1954

PROBLEM

To the Contestant:

The Student Contest Problem for 1954 has been selected by the committee to emphasize the overall economics of a practical industrial situation. The problem is one of future planning which confronts many petroleum refiners today. The refiner must be able to produce finished regular- and premium-grade gasolines which will meet the estimated demand in both quantity and octane requirements over the next several years.

In this problem a refiner owns and operates a thermal reforming unit in which a heavy-petroleum naphtha is reformed to produce gasoline with a higher octane number. Recently catalytic reforming processes have been developed. A catalytic reforming unit if installed in place of the thermal reforming unit would permit the refiner to obtain higher yields and higher octane numbers for reformed gasoline.

The refinery manager must decide whether, for the octane levels expected over the next several years, continued operation of the existing thermal reforming unit is economically justified or whether installation of a catalytic reforming unit is to be preferred. To aid him in this decision, the manager has called on the Technical Division for an economic survey. The manager expects a summary report which will aid him in making the necessary decision.

Henceforth the student shall consider himself to be R. M. Tindall, process engineer in the Technical Division, Oilton Refinery, Pan Eastern Refining Company. Mr. Tindall's supervisor is A. L. Spano, Manager of the Technical Division. W. F. Lehman is a fellow process engineer in the Technical Division.

The following letters and reports present the detailed instructions and background information for the problem. Since the student may not be acquainted with many of the terms and processes employed by the petroleum industry, a glossary and list of references are presented.

GLOSSARY OF TERMS

Barrel (bbl.) = 42 U.S. gal. (not the 31.5 gal. barrel used in nonpetroleum industries)

Barrels per stream day = barrels of feed or product for each day a processing unit is operating full time

Butanes = a mixture of n-butane and i-butane. Unsaturates are not included.

Butenes = a mixture of 1-butene, 2-butene, and i-butene. The total C_4 cut is equal to the butanes plus the butenes, since the concentration of diolefins and alkines in conventional petroleum processing can be neglected.

C_1 = $CH4$

C_2 = C_2H_6 plus C_2H_4

C_3 = C_3H_8 plus C_3H_6

C_4 = C_4H_{10} plus C_4H_8

C_2 and lighter = ethane and all gases of lower molecular weight

C_3 and lighter = propane and all gases of lower molecular weight

C_4+ gasoline or reformate = gasoline or reformate containing no C_3 or lighter hydrocarbons

C_5+ gasoline or reformate = gasoline or reformate containing no C_4 or lighter hydrocarbons

Catalytic cracking = the conversion of gas oil to gasoline and secondary products over natural or synthetic catalysts at temperatures of about 850° to 960°F. and a pressure of about 10 lb./sq. in. gauge

Catalytic reforming = conversion of low-octane naphtha to high-octane reformate at temperatures of 850° to 1,050° F., hydrogen partial pressures of 80 to 800 lb./sq.in.abs., and total pressures of 150 to 900 lb./sq.in.abs.

F-1 octane number = octane number determined by the research method on a C.F.R. (coöperative fuel research) engine; also called research octane number.

F-1 clear = F-1 octane number for a gasoline or a component with 0.0 cc. tetraethyl lead/gal.

F-1 + 3cc TEL = F-1 octane number of a gasoline or component containing 3 cc. of tetraethyl lead/gal.; similarly F-1 + x cc. TEL designates x cc. tetraethyl lead/gal.

F.O.E. = fuel-oil equivalent of gaseous products on an approximate-heating-value basis; gas in pounds is divided by 300 to obtain the fuel-oil equivalent in barrels.

Heavy gas oil = a crude fraction boiling in the range of about 630°F. to as high as 1,050°F.

Heavy naphtha = a crude fraction boiling in the range of about 220° to 400°F.

Light gas oil = a crude fraction boiling in the range of about 500° to 630°F.

Light naphtha = a crude fraction boiling in the range of about 90° to 220°F.

O.N. = octane number

On-stream factor = time that a processing unit is in operation, % of calendar time

Pay-out time = time required for the differential net earnings of a new facility to pay for the investment

Reid vapor pressure (R.V.P.) = See reference 1.

Reformate = product from a reforming unit which boils in the gasoline range

S.S.F. = Saybolt furol viscosity, sec. (See reference 1.)

S.S.U. = Saybolt universal viscosity, sec. (See reference 1.)

