

ENGINEERING DESIGN SEMINAR

SEPTEMBER 6, 1994 – NOVEMBER 11, 1994

CRUDE OIL BREAKUP

CRUDE OIL BREAKUP PROCEDURE

INTRODUCTION

This section of the course presents the UOP method for breaking up crude oils. Using the procedure provides crude oil fraction yields, crude oil fraction properties, and fractionation requirements consistent with modern Crude and Vacuum Distillation Unit design and commercial experience. The procedure provides a standard (non-computerized) method of evaluating crudes. This presentation contains the following sections.

Section 1	Introduction
Section 2	History
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Appendix 2	Light Arabian Crude Assay

HISTORY

The need for a standard procedure was precipitated by:

- a. Demands for higher Crude and Vacuum Distillation Unit performance.
- b. The need for clear communication between the refiner and UOP and also interdepartmentally within UOP.
- c. The absence of a consistent method to provide a sound design basis for commercial units.

3.0 CRUDE ASSAY

3.1 Definition

A crude assay is a compilation of laboratory data on various crude oil fractions. The information is normally published for two basic categories:

distillate cuts
residual cuts

Data is presented in tabular and/or graphic form. Refer to Appendix 2 for an example of a crude assay presenting data in tabular form.

3.2 Source/Type

Crude assays are available from crude oil suppliers. They are also prepared in UOP's analytical laboratories from samples furnished by refiners. Assays provided by major suppliers tend to be more comprehensive than those published by UOP.

3.3 User's Responsibilities

Regardless of the assay's origin, the user must fully understand the information, take care in reading the data and recheck the information being used. Supplemental data from other assays and/or operating units should also be referenced as required.

4.0 OBJECTIVES

Primary uses of a crude oil breakup are to predict commercial product yields and properties. Yields are obtained from the true boiling (TBP) distillation curve. Properties are obtained from the theoretical cuts produced in the laboratory.

4.1 Yields

- a. Theoretical yields are represented by the fractions prepared in the laboratory. A high degree of separation is achieved by the laboratory TBP distillation apparatus.
- b. Commercial yields do not match those obtained in the laboratory. A lesser degree of separation is attained because commercial units use a single flash for the initial separation. This flash will not quantitatively separate all the distillates from the residual liquid. Commercial yields are also a function of internal reflux and the number of trays.

4.2 Properties Required For Design

- a. Crude and Vacuum Distillation Units

Properties typically used to characterize hydrocarbon fractions:

°API/Specific Gravity
Boiling Point/Distillation
UOP Characterization Factor (UOP K)
Molecular Weight

Metallurgy selection is based on :

Total sulfur
Hydrogen sulfide
Salt content
Acid Number (Neutralization No.)

Line sizing and heat tracing are a function of:

Viscosity
Pour point

- b. In addition to the above, the following are representative properties needed for design of downstream units and product blending systems.

Mercaptan Sulfur
Paraffin, Olefin, Napthene and Aromatic content (PONA)
Octane Number
Cetane Number
Smoke Point
Cloud Point
Freeze Point
Aniline Point
Total Nitrogen
Metals content
Carbon residue
C7-insolubles

5.0 POINTS REQUIRING EMPHASIS

5.1 General

The procedure is not intended to provide a rigid set of rules. It is offered as a practical guideline and relies heavily on UOP's experience. The use of common sense in dealing with specific crude assays will be evident. There will be occasions where conflicting or missing data will be encountered. Supplemental data must then be used to provide the missing information or verify questionable data. The user must decide which data is most reliable.

5.2 Flash Zone Conditions

In addition to using data obtained directly from the crude assay, particular attention must be given in selecting the flash zone temperature and pressure. Predicted yields must be compatible with realistic flash zone operating conditions.

5.3 ASTM Distillation

Estimating the ASTM distillation of individual fractions also requires special effort. Distillation specifications are frequently imposed on distillate fractions. The method of estimating ASTM distillations given in the procedure should be used **only** when better information is lacking.

5.4 Degree of Fractionation

The degree of fractionation in an atmospheric crude column is defined in terms of gap. Typically, the gaps listed below are specified or required in the design basis. A negative gap is referred to as **overlap**. **Gap** is defined as the difference between the 5 volume percent distilled point of the heavier cut and the 95 volume percent distilled point of the adjacent lighter cut.

