.2	6.46	11.30
0.809	.4	283.3	6.74	11.80	0.774	.4	270.9	6.45	11.29
0.808	.6	283.0	6.74	11.79	0.773	.6	270.6	6.44	11.27
0.807	.8	282.6	6.73	11.77	0.772	.8	270.3	6.44	11.26
0.806	44.0	282.3	6.72	11.76	0.771	52.0	270.0	6.43	11.25
0.805	.2	282.0	6.71	11.75	0.770	.2	269.7	6.42	11.24
0.804	.4	281.7	6.70	11.74	0.769	.4	269.4	6.41	11.22
0.804	.6	281.4	6.70	11.72	0.769	.6	269.1	6.41	11.21
0.803	.8	281.0	6.69	11.71	0.768	.8	268.8	6.40	11.20
0.802	45.0	280.7	6.69	11.70	0.767	53.0	268.5	6.39	11.19
0.801	.2	280.4	6.68	11.68	0.766	.2	268.3	6.39	11.18
0.800	.4	280.1	6.67	11.67	0.765	.4	268.0	6.38	11.17
0.799	.6	279.8	6.66	11.66	0.764	.6	267.7	6.37	11.15
0.798	.8	279.5	6.65	11.65	0.764	.8	267.4	6.37	11.14

TABLE B. 1 (Continued)

Specific gravity 60/60°F	Density in vacuo °API	lb/bbl	lb/gal	lb/hr* from bbl/day	Specific gravity 60/60°F	Density in vacuo °API	lb/bbl	lb/gal	lb/hr* from bbl/day
0.763	54.0	267.1	6.36	11.13	0.731	62.0	256.1	6.10	10.67
0.762	.2	266.8	6.35	11.12	0.730	.2	255.8	6.09	10.66
0.761	.4	266.5	6.34	11.10	0.730	.4	255.5	6.08	10.65
0.760	.6	266.2	6.34	11.09	0.729	.6	255.3	6.08	10.64
0.760	.8	265.9	6.33	11.08	0.728	.8	255.0	6.07	10.62
0.759	55.0	265.7	6.33	11.07	0.728	63.0	254.7	6.07	10.61
0.758	.2	265.4	6.32	11.06	0.727	.2	254.5	6.06	10.60
0.757	.4	265.1	6.31	11.05	0.726	.4	254.2	6.05	10.59
0.756	.6	264.8	6.30	11.03	0.725	.6	254.0	6.05	10.58
0.756	.8	264.5	6.30	11.02	0.724	.8	253.7	6.04	10.57
0.755	56.0	264.3	6.29	11.01	0.724	64.0	253.4	6.03	10.56
0.754	.2	264.0	6.29	11.00	0.723	.2	253.2	6.03	10.55
0.753	.4	263.7	6.28	10.99	0.722	.4	252.9	6.02	10.54
0.752	.6	263.4	6.27	10.97	0.722	.6	252.7	6.02	10.53
0.752	.8	263.1	6.27	10.96	0.721	.8	252.4	6.01	10.52
0.751	57.0	262.9	6.26	10.95	0.720	65.0	252.2	6.00	10.51
0.750	.2	262.6	6.26	10.94	0.719	.2	251.9	6.00	10.50
0.749	.4	262.3	6.24	10.93	0.719	.4	251.6	5.99	10.48
0.748	.6	262.0	6.24	10.92	0.718	.6	251.4	5.98	10.47
0.748	.8	261.7	6.23	10.90	0.717	.8	251.1	5.98	10.46
0.747	58.0	261.5	6.23	10.89	0.716	66.0	250.9	5.97	10.45
0.746	.2	261.2	6.22	10.88	0.716	.2	250.6	5.97	10.44
0.745	.4	260.9	6.21	10.87	0.715	.4	250.4	5.96	10.43
0.744	.6	260.6	6.20	10.86	0.714	.6	250.1	5.95	10.42
0.744	.8	260.4	6.20	10.85	0.714	.8	249.9	5.95	10.41
0.743	59.0	260.1	6.19	10.84	0.713	67.0	249.6	5.94	10.40
0.742	.2	259.8	6.19	10.82	0.712	.2	249.4	5.94	10.39
0.741	.4	259.6	6.18	10.81	0.711	.4	249.1	5.93	10.38
0.740	.6	259.3	6.17	10.80	0.711	.6	248.9	5.93	10.37
0.740	.8	259.0	6.17	10.79	0.710	.8	248.6	5.92	10.36
0.739	60.0	258.7	6.16	10.78	0.709	68.0	248.4	5.91	10.35
0.738	.2	258.5	6.15	10.77	0.709	.2	248.1	5.91	10.34
0.737	.4	258.2	6.15	10.76	0.708	.4	247.9	5.90	10.33
0.737	.6	257.9	6.14	10.75	0.707	.6	247.6	5.90	10.32
0.736	.8	257.7	6.14	10.74	0.706	.8	247.4	5.89	10.31
0.735	61.0	257.4	6.13	10.72	0.706	69.0	247.1	5.88	10.30
0.734	.2	257.1	6.12	10.71	0.705	.2	246.9	5.88	10.29
0.734	.4	256.9	6.12	10.70	0.704	.4	246.6	5.87	10.28
0.733	.6	256.6	6.11	10.69	0.704	.6	246.4	5.87	10.27
0.732	.8	256.3	6.10	10.68	0.703	.8	246.1	5.86	10.26

TABLE B.1 (Continued)