Tar separator = tower for the separation of heavy gas oil from crude bottoms

TEL = tetraethyl lead

Thermal reforming = conversion of low-octane naphtha to moderate-octane naphtha by thermal treatment only, at temperatures of about 950° to 1,050°F. and pressures of about 250 to 1,200 lb./sq.in. gauge

Virgin = naturally occurring in the crude and not altered chemically by thermal or catalytic treatment

REFERENCES

General

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Catalytic Reforming Processes

2. Sittig, Marshall, Petroleum Refiner, 31, 287 (1952).

Octane Blending Chart

3. Hebl, L. E., T. B. Rendel, and F. L. Garton, Ind. Eng. Chem., 31, 862 (1939).
4. Ryan, J. G., Ind. Eng. Chem., 34, 825 (1942).

SUBJECT: Job No. 1645 - Economic Evaluation of Thermal and Catalytic Reforming, Oilton Refinery

DATE: February 11, 1954

FROM: A. L. Spano

TO: R. M. Tindall

As you perhaps realize, the octane-number requirements for both premium- and regular-grade gasolines are expected to continue to increase for the next several years: This fact makes it imperative that management plan ahead and provide the most economical equipment to meet future octane requirements. Specifically we need to ascertain whether our existing thermal reforming unit can economically meet octane needs for several years or whether it should be replaced by one of the more modern catalytic reforming processes. This problem can be resolved by an economic evaluation of thermal and catalytic reforming relative to the Oilton Refinery. You are hereby assigned to carry out this evaluation.

The bases to be used in this study are listed below:

Refinery charge rate=10,000 bbl./stream day

Crude source-Texarkana(same as Jan.,1954)

Production rate for cuts from crude tower, tar separator and catalytic cracking unit same as Jan.,1954(see Tables 1 and 2, which are attached)

Disposition of products same as January, 1954 (see Tables 1 to 3)

Reformer charge: 220° to 400°F. naphtha (Economic studies on reforming other boiling-range naphthas will be carried out at a later date.)

Gasoline specifications:

	Regular grade	Premium grade
F-1 octane number	90	96
Reid vapor pressure, lb./sq.in.abs.	10	10
Maximum TEL content, cc./gal.*	2	2

*The maximum lead content selected is relatively low in order to permit an increase in octane level at a later date by raising lead content.

Volumetric ratio of premium to regular gasoline

Maximum 1:2
Minimum 0

Reid vapor pressure of butanes employed in vapor blending - 60 lb./sq.in.abs.

Source of butanes—refinery butanes to be first used; additional butanes, if required, to be purchased outside at market price (Table 7)

On-stream factor for all refinery units - 90%

Pay-out time to justify additional investment - less than 3 yr. (federal taxes and depreciation not to be deducted from earnings; octane number to be considered constant at the aforementioned level over the pay-out period)

It may be assumed that all thermal reformer tar can be blended with the other components of the No. 6 fuel without affecting the salability of No. 6 fuel. The price structure for the present study should be taken to be the same as that reported in Table 7. I have instructed W. H. Lehman to transmit to you (a) information which you will find helpful in making octane-number and vapor-pressure blending calculations and (b) information concerning investment costs, operating costs, and product distributions from both thermal and catalytic reforming.

The results of the foregoing evaluation must answer the following questions:

1. Will the existing thermal reformer together with other existing refinery units permit the marketing of 96 F-1 O.N. premium and 90 F-1 O.N. regular gasoline in the volume ratio of 1:2?

2. If not, how much 96 F-1 O.N. premium gasoline can be made with existing equipment while 90 F-1 O.N. regular gasoline is marketed?

3. For the stated octane levels, will it be economically justified to continue to operate the thermal reformer or should it be replaced by a more modern catalytic reformer?

4. If a catalytic reformer is installed, what amount of the heavy-naphtha cut (220° to 400°F.) should be reformed? What octane level of catalytic reformate will lead to the maximum return on investment? What should be the tetraethyl lead content of premium and regular gasoline to maximize net refinery income?

The results of the study should be presented in a report to management. Management will use these results as a guide for planning future operations and construction work at the Oilton Refinery. Therefore, the report should contain specific recommendations concerning the most economic processing plan for the production of 90 F-1 O.N. regular and 96 F-1 O.N. premium gasoline. These recommendations must be supported by data in the form of simplified flow diagrams, material balances, and the results of the economic analysis.