<u>Adjacent Distillate Cuts</u>	<u>Typical Gap, °F</u>
Overhead → Kerosine	20 – 30
Kerosine → Diesel	10 – 15
Diesel → Atm. Gas Oil	0 – 10

5.5 Typical Design Criteria

The procedure is based on a new, properly designed, single column Crude Distillation Unit having a stripper on each product side-draw, overflash and steam stripping of the column bottoms. **Typical design** values for the crude column are:

6-10 **fractionating** trays between adjacent side-draws.

3-5 volume percent overflash. **Overflash** is defined as the percent feed vaporization exceeding that required to vaporize all products yielded above the flash zone. The concept of overflash should be visualized as internal reflux in the area just above the flash zone.

Equivalent of 1/1 volumetric reflux ratio (external reflux/net overhead product) when the overhead material has a 350-400°F ASTM end point (EP).

8-10 lb/hr stripping steam per bbl/hr stripped liquid.

Deviation from these typical **design values** may alter expected yields or product qualities. However, deviations may be justified due to specific refiner requirements.

6.0 PROCEDURE

The following procedure is used for breaking up crude oils into desired fractions (cuts). The resultant yields and properties are based on a crude assay selected when the design basis is established. The method is illustrated in a sample problem (Appendix 1).

- 6.1 Check the bottoms sediment and water (BS&W) content of the crude. If it exceeds 0.5 volume percent, remove the water and adjust the °API gravity of the crude to a dry basis. If the BS&W content is 0.5 volume percent or less, make no correction.
- 6.2 Plot the TBP distillation curve of the crude. Depending on the basis for the crude breakup, this can be done on either a volume or weight basis. Refer to Figure 1 (Appendix 1).
- 6.3 Plot the °API gravity versus (vs) **mid-volume** percent (or **mid-weight** percent) for the reported **distillate** fractions. See Figure 2 (Appendix 1). **Mid-volume** (weight) percent is defined as half the volume (weight) percent of a specific distillate cut plus the total volume (weight) percent of all distillate cuts preceding it.

Plot the °API gravity vs volume (weight) percent on crude for the reported **residual** fractions. See Figure 3 (Appendix 1)

Also plot the weight percent sulfur for reported distillate and residual fractions in a similar manner. Refer to Figure 4 (Appendix 1).

Plotting properties and contaminants is important. Interpolation or extrapolation of tabular data can mask the true property distribution which should **not** be assumed to be linear nor a smooth curve. Plotting provides a clearer picture of property distributions and alerts the designer to any potential impact on product properties or contaminants if the refiner deviates from the design product slate.

6.4 Targeted crude yields are usually defined on one of the two following bases:

- a. As TBP cut points on crude. The expected or **commercial** volume(weight) percent yield of each cut is read directly from the TBP distillation curve. If the crude assay contains tabular yields, the desired or specified yields may be obtained from the tabular data, interpolating as needed. **Unless the refiner states otherwise, UOP policy is to interpret design basis documents as reflecting commercial yields;** i.e., the cut quantities the refiner expects to produce from the unit. Yields shown in design basis documents may be specified as nominal TBP cut points or liquid volume percent or weight percent on crude. The properties of the crude fractions must then be calculated to be consistent with yield structure.
- b. By ASTM distillation range or other **product quality** specifications. The yields must then be calculated to be consistent with required product specifications.

6.5 Prepare a work table with the following column headings. This table will contain one row for each desired cut. Refer to Table 1 (Appendix 1). Normally the table is completed from left to right when the basis is "TBP cut points on crude" (Section 6.4a). If the basis is a "Product quality specification" (Section 6.4b), begin by entering data which forms the basis of design. Once primary data has been entered, the remaining data can be determined.

Column No.	Column Heading
1	TBP Cut Point, °F
2	Cumulative Volume (Weight) Percent
3	Nominal TBP Range, °F
4	Cut Volume (Weight) Percent
5	Correction Factor
6	Volume (Weight) Percent for Properties
7	Cumulative Volume (Weight) Percent
8	Mid-Volume (Weight) Percent Distilled
9	°API Gravity
10	Corrected TBP Cut Point, °F
11	Corrected TBP Range, °F
12	Estimated ASTM Initial Boiling Point, °F
13	Estimated ASTM End Point, °F
14	Estimated ASTM 50 Percent Point, °F
15	UOP Characterization Factor
16	Molecular Weight
17	Weight Percent Sulfur

Table size has been limited here in order to illustrate simply the breakup procedure. Additional properties such as those listed in Section 4.2 can be derived and easily added.