Specific gravity 60/60°F	Density in vacuo °API	lb/bbl	lb/gal	lb/hr* from bbl/day	Specific gravity 60/60°F	Density in vacuo °API	lb/bbl	lb/gal	lb/hr* from bbl/day
0.702	70.0	245.9	5.85	10.25	0.646	.5	226.2	5.39	9.42
0.701	.5	245.3	5.84	10.22	0.645	88.0	225.7	5.38	9.40
0.699	71.0	244.7	5.83	10.20	0.643	.5	225.2	5.36	9.38
0.697	.5	244.1	5.81	10.17	0.642	89.0	224.7	5.35	9.36
0.695	72.0	243.5	5.80	10.15	0.640	.5	224.2	5.34	9.34
0.694	.5	242.9	5.78	10.12	0.639	90.0	223.7	5.33	9.32
0.692	73.0	242.3	5.77	10.10	0.637	.5	223.2	5.31	9.30
0.690	.5	241.7	5.75	10.07	0.636	91.0	222.7	5.30	9.28
0.689	74.0	241.1	5.74	10.05	0.635	.5	222.2	5.29	9.26
0.687	.5	240.5	5.73	10.02	0.633	92.0	221.7	5.28	9.24
0.685	75.0	239.9	5.71	10.00	0.632	.5	221.2	5.27	9.22
0.684	.5	239.4	5.70	9.97	0.630	93.0	220.7	5.26	9.20
0.682	76.0	238.8	5.69	9.95	0.629	.5	220.2	5.24	9.18
0.680	.5	238.2	5.67	9.92	0.628	94.0	219.7	5.23	9.16
0.679	77.0	237.6	5.66	9.90	0.626	.5	219.2	5.22	9.14
0.677	.5	237.1	5.64	9.88	0.625	95.0	218/8	5.21	9.12
0.675	78.0	236.5	5.63	9.85	0.623	.5	218.3	5.20	9.10
0.674	.5	235.9	5.62	9.83	0.622	96.0	217.8	5.19	9.03
0.672	79.0	235.4	5.60	9.81	0.621	.5	217.3	5.17	9.06
0.671	.5	234.8	5.59	9.78	0.619	97.0	216.8	5.16	9.04
0.669	80.0	234.3	5.58	9.76	0.618	.5	216.4	5.15	9.02
0.668	.5	233.7	5.56	9.74	0.617	98.0	215.9	5.14	9.00
0.666	81.0	233.2	5.55	9.72	0.615	.5	215.4	5.13	8.98
0.664	.5	232.6	5.54	9.69	0.614	99.0	215.0	5.12	8.96
0.663	82.0	232.1	5.53	9.67	0.613	.5	214.5	5.11	8.94
0.661	.5	231.5	5.51	9.65	0.611	100.0	214.0	5.10	8.92
0.660	83.0	231.0	5.50	9.62	0.610	.5	213.6	5.09	8.90
0.658	.5	230.4	5.49	9.60	0.609	101.0	213.1	5.07	8.83
0.657	84.0	229.9	5.48	9.58	0.607	.5	212.7	5.06	8.86
0.655	.5	229.4	5.46	9.56	0.606	102.0	212.2	5.05	8.84
0.654	85.0	228.9	5.45	9.54	0.605	.5	211.7	5.04	8.82
0.652	.5	228.3	5.44	9.51	0.603	103.0	211.3	5.03	8.80
0.651	86.0	227.8	5.43	9.49	0.602	.5	210.8	5.02	8.78
0.649	.5	227.3	5.41	9.47	0.601	104.0	210.4	5.01	8.77
0.648	87.0	226.8	5.40	9.45	0.600	.5	209.9	5.00	8.75
					0.598	105.0	209.5	4.99	8.73

Source: From ASTM D-1250.

*Multiply barrels/day by the factor in this column corresponding to the API gravity to obtain pounds/hour.

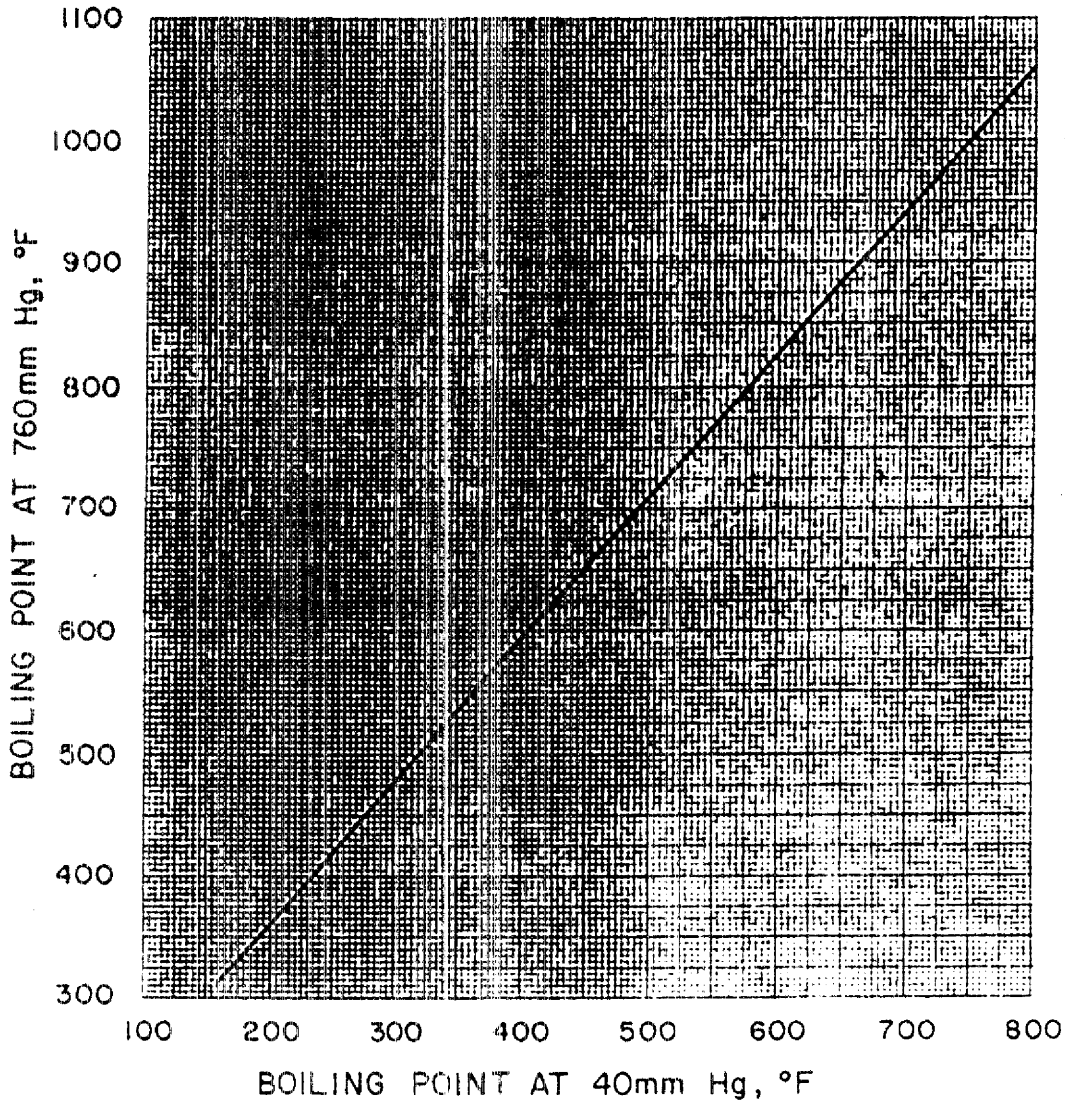

FIG. Boiling point at 760 mm Hg vs boiling point at 40 mm Hg.