A. L. Spano

Manager, Technical Department

TABLE 1

MATERIAL BALANCE FOR THE CRUDE TOWER PLUS TAR SEPARATOR
OILTON REFINERY - JANUARY, 1954,
TEXARKANA CRUDE

Cut	Vol. % on crude	Wt. % on crude	°A.P.I.	Sp. gr.	Lb./gal.	Avg. quantity/stream day Bbl.	Gal.	Lb.
Charge								
Crude	100.0	100.0	38.4	0.8328	6.935	10,000	420,000	2,910,000
Intermediate stream								
Butanes	1.8	1.2	-	0.571	4.76	180	7,560	34,900
C_5 - 220°F.	10.7	9.2	66.5	0.7146	5.949	1,070	44,940	267,500
220 - 400°F.	27.5	25.5	51.7	0.7724	6.430	2,750	115,500	742,200
Light gas oil	16.0	16.1	37.4	0.8378	6.976	1,600	67,200	468,400
Heavy gas oil	29.0	30.7	28.9	0.8822	7.346	2,900	121,800	893,500
Bottoms	15.0	17.3	15.6	0.9619	8.011	1,500	63,000	503,500

Disposition of crude fractions

C_3 and lighter - negligible amount present
Butane cut - to gasoline-vapor-pressure adjustment and sales
Light naphtha (C_5-220°F.) - to gasoline pool (sales)
Heavy virgin naphtha (220°-400°F.) - thermal reformer charge
Light gas oil - to sale as No. 2 fuel
Heavy gas oil - catalytic cracking charge
Bottoms - to sale as a component of No. 6 fuel

TABLE 2

MATERIAL BALANCE FOR THE CATALYTIC CRACKING UNIT
OILTON REFINERY - JANUARY, 1954,
TEXARKANA CRUDE

Cut	Vol. %	Wt. %	°A.P.I.	Sp.gr.	Lb./gal.	Avg. quantity/stream day Bbl.	Gal.	Lb.
Charge	100.0	100.0	28.9	0.8822	7.346	2,900	121,800	893,500
Products								
Coke	-	4.3	-	-	-	-	-	38,400
C_2 and lighter	-	3.6	-	-	-	-	-	32,200
Propane	-	1.7	-	-	-	-	-	15,200
Propene	-	3.8	-	-	-	-	-	34,000
Butanes	7.0	4.5	-	0.571	4.76	202	8,450	40,200
Butenes	6.4	4.4	-	0.60	5.00	187	7,850	39,300
C_5+ Gasoline	42.9	36.7	56.0	0.7547	6.283	1,250	52,300	328,000
Catalytic gas oil	40.0	41.0	25.0	0.9042	7.529	1,160	48,700	366,200

Disposition of products from catalytic cracking
Coke - burned in the kiln of the catalytic cracking unit
C_2 and lighter gas - used as fuel
Propane - used as fuel
Propene and butenes - sold to polymer products company
Butanes - to gasoline-vapor-pressure adjustment and sales
Gasoline - to gasoline pool (sales)
Catalytic gas oil - to sales as a component of both No. 2 and No. 6 fuel oils

TABLE 3

MATERIAL BALANCE FOR THE THERMAL REFORMING UNIT
OILTON REFINERY - JANUARY, 1954,
TEXARKANA CRUDE

Cut	Vol. %	Wt. %	°A.P.I.	Sp.gr.	Lb./gal.	Avg. quantity/stream day Bbl.	Gal.	Lb.
Charge	100.0	100.0	51.7	0.7724	6.430	2,750	115,500	742,200
Products								
Propane+C_2 & lighter	-	9.0	-	-	-	-	-	66,800
Propene	-	2.7	-	-	-	-	-	20,100
Butanes	3.3	2.5	-	0.571	4.76	90	3,900	18,600
Butenes	-	3.4	-	0.60	5.00	120	5,040	25,200
C_5+ Gasoline	78.5	78.1	52.6	0.7686	6.399	2,160	90,600	580,000
Tar	1.7	-	-	-	-	470	1,960	

Disposition of products from thermal reforming
C_2 and lighter gas - used as fuel
Propane - used as fuel
Propene and butenes - sold to polymer products company
Butanes - to gasoline vapor pressure adjustment and sales
Gasoline - to gasoline pool (sales)
Tar - component of No. 6 fuel oil