Complete **columns 1-4** for each product cut.

- 6.6** Because of differences between commercial and laboratory distillation data, commercial yields and properties do not correspond directly to those obtained from the TBP distillation curve. This occurs primarily because a simple flash will not quantitatively separate all the distillates from the residual liquid as discussed in Section 4.1b. Distillate material which remains in the residual liquid leaving the crude column flash zone is called **slump**.

The following table relates theoretical (laboratory) and commercial (actual) yields:

	<u>Yield Correction,</u> Fraction of Theoretical
C5-light ends	1.00
C6 to 400° F ASTM EP	0.99
To 550° F ASTM EP	0.97
To 700° F ASTM EP	0.94
Light Vacuum Gas Oil (LVGO)	By difference
Heavy Vacuum Gas Oil (HVGO)	1.00
Slop Wax	1.00
Vacuum column bottoms	1.00

The yield correction factors are based upon UOP's experience. They are not precise. One may interpolate between the given values. The factors should be applied in a conservative manner; e.g., if the crude column can not remove all the distillates from the residual liquid, the vacuum column must be able to process the extra material.

Note - for this crude breakup procedure the ASTM EP is greater than the TBP cut point. This is discussed in Section 6.12.

If there is no Vacuum Distillation Unit, crude column bottoms (reduced crude) is the heaviest product. This reduced crude yield is then calculated by difference. Distillate material (slump) remaining in the reduced crude will be recovered along with the LVGO if a vacuum column follows the crude column.

Enter appropriate yield correction factors in **column 5**.

If the crude breakup is based on a desired yield defined by TBP curve cut points, correct this commercial yield to a theoretical yield for properties determination. **Divide** the actual cut volume (weight) percent (column 4) by the correction factor (column 5) and enter the resulting percent in **column 6**. This

entry represents the theoretical (laboratory) yield necessary for producing the targeted commercial cut.

If the crude breakup is based on product quality specification, correct the theoretical yield, meeting the specification, to its corresponding commercial yield. **Multiply** the theoretical cut volume (weight) percent (column 6) by the correction factor (column 5) and enter the result in **column 4**. Slump the excess distillate material into the reduced crude, or LVGO if there is a vacuum column. Properties are based on the theoretical cuts.

- 6.7 Calculate the cumulative volume (weight) percents and enter into **column 7** by successively adding the crude fraction yields from column 6.
- 6.8 Using the cumulative volume (weight) percents (column 7) , calculate the mid-volume percent distilled point for each cut and record in **column 8**.
- 6.9 Using the °API gravity vs mid-volume (weight) percent curve (Figure 2) determine the °API gravities for distillate cuts and enter into **column 9**. Use the °API gravity vs volume (weight) percent curve (Figure 3) to determine the °API gravity for the residual cut. Enter this in **column 9**.
- 6.10 From the TBP distillation curve (Figure 1) read the cut temperatures which correspond to the cumulative percents in column 7. Record these in **column 10**.
- 6.11 Using the cut points in column 10, tabulate the corrected TBP boiling range of each cut in **column 11**.
- 6.12 Estimate the ASTM boiling range by the following procedure. **This method of estimating ASTM distillations should be used only when better information is lacking.**
not available or lacking
 - a. If the lightest C_6^+ distillate cut has a TBP cut point of 350°F or less, use it as the ASTM end point EP. The initial boiling point (IBP) of this cut depends on the downstream fractionation scheme and is difficult to define.
Figure 7

- b. For all subsequent distillate cuts, except the vacuum gas oils (VGO), set the ASTM IBP 15°F lower than the initial TBP cut point. The ASTM EPs are taken from Figure 7 (Appendix 1).
- c. For each VGO cut set the ASTM IBP 50°F lower than the initial TBP cut point. Set the ASTM EP for the LVGO from Figure 7 or 50°F higher than its TBP end point. Set the ASTM EP for the remaining VGO cuts 50°F higher than their TBP end points.