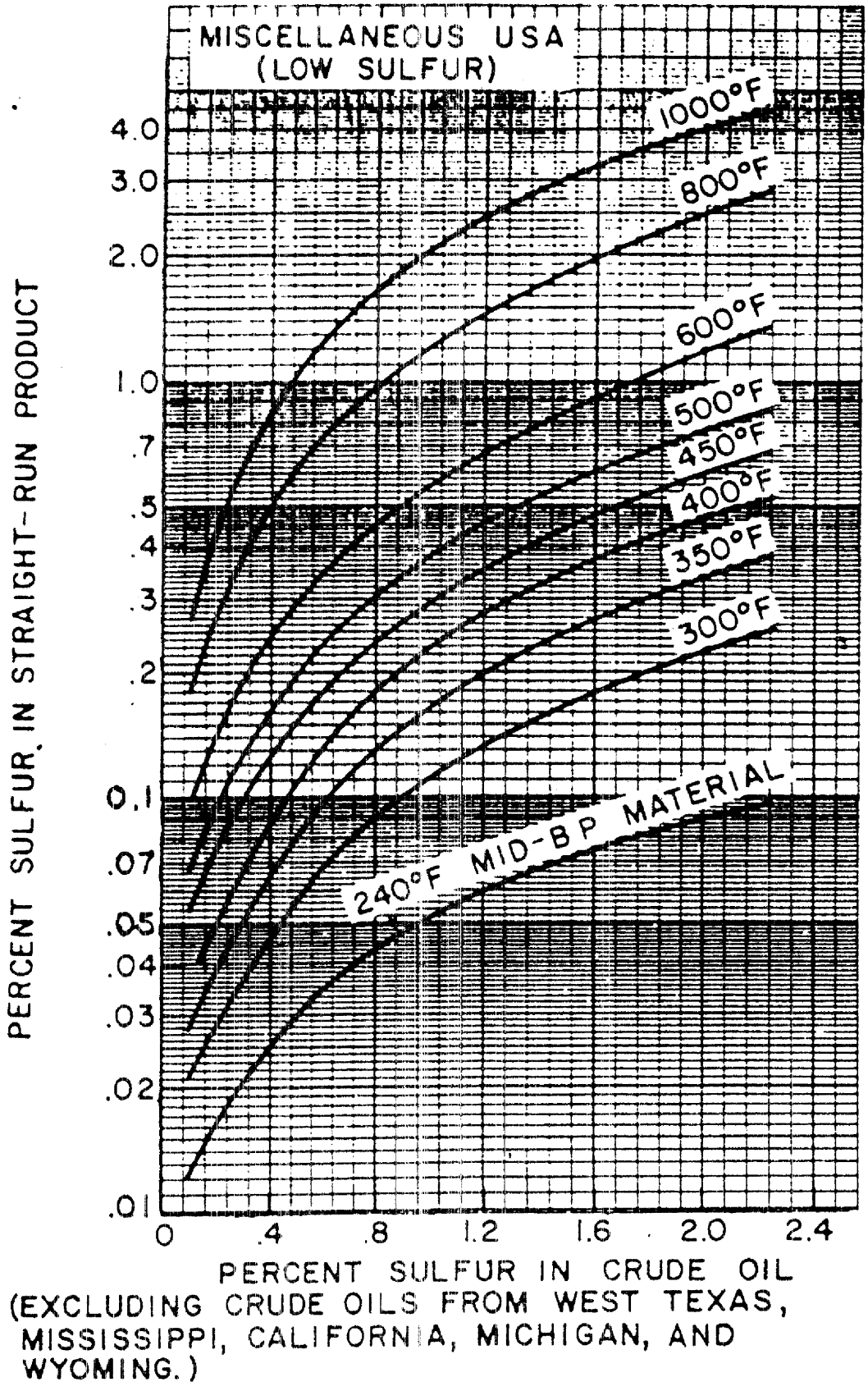

FIG. Sulfur content of products from miscellaneous U. S. crude oils

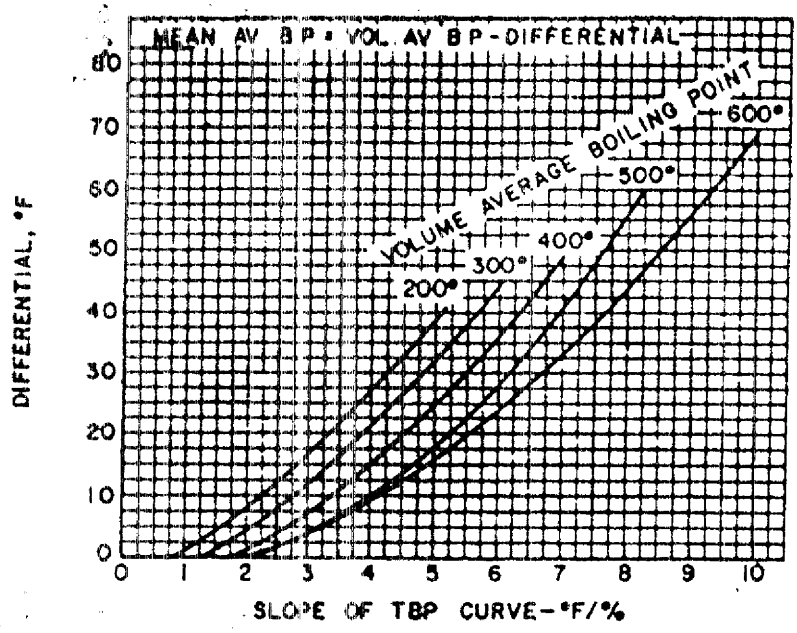

FIG. Mean average boiling point of petroleum fractions.

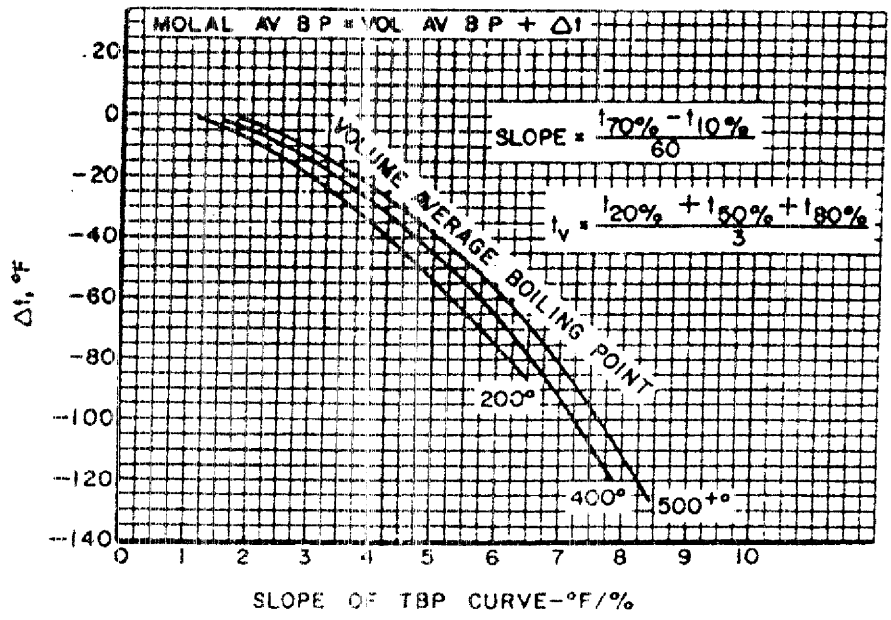

FIG. Molal average boiling point of petroleum fractions.