TABLE 4

PROPERTIES OF TYPICAL STRAIGHT-RUN FRACTIONS
OILTON REFINERY - JANUARY, 1954

Cut	C_5-220°F.	220°-400°F.	Lt. gas oil	Hvy. gas oil	Tar
°A.P.I.	66.5	51.7	37.4	28.9	15.6
Distillation	A.S.T.M.	A.S.T.M.	A.S.T.M.	Vacuum-corrected to atmospheric pressure	
Initial, °F.	102	223	413	550	555
10%	119	266	481	600	860
30%	148	283	507	691	918
50%	168	300	530	760	
70%	185	322	566	830	
90%	205	358	631	922	
End point or maximum temperature	234	396	712	950	919
Recovery, vol. %	99	99	99	95	35
Reid vapor pressure, lb./sq. in. abs.	5.2	0.5			
Molecular weight	78	125			
Gasoline octane numbers					
F-1 Clear	67.5	42.5			
F-1 + 3 cc. TEL	86.5	68.5			
Viscosity					
Saybolt seconds furol (S.S.F.)					
At 160°F.	-	-	-	-	247
At 210°F.	-	-	-	-	59
Saybolt seconds universal (S.S.U.)					
At 130°F.	-	-	-	63.6	
At 160°F.	-	-	-	49.6	
At 100°F.	-	-	37.7		

TABLE 5

PROPERTIES OF TYPICAL PRODUCTS
FROM CATALYTIC CRACKING
OILTON REFINERY - JANUARY, 1954

Cut	C_5+ Gasoline	Catalytic gas oil
°A.P.I.	56.0	25.0
Distillation	A.S.T.M.	A.S.T.M.
Initial, °F.	104	464
10%	134	526
30%	164	566
50%	223	614
70%	308	666
90%	388	740
End point or max. temp.	428	760+
Recovery	98.2	95
Reid vapor pressure, lb./sq. in. abs.	7.4	
Molecular weight	98	
Octane number		
F-1 clear	92.8	
F-1 + 3 cc. TEL	98.4	
Viscosity		
S.S.U. at 130°F.	-	40.1
S.S.U. at 100°F.	-	46.5

TABLE 6

PROPERTIES OF
TYPICAL THERMAL REFORMATE
OILTON REFINERY - JANUARY, 1954

Reformate plus butanes	
°A.P.I.	54.5
Reid vapor pressure, lb./sq.in.abs.	10.7
Molecular weight	109
C_5+ reformate octanes	
F-1 clear	72.5
F-1 + 3 cc. TEL	85.5

TABLE 7

AVERAGE DAILY REFINERY
PRODUCTION AND PRICES
OILTON REFINERY - JANUARY, 1954

Product	Production rate, units per stream day	Market price
Premium gasoline	1,180 bbl.	$6.72/bbl.
Regular gasoline	3,539 bbl.	6.09/bbl.

(Continued)

TABLE 7 (Continued)

Product	Production rate, units per stream day	Market price
No. 2 fuel*	2, 180 bbl.	$ 4. 37/bbl.
No. 6 fuel§	2, 550 bbl.	2. 10/bbl.
Butanes	233 bbl.	1. 70/bbl.
Butenes	64, 500 lb.	0. 015/lb.
Propene	54, 100 lb.	0. 012/lb.
Propane plus C_2 & lighter gas	381 bbl.(F.O.E.)	1. 50/bbl.
Charge		
Crude	10, 000 bbl.	3. 25/bbl.
Tetraethyl lead		0. 231 cent/cc.

*Virgin light gas oil plus initial-to-50% cut from the gas oil from catalytic cracking.

§ Virgin bottoms plus thermal reformer tar plus 50%-to-end-point cut from the gas oil from catalytic cracking.

SUBJECT: Octane Number and Vapor-pressure Blending. Process and Economic Data for Thermal and Catalytic Reforming.

DATE: February 11, 1954

FROM: W. H. Lehman

TO: R. M. Tindall

According to Mr. A. L. Spano's oral request, I am transmitting herewith the following two memoranda:

53-T-16 - Octane Number and Vapor Pressure Blending Calculations.

53-T-17 - Basic Process and Economic Data for Thermal and Catalytic Reforming.

W. H. Lehman

MEMORANDUM 53-T-16

Octane Number and Vapor-pressure Blending Calculations

This memorandum presents recommended methods for estimation of the octane number and Reid vapor pressure of blends of gasoline components.