Note - Figure 7 is not a procedure for converting a TBP distillation to an ASTM distillation. If one needs to make such a conversion, one of the following should be used:

API Technical Data Book Chapter 3
UOP Chart PD-258 C and D
UOP Computer Program 14.7

Enter the estimated ASTM IBPs in **column 12** and the ASTM EPs in **column 13**.

- 6.13** For each distillate cut, plot the estimated ASTM distillation on UOP Chart PD-544 (Figure 6). This probability chart was published in the Oil and Gas Journal, 9-4-61, page 180. It was developed to help identify the cause of faulty crude column performance. Connect the ASTM IBP and EP (from columns 12 and 13) with a straight line. Check the 5 and 95 percent points to see if any specified gaps are being met. Record the estimated ASTM 50 percent points in **column 14**. Also calculate and note the 10-90 percent slope of the individual distillate cuts.
- 6.14** Based on available properties given for distillate and residual fractions, calculate the UOP K for the published cuts. Plot the UOP K vs mid-volume (weight) percent for the reported distillate fractions. Plot the UOP K vs volume (weight) percent on crude for residual fractions. See Figure 5 (Appendix 1).

UOP K can be determined in different ways depending on what data is provided in the crude assay. The best source is the narrow TBP cuts furnished in some assays. Narrow cuts permit calculating UOP K from its basic definition since

each fraction is characterized by a narrow TBP boiling range and specific gravity.

$$UOP K = [(CABP, ^\circ R)^{1/3} / sp\ gr @ 60^\circ F]$$

The second method makes use of UOP R.E. Charts B-1, 2 and 3. $^\circ$ API gravity and ASTM distillation for each fraction are used in conjunction with these charts.

The least accurate method uses UOP Charts PD-431 A/B, 432 A/B and 433 A/B. $^\circ$ API gravity and viscosity are needed. Although least desirable, this frequently is the only method of getting the UOP K for residual cuts.

- 6.15** Using the mid-volume (weight) percent found in column 8 along with Figure 5, record the UOP K of each distillate cut in **column 15**. Use the UOP K vs volume (weight) percent curve (Figure 5) to determine the UOP K for the residual cut. Enter this into **column 15**.
- 6.16** With the estimated ASTM 50 percent point (column 14) and the $^\circ$ API gravity (column 9), read the UOP K from UOP R.E. Charts B2 and B3. For all practical purposes, the ASTM 50 percent point can be used as the cubic average boiling point (CABP). Compare these UOP K values with those previously entered in column 15. If there is a discrepancy of more than ± 0.05 , adjust the ASTM 50 percent point in column 15 to bring the UOP K values within the indicated tolerance. If a major discrepancy is encountered, recheck your calculations.

With good agreement between UOP K and estimated ASTM 50 percent point for distillate cuts, make a slight adjustment to the CABP to get a mean average boiling point (MABP). Use UOP R.E. Chart B1 and the slope of the cut to make this boiling point adjustment. Enter the resultant molecular weight (mol wt) from the UOP R.E. Chart B2 or B3 in **column 16**.

The molecular weight of reduced crude or vacuum residue if there is a vacuum column, is obtained by first calculating the UOP K from properties of assay residual cuts. See Figure 5 (Appendix 1). The CABP is then obtained from $^\circ$ API gravity and UOP K. The CABP of the residual cut should be confirmed by estimating a 50 percent point for the cut by using the TBP distillation curve. The

slope of the reduced crude or vacuum residue must then be estimated to arrive at the MABP using UOP R.E. Chart B1. The molecular weight is then read from UOP R.E. Chart B3 using °API gravity and MABP.

Historically, there have been difficulties generating properties for high boiling point (above 1000°F) materials when using UOP's computerized curve fits of R.E. Charts B2 and B3. Alternate correlations are available for computer generated molecular weights and critical properties. The °API Technical Data Book correlation (Chapter 2) should be used to determine the molecular weight of **all** cuts if a Vacuum Distillation Unit is included in the design. This will ensure use of consistent molecular weights with the crude breakup and subsequent computerized calculations.