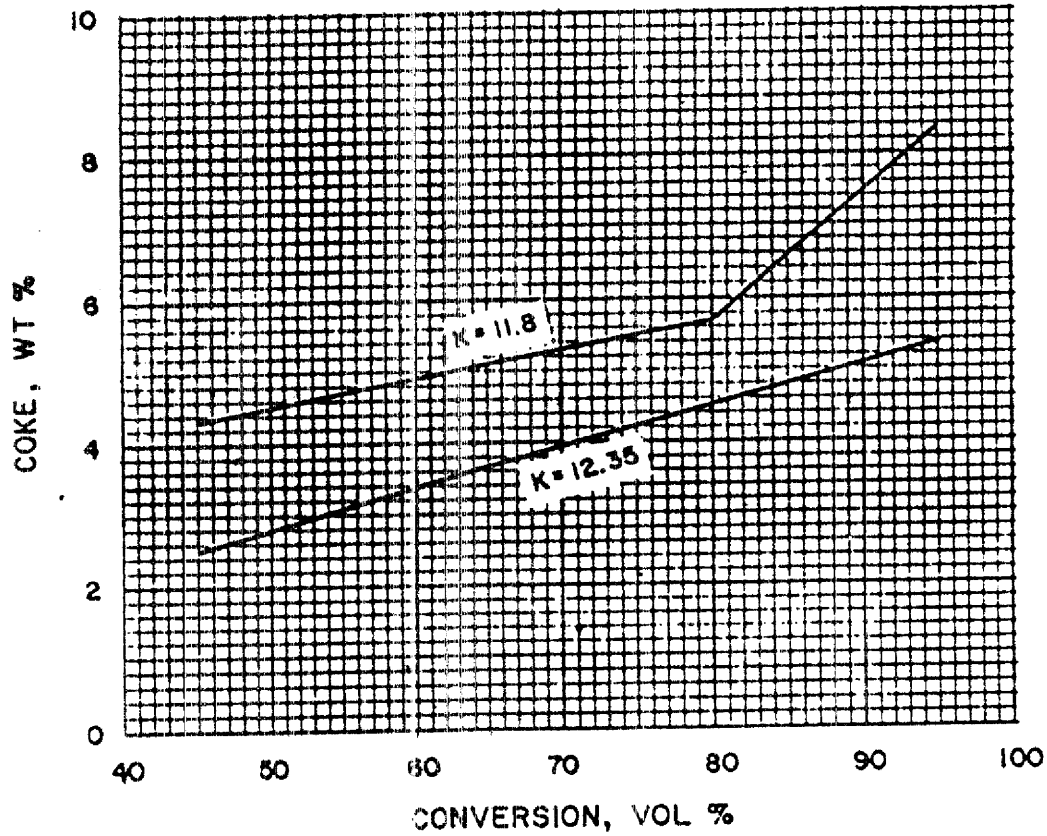

FIG. Catalytic cracking yields. Zeolite catalyst (coke).

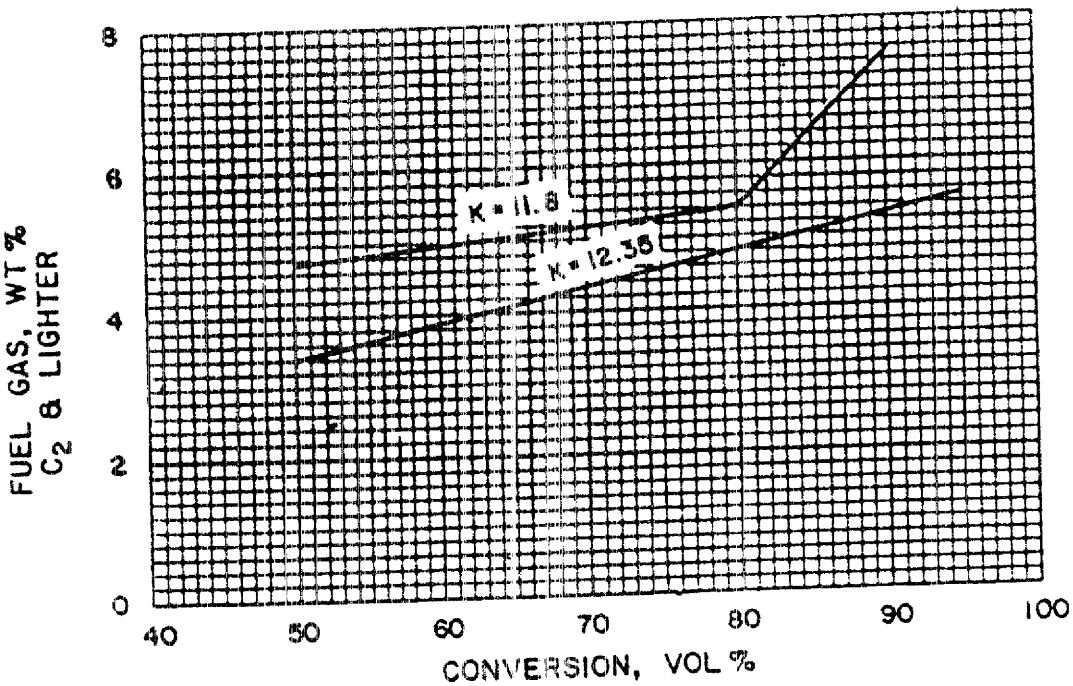

FIG. Catalytic cracking yields. Zeolite catalyst (fuel gas).

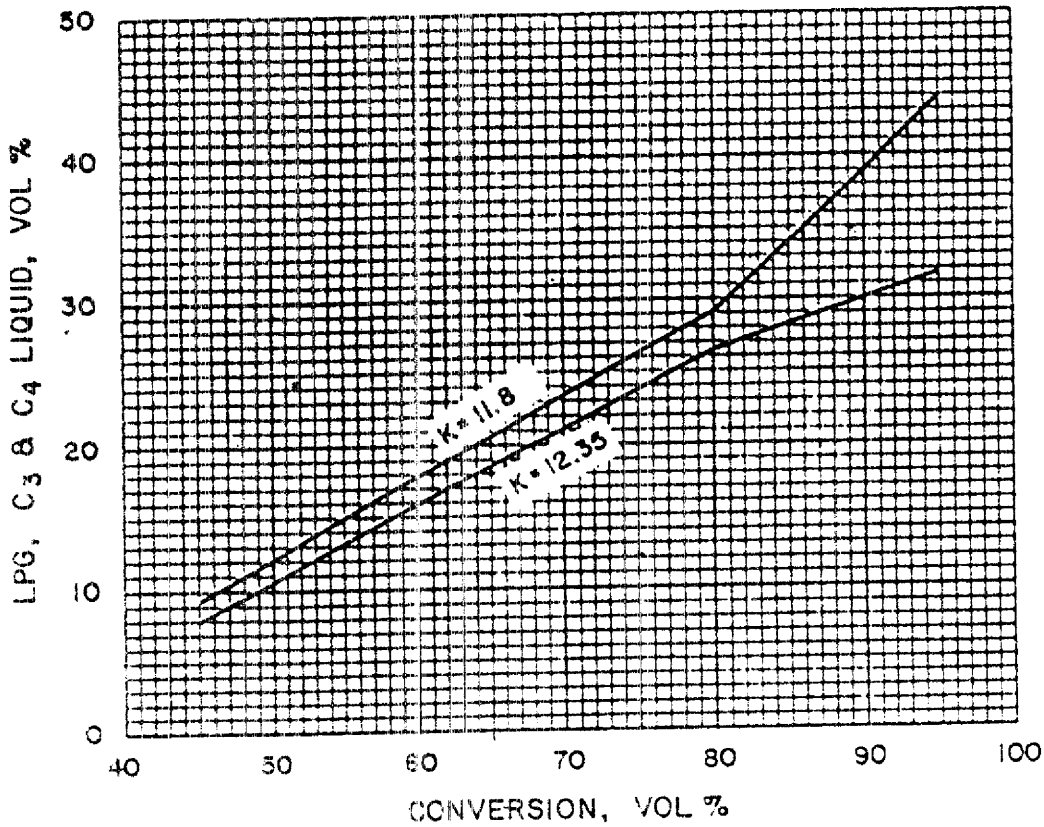

FIG. Catalytic cracking yields. Zeolite catalyst (C_3 and C_4).