The octane number of a blend may be taken as simply the volume average of the octane numbers of the components of the blend. When tetraethyl lead is added, it is convenient to use the blending chart presented in Figure 1 to obtain octane numbers over a range in lead content. If the octane number for two different lead concentrations is known for a given component or blend, octane numbers at any other lead content may be obtained from a straight line drawn on the chart through the two known values. The leaded octane of a blend may be estimated in either of two ways. One method consists in (1) obtaining the leaded octane number for each component of the blend

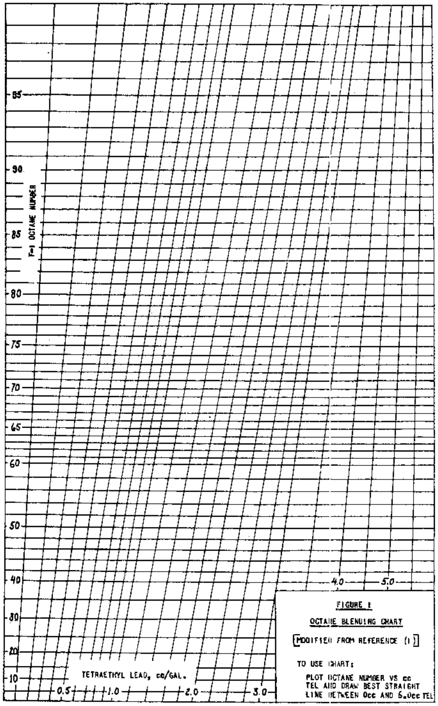


Fig. 1.

from the blending chart at the desired lead content of the final blend and (2) volumetrically averaging these leaded octane numbers. In the second method (1) the leaded octane number of the blend at two lead levels is estimated by volumetric averaging of the component octane numbers at the same lead levels and (2) the lead susceptibility chart is employed to obtain octane numbers for the blend at other lead levels. Both of these methods are acceptable.

Leaded blending octane numbers for butanes are above the octane scale of Figure 1. For the purposes of octane-blending calculations, butanes can be assumed to have F-1 leaded octane numbers as follows:

TEL cc. /gal.	F-1 Blending octane numbers for butanes
0	100. 0
0. 5	102. 4
1. 0	103. 5
1. 5	104. 1
2. 0	104. 5
2. 5	104. 8
3	105. 0

Estimation of Reid Vapor Pressures

Basically the Reid vapor pressure of a blend is estimated by the linear blending on a molar basis of the initial vapor pressures of the components of the blend in accordance with Raoult's law. Initial vapor pressure (I.V.P.), which is an approximation of the true vapor pressure (at 100°F.), is a function of Reid vapor pressure (R.V.P.). This relationship is given in Table 8 attached hereto. For pure compounds the true vapor pressure (pounds per square inch absolute) at 100°F. and the I.V.P. are identical. To estimate the Reid vapor pressure of a blend, the molar average I.V.P. is calculated and the corresponding R.V.P. read from Table 8. Sample calculations of both vapor-pressure blending and octane blending are appended.

Sample Calculations

Vapor Pressure Blending

Problem: Blend a 1.0-lb.R.V.P. naphtha to 10 lb./sq. in. abs. R.V.P. with 60 lb./sq. in. abs. R.V.P. mixed butanes.

Given: Molecular weight of naphtha = 120
Specific gravity of naphtha = 0.7699
Specific gravity of butanes = 0.571

Material	R. V. P., lb./sq. in. abs.	I.V.P. (from Table 8), lb./sq. in. abs.
Naphtha	1.0	1.30
Butanes	60.0	60.0
Blend	10.0	12.0

Solution: Basis: 100 moles naphtha
x = moles butanes required

$$\frac{(x)(60)}{100 + x} + \frac{(100)(1.3)}{100 + x} = 12.0$$

x = 22.3 moles butanes to add

Amount of naphtha: (100) (120) = 12,000 lb.

$$\frac{12,000}{(8.33)(0.7699)} = 1,868 \text{ gal.}$$

Amount of butanes: 22.2 × 58 = 1,288 lb.

$$\frac{1,288}{(8.33)(0.571)} = 270 \text{ gal.}$$

Volume of blend: 270 + 1,868 = 2,138 gal.

$$\% \text{ butanes in blend: } \frac{270}{2,138} = 12.6 \text{ vol. } \%$$

Octane Blending

Problem:

1. Determine the F-1 octane number for a blend of 87.4 vol.% C_5+ naphtha and 12.6 vol.% butanes (a) with no lead added and (b) with 2 cc. TEL added/gal. of blend.

2. Determine the F-1 +2 cc. TEL octane number of a 50:50 mixture by volume of the blend in pounds with a gasoline testing 98.0 F-1 + 2 cc. TEL.