- 6.17** Read the weight percent sulfur from the sulfur vs mid-volume (weight) percent curve (Figure 4) for distillate cuts. Use the sulfur vs volume (weight) percent curve (Figure 4) to determine the sulfur for the residual cut. Enter this data in **column 17**.

Compare the sulfur (lb/h) in the crude with the sulfur (lb/h) obtained by adding the product fractions.

- 6.18** Construct a flash curve for the crude using both Packie's method (UOP Charts PD-167, 168-1, 168-2, 168-3, 187-1 and 187-2) and UOP computer program 9.8 or other simulation methods. Given good input, the computer result is more realistic than the Packie method. Operating data should always be used to verify the calculated flash zone conditions.

A flash curve is needed to ensure the flash zone temperature required to yield the targeted distillate is below the point of incipient thermal cracking. This temperature can be as low as 650°F for very paraffinic crudes (12.2 UOP K and above) and as high as 725°F for naphthenic crudes (11.7 UOP K and below). For vacuum column flash zones, temperatures should not exceed 750° at 25-50 mm Hg absolute pressure unless commercial data is available indicating it is safe to go higher.

- 6.19** Estimate viscosities of crude fractions from °API gravity and UOP K, using Charts PD-431 A/B, 432 A/B, 433 A/B and R. E. Chart A-4.

- 6.20 Estimate other desired/required properties based on information given in the crude assay; e.g., mercaptan sulfur, PONA, octane number, cetane number, smoke point, cloud point, freeze point, aniline point, nitrogen, metals, con-carbon, C7-insolubles, pour point and acid number. Much of this information affects the design of downstream units. If any of these properties fall outside the desired range, it may be necessary to start over again with revised cut points or suggest a processing scheme which will correct the undesirable property. Other crude data such as hydrogen sulfide evolution, hydrogen chloride evolution and salt content should also be noted if available.
- 6.21 Having finalized the crude breakup, the crude column receiver equilibrium should be checked at 5 psig and 100°F for the total net overhead. If the receiver gas is less than 0.5 volume percent of the crude, a fictitious light tends **spike** may need to be added to the crude breakup for design purposes. The spike compensates for light ends loss due to sample weathering (exposure to the atmosphere). It is intended to provide a reasonable basis for specifying the crude column gas compressor and associated gas (light ends) recovery equipment. Consideration must be given to the method of transporting crude to the refinery. If the crude arrives by pipeline, there is a greater chance of having more light ends than the crude sample reflects. If the crude is shipped by tanker, actual light ends will be reduced due to weathering.

Any spike should be added to the nominal crude design rate. As a first approximation, double the reported methane and ethane and triple the reported propane. If the resultant receiver gas is approximately 0.5 volume percent of the crude, use the spike as calculated. If the spike has raised the gas quantity substantially above 0.5 volume percent of the crude, reduce the spike until the gas rate approximates the targeted value. Referencing a different assay for the design crude may provide a better definition of light ends and provide a better basis for setting the spike. Designing for both light and heavy crudes does **not** necessarily ensure a proper basis for establishing the governing gas rate from the crude column receiver. The terms "light" and "heavy" when used to describe crudes, do **not** reflect the amount of light ends present in the crude.

APPENDIX 1

Sample Problem

Design a Crude Distillation Unit for 100,000 barrels per stream day (BPSD) of Light Arabian crude oil. This crude is defined in Chevron Oil Trading Company assay dated March, 1972 (Appendix 2). The **desired commercial cuts** are as follows, where all temperatures are TBP cut points:

Light straight run gasoline	IBP - 300°F
Naphtha	300 - 385
Kerosine	385 - 525
Diesel	525 - 600
Atmospheric gas oil (AGO)	600 - 675
*Vacuum gas oil (VGO)	675 - 1000
*Vacuum resid	1000+

*Although the crude column will produce a nominal 675+°F reduced crude, the example shows a 675-1000°F total VGO and 1000+°F vacuum resid for illustrative purposes.

A crude breakup can be done on either a volume or weight basis. Due to the fact that volumes do not blend on an ideal basis, a crude breakup done on a weight basis will have a volumetric product yield exceeding the volumetric charge rate. If done on a volume basis, the weight yield of products will be less than the weight charge rate. This example reflects a volumetric breakup.