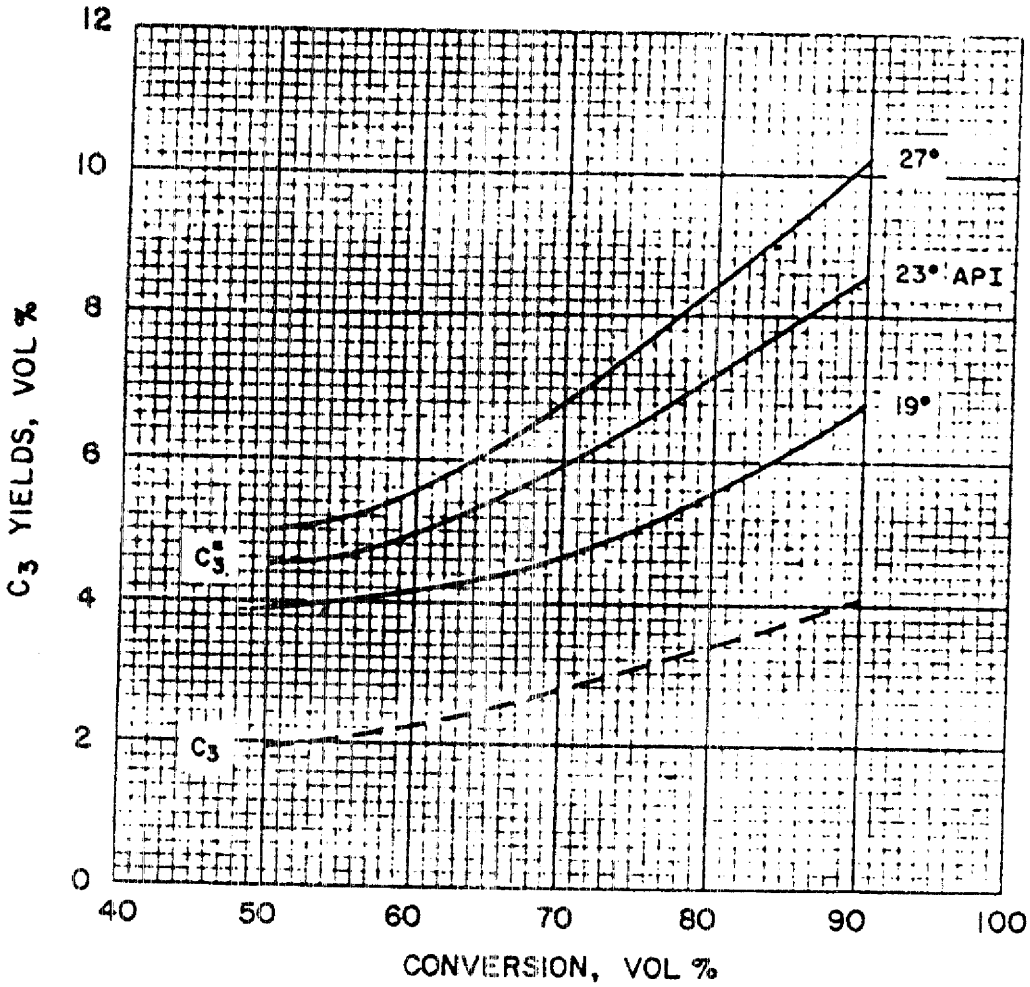

FIG. Catalytic cracking yields. Zeolite catalyst (C_3 ratios).

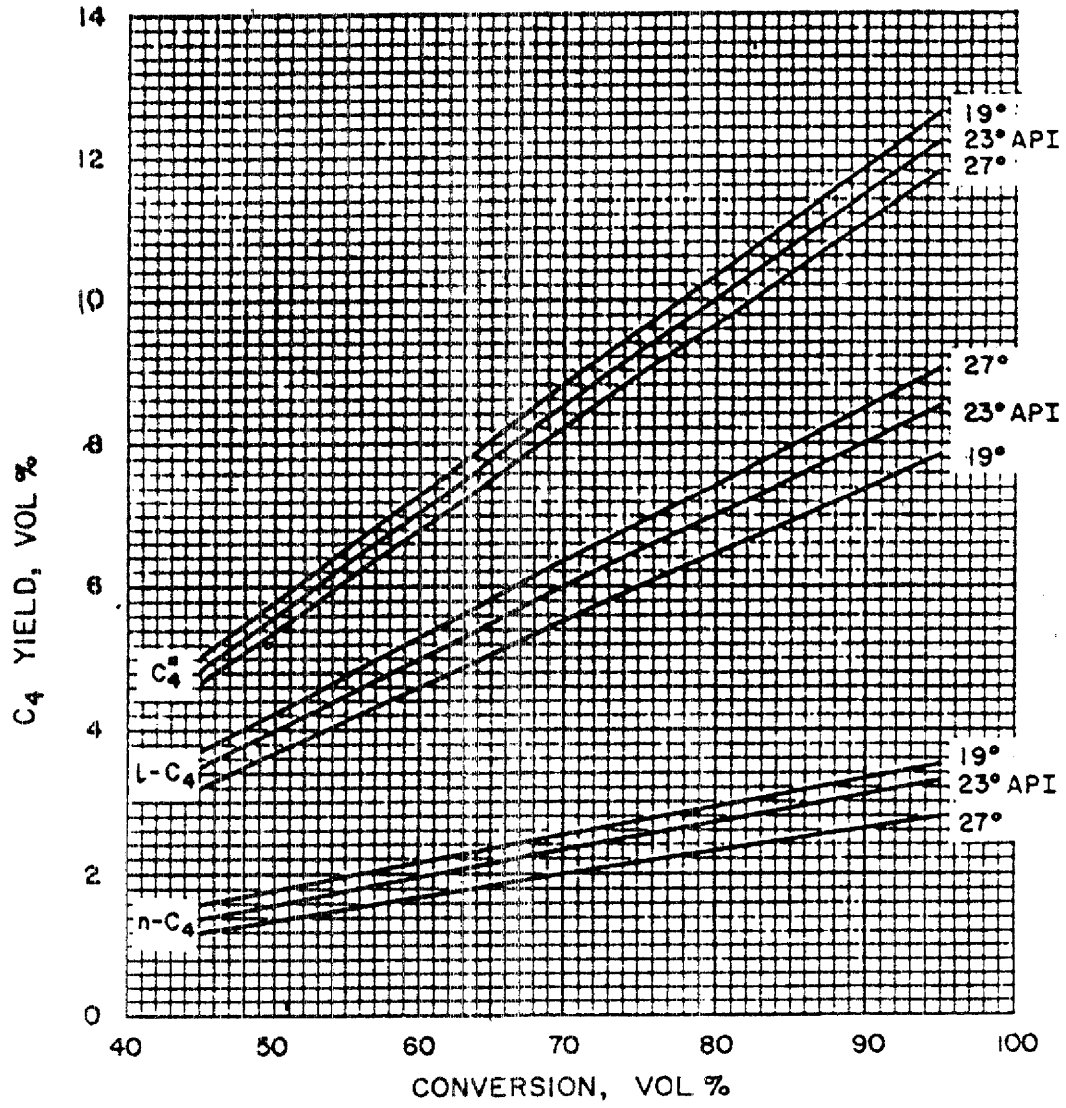

FIG. Catalytic cracking yields. Zeolite catalyst (C_4 ratios).