Given:

	F-1 Octane numbers Clear	+3 cc. TEL
C_5+ naphtha in Problem 1	50	70

Solution:

		F-1 Octane No., O.N.	Volume fraction, f	f × O.N.
Clear:	C_5+ naphtha	50	0.874	43.7
	Butanes	100	0.126	12.6
	Octane No. of blend			56.3
3 cc. TEL:	C_5+ naphtha	70	0.874	62.1
	Butanes	105	0.126	13.2
	Octane No. of blend			75.3

Plotting these points on Figure 1 yields a value of 72.0 at a tetraethyl lead content of 2 cc./gal.

Blend 3 - a 50:50 volume mixture of blends 1 and 2

	F-1 + 2 cc. TEL octane No.	f	O.N. × f
Blend 1	72.0	0.50	36.0
Blend 2	98.0	0.50	49.0
Octane No. of blend 3			85.0

TABLE 8

R.V.P. vs. I.V.P.

R.V.P., lb./sq. in. abs.	0.0	0.2	0.4	0.6	0.8
			I.V.P., lb./sq. in. abs.		
0	0.00	0.26	0.52	0.78	1.04
1	1.30	1.55	1.81	2.07	2.32
2	2.6	2.8	3.1	3.3	3.6
3	3.8	4.1	4.3	4.6	4.8
4	5.1	5.3	5.5	5.8	6.0
5	6.3	6.5	6.7	7.0	7.2
6	7.4	7.7	7.9	8.1	8.4
7	8.6	8.8	9.1	9.3	9.5
8	9.7	10.0	10.2	10.4	10.6
9	10.9	11.1	11.3	11.5	11.7
10	12.0	12.2	12.4	12.6	12.8
11	13.0	13.3	13.5	13.7	13.9
12	14.1	14.3	14.5	14.7	14.9
13	15.1	15.3	15.5	15.7	16.0
14	16.2	16.4	16.6	16.8	17.0
15	17.2	17.4	17.6	17.8	18.0
16	18.1	18.3	18.5	18.7	18.9
17	19.1	19.3	19.5	19.7	19.9
18	20.0	20.3	20.5	20.7	20.9
19	21.1	21.2	21.4	21.6	21.8
20	22.0	22.2	22.4	22.6	22.7
21	22.9	23.1	23.3	23.5	23.7
22	23.9	24.0	24.2	24.4	24.6
23	24.8	25.0	25.1	25.3	25.5
24	25.7	25.9	26.0	26.2	26.4
25	26.6	26.8	26.9	27.1	27.3
26	27.5	27.7	27.8	28.0	28.2
27	28.4	28.6	28.7	28.9	29.1
28	29.3	29.4	29.6	29.8	30.0
29	30.1	30.3	30.5	30.7	30.8
30	31.0	31.2	31.4	31.5	31.7
31	31.9	32.1	32.2	32.4	32.6
32	32.7	32.9	33.1	33.3	33.4
33	33.6	33.8	33.9	34.1	34.3
34	34.4	34.6	34.8	35.0	35.1
35	35.3	35.5	35.6	35.8	36.0
36	36.2	36.3	36.5	36.7	36.8
37*	37.0				

* For R.V.P.'s above 37, R.V.P. is equal to I.V.P.

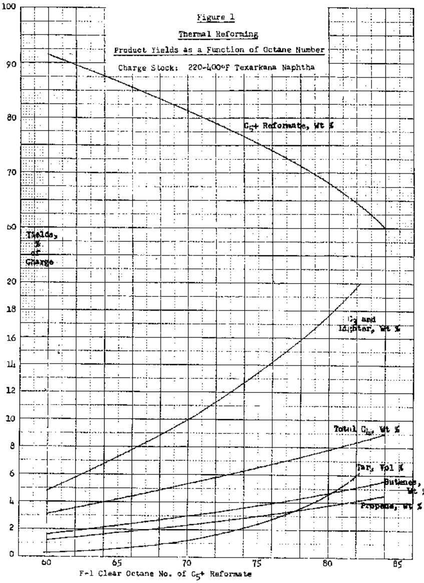
Basic Process and Economic Data for Thermal and Catalytic Reforming

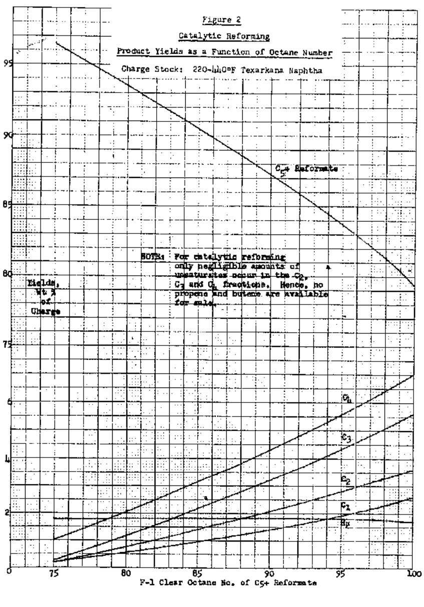
Because of increasing gasoline octane level, modifications to the present Oilton Refinery processing procedure will have to be made to meet future market demands. Methods of meeting these demands include (1) operation of the existing thermal reformer to give reformate of higher octane number or (2) replacement of the thermal reformer with a catalytic reforming unit. Economic evaluations are required to ascertain which of these methods is the more attractive. To provide basic information for these economic evaluations, process and economic data for both thermal and catalytic reforming have been obtained. These data are presented in this memorandum. Catalytic reforming data were obtained from process licensors. Thermal reforming data were obtained from the Oilton thermal reformer.

Investment data for thermal reforming are not required since the reforming unit is already in existence at the Oilton Refinery and has been operated beyond the initial pay-out period. This unit will have a scrap value of $90,000 in the event that it is replaced by a catalytic reforming unit. The existing unit without modification permits the production of reformate octane numbers up to 82 F-1 clear simply by raising the temperature and pressure of operation.

Investment costs for catalytic reforming can be divided into two parts. The major portion of the investment cost, which includes most items except the reactors and catalyst, can be considered independent of octane level. These costs are presented in Figure 5 as a function of naphtha feed rate. The second portion of investment cost, which is predominantly for reactors and catalyst, depends on both octane level and naphtha feed rate. These cost data are given in Figure 6A.

Operating costs for thermal and catalytic reforming are as follows. For the thermal reformer maintenance, insurance, and local taxes are estimated to be $35,000/calendar year. These costs are normally estimated as fixed percentages of the value of the unit and hence for an existing unit are constant and independent of octane number. For labor, fuel, and other expenses $0.25/bbl. of heavy naphtha should be charged in case of thermal reforming at all octane levels. Increases in cost for fuel with increase in octane level can be neglected. For catalytic reforming maintenance, insurance, and local taxes should be taken as 6% of total reformer investment/yr. Other operating costs, which are dependent on octane level, are presented in Figure 6B. Catalyst cost, the major factor in these costs, increases markedly with octane level.





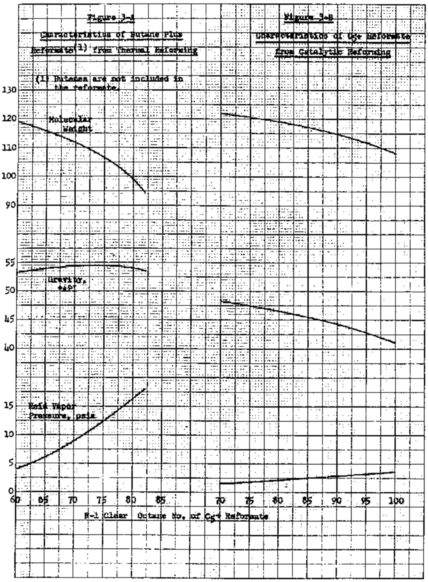


Figure 3-A
Characteristics of Butane Plus Reformate(1) from Thermal Reforming
(1) Butanes are not included in the reformate.
Figure 3-B
Characteristics of C5+ Reformate from Catalytic Reforming
Molecular Weight
Gravity, °API
Reid Vapor Pressure, psia
F-1 Clear Octane No. of C5+ Reformate