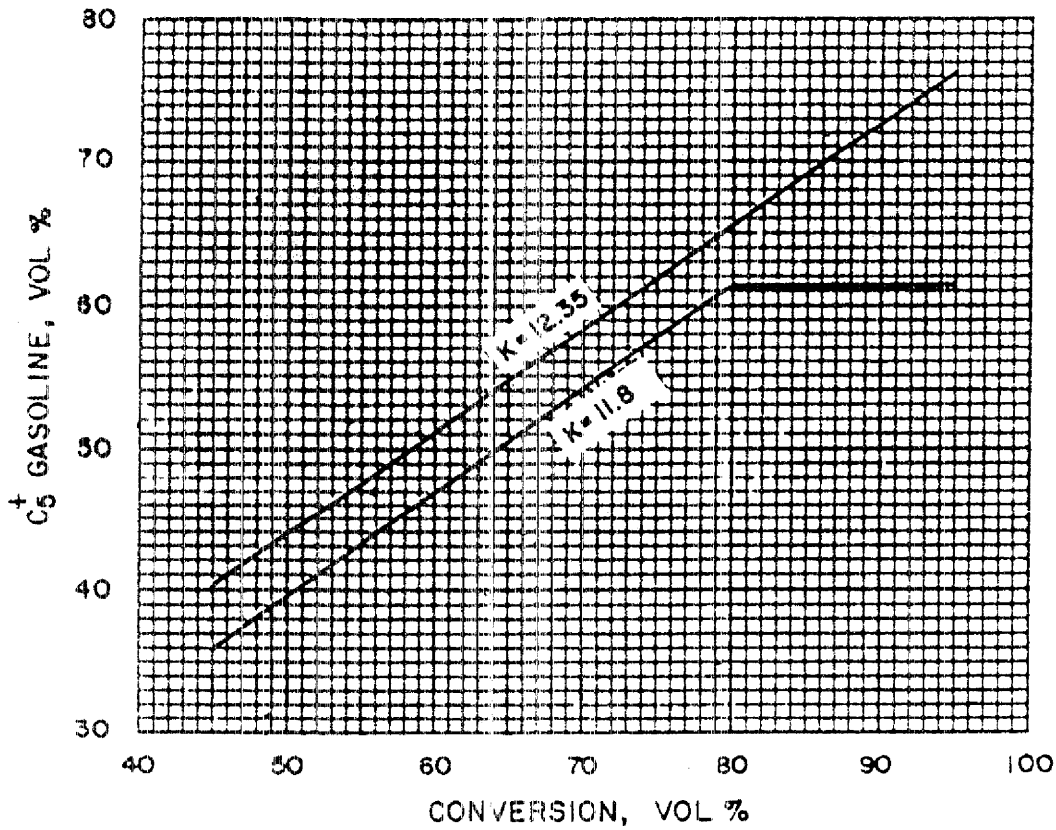

FIG. Catalytic cracking yields. Zeolite catalyst (C_5^+ gasoline).

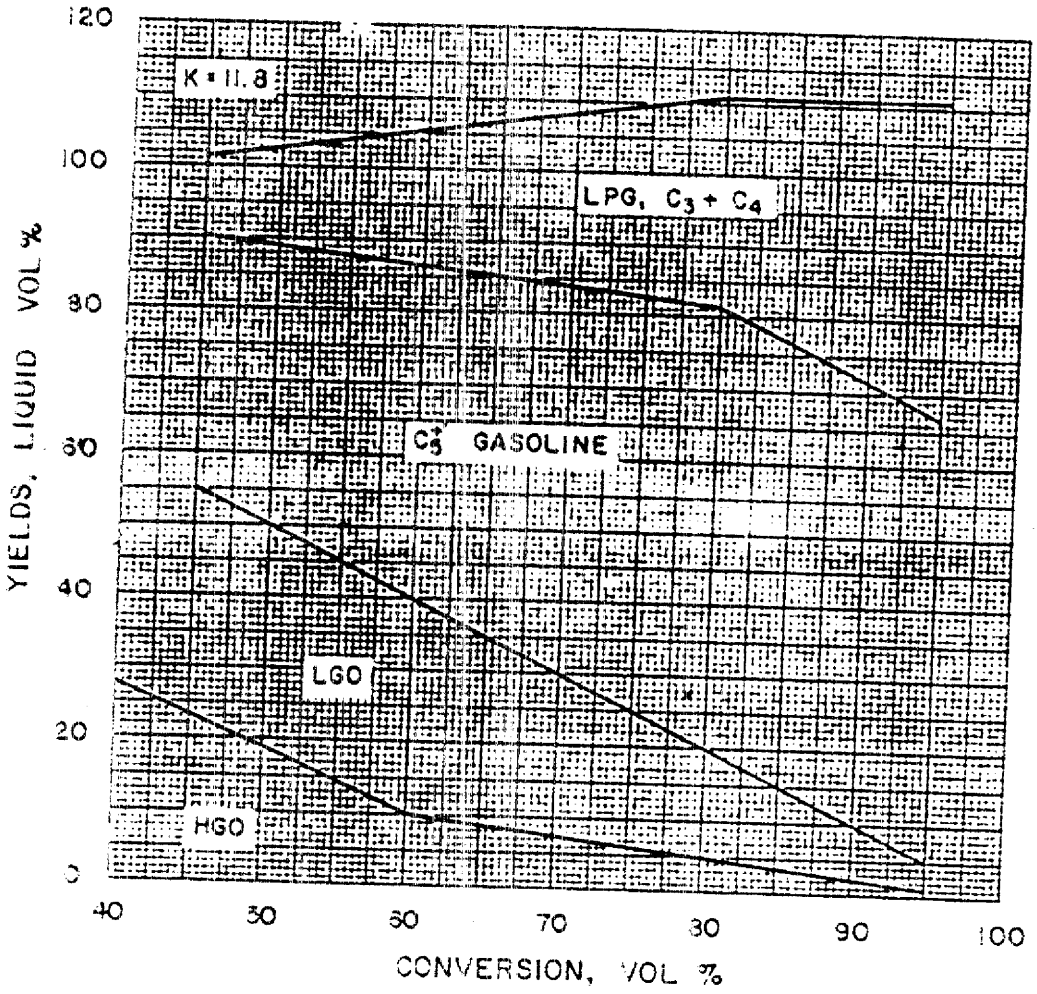

FIG. Catalytic cracking yields. Zeolite catalyst (heavy gas oil, feed K = 11.3).