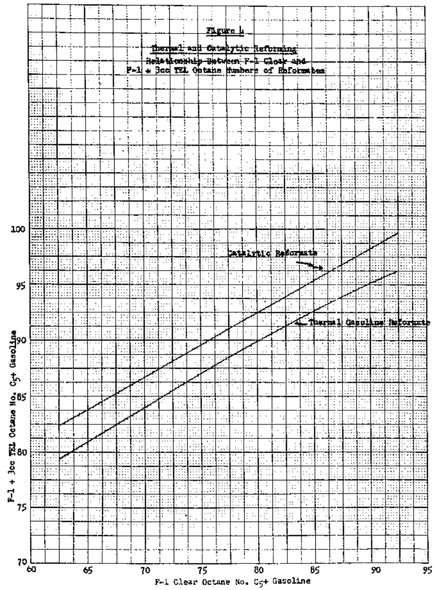
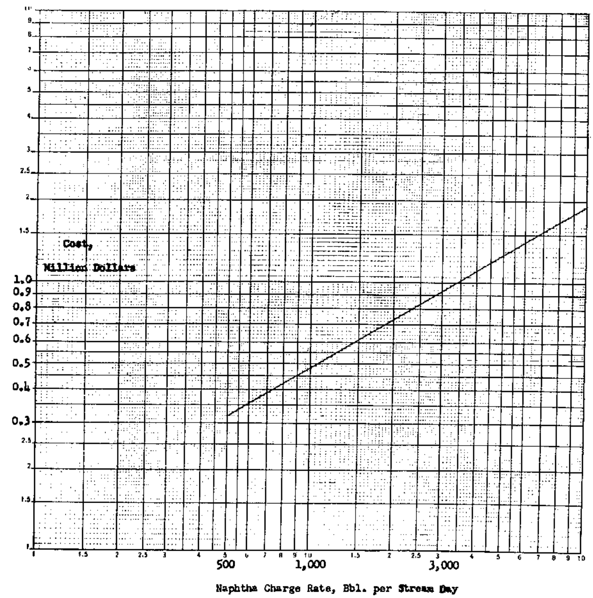
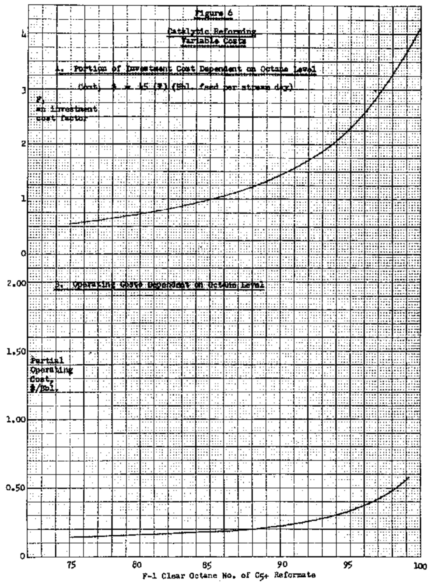


Figure 4
Thermal and Catalytic Reforming
Relationship Between F-1 Clear and F-1 + 3cc TEL Octane Numbers of Reformates
Catalytic Reformate
Thermal Gasoline Reformate
F-1 + 3cc TEL Octane No. C5+ Gasoline
F-1 Clear Octane No. C5+ Gasoline

Fig. 5.


Cost, Million Dollars
500
1,000
3,000
Naphtha Charge Rate, Bbl. per Stream Day



SOLUTION

SUBJECT: Job 1645 — Economic Evaluation of Thermal and Catalytic Reforming, Oilton Refinery

April 5, 1954

To: A. L. Spano
From: R. M. Tindall

I am submitting the following report in answer to your request for an economic evaluation of thermal and catalytic reforming relative to the Oilton Refinery.

As you know, the present Oilton Refinery processing procedure will have to be modified to meet future market demands. The purpose of this study was to determine the most economic processing plan for the production of 90 F-1 O.N. regular and 96 F-1 O.N. premium gasoline.

Basing my conclusions on the data furnished by the Technical Department, I strongly recommend that the thermal reformer be replaced by a more modern catalytic reformer.

I hope that you will find this report satisfactory. However, if you have any questions, please do not hesitate to get in touch with me.

SUMMARY

The pertinent results of this evaluation of thermal and catalytic reforming relative to the Oilton Refinery are as follows:

1. The existing thermal reformer together with other existing refinery units will not permit the marketing of 96 F-1 O.N. premium and 90 F-1 O.N. regular gasoline in the ratio of 1:2.

2. The maximum amount of 96 F-1 O.N. premium gasoline that can be made with existing equipment is 454 bbl. while 90 F-1 O.N. regular gasoline (3,660 bbl.) is being marketed.

3. For the stated octane levels it will not be economically justifiable to continue to operate the thermal reformer. It should be replaced by a catalytic reformer.

4. If a catalytic reformer is installed, the entire heavy naphtha cut (220°-400° F.) should be reformed. A catalytic reformate octane level of 79 F-1 clear will lead to the maximum return on investment, and the TEL content of premium and regular gasoline should be 2 cc./gal. for highest net refinery income.