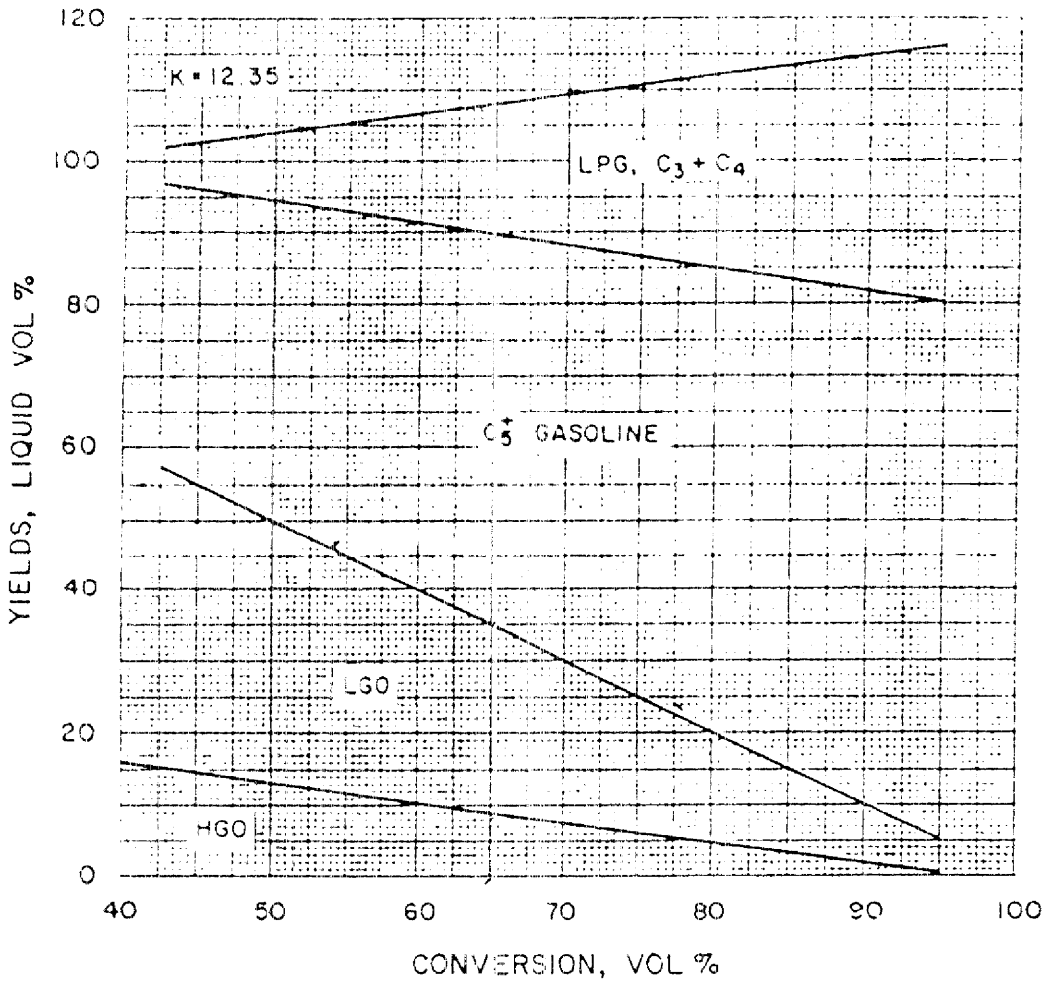

FIG. Catalytic cracking yields. Zeolite catalyst (heavy gas oil, feed K = 12.35).

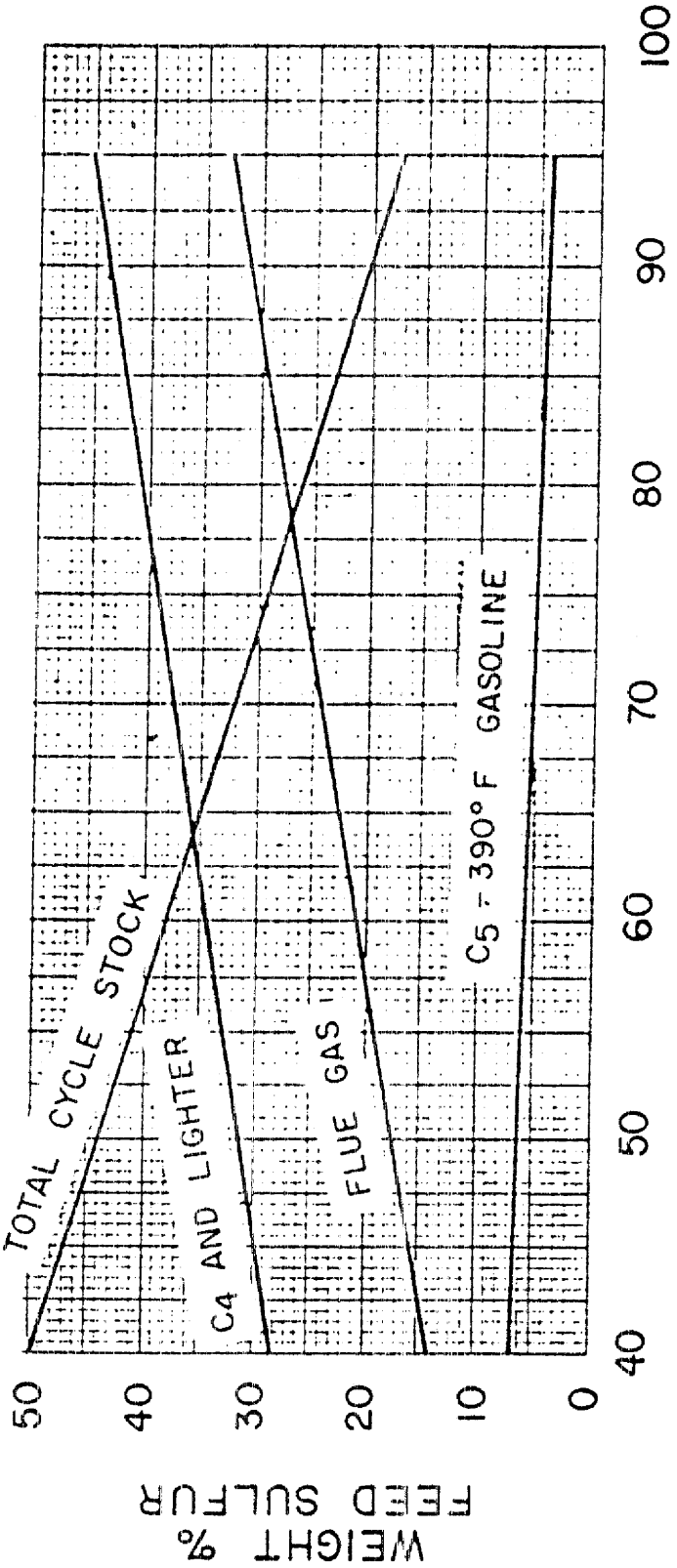

FIG. Distribution of sulfur in catalytic cracking products

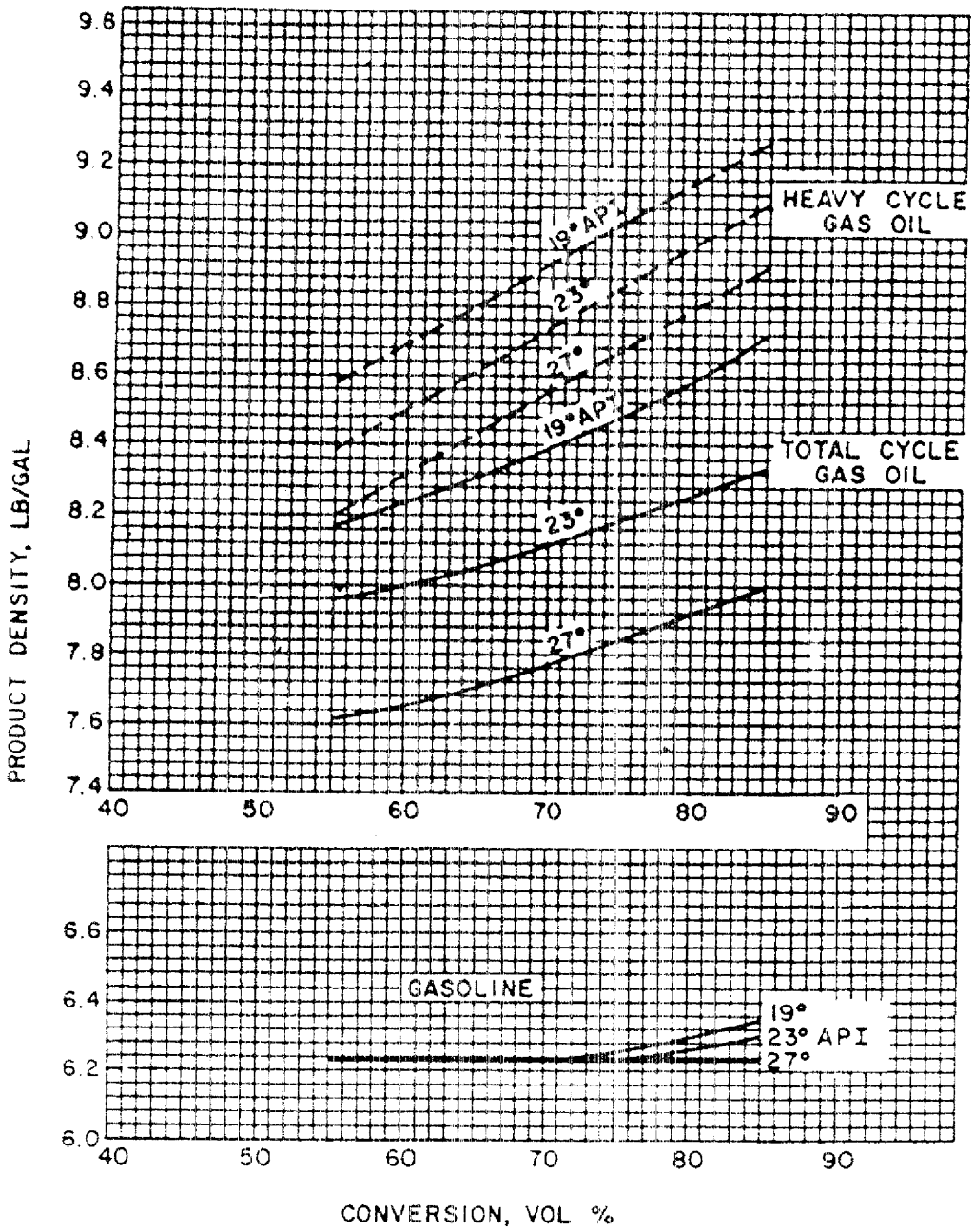

FIG. FCC product gravity. Zeolite catalyst.

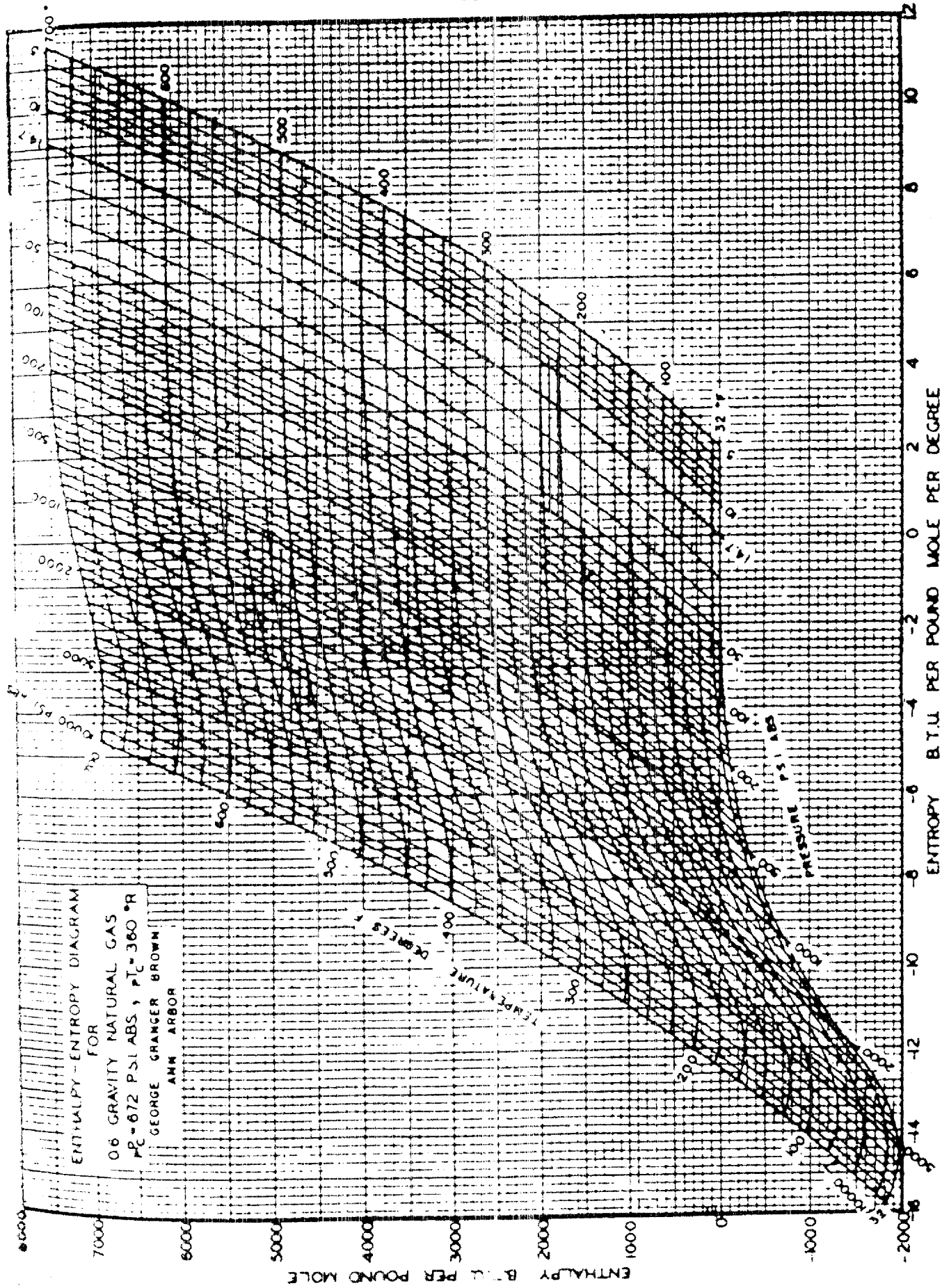

FIGURE
Enthalpy-entropy diagram for 0.6 gravity nat[illegible] gas