UOP forces both a volume and weight balance for design purposes. In order to do this, the °API gravities of the crude charge and/or product cuts must be adjusted to force a balance. In general, a minor change should be made to a large stream. There is no set rule to force a balance, but judgement should be used so downstream unit designs are not unduly affected.

1. Prepare a work table as outlined in Section 6.5. Refer to Table 1.
2. The assay reports no BS&W in the crude. Therefore, no corrections for water are required.

3. TBP distillation data is given in Table A-V of the assay. It has been plotted as Figure 1.
4. °API gravity of distillate cuts vs volume percent of crude is available in Tables A-III and A-IV of the assay. Calculated mid-volume percents and published °API gravities are shown here.

Assay TBP Range, °F	Position in Crude, Vol Pct	Mid Vol Pct Distilled	°API Gravity
60 – 200	1.5 – 9.6	5.55*	79.9
60 – 300	1.5 – 20.0	10.75	67.8
60 – 400	1.5 – 31.4	16.45	59.0
200 – 300	9.6 – 20.0	14.80	61.3
200 – 400	9.6 – 31.4	20.50	54.5
300 – 400	20.0 – 31.4	25.70	50.2
300 – 500	20.0 – 41.2	30.60	46.8
300 – 600	20.0 – 51.6	35.80	43.6
400 – 500	31.4 – 41.2	36.30	43.3
400 – 600	31.4 – 51.6	41.50	40.3
500 – 600	41.2 – 51.6	46.40	37.3
600 – 800	51.6 – 70.8	61.20	28.8
800 – 1000	70.8 – 84.0	77.40	22.7

$$*1.5 + \frac{[9.6 - 1.5]}{2} = 5.55$$

Figure 2 is a plot of °API gravity vs mid-volume percent distilled.

°API gravity vs volume percent residual fraction in crude is available in Table A-1 of the assay. Figure 3 is a plot of this data.

Plot the weight percent sulfur vs mid-volume percent distilled and weight percent sulfur vs volume percent residual fractions (see Figure 4).

5. Read the following from the TBP distillation curve, Figure 1.

(1) TBP Cut Pt, °F	(2) Cum Vol Pct	(3) Nominal TBP Range, °F	(4) Cut Vol Pct
300	20.0	IBP - 300	20.0
385	29.8	300 - 385	9.8
525	43.6	385 - 525	13.8
600	51.6	525 - 600	8.0
675	59.5	600 - 675	7.9
1000	84.0	675 - 1000	24.5
EP	100.0	1000 +	16.0

The entries in columns 3 and 4 represent the **commercial** yields to be produced in the Crude Distillation Unit.

6. Since there is a difference between laboratory and commercial fractionation, the correction factors discussed in Section 6.6 must be applied to provide a basis for determining properties of the commercial cuts.

Complete columns 1 through 11 of the work table.

(3) Nominal TBP Range, °F	(4) Cut Vol Pct	(5) Correction Factor	(6) Vol Pct for Properties	(7) Cum Vol Pct	(8) Mid Vol Pct Distilled	(9) °API Gravity	(10) Corr TBP Cut Pt, °F	(11) Corr TBP Range, °F
IBP - C ₅	3.67(a)	1.00	3.67	3.67	(d)	(d)	(d)	(d)
C ₆ - 300	16.33(b)	0.99	16.49	20.16	11.92	65.9	302(c)	C ₆ - 302
300 - 385	9.80	0.99	9.90	30.06	25.11	50.6	388	302 - 388
385 - 525	13.80	0.97	14.23	44.29	37.18	42.9	530	388 - 530
525 - 600	8.00	0.94	8.51	52.80	48.55	36.3	611	530 - 611
600 - 675	7.90	0.94	8.40	61.20	57.00	31.1	692	611 - 692
675 - 1000	24.50(e)	(Diff)	22.80(f)	84.00	72.60	24.2	1000	692 - 1000
1000+	16.00	1.00	16.00	100.00	---	8.5	--	1000+

Notes:

- (a) The C₅ content of the crude oil is shown in Table A-II of the crude assay. This quantity is used without modification.
- (b) The resultant C₆-300°F fraction is (20.00 - 3.67) = 16.33 volume percent.

- (c) From the TBP distillation curve, Figure 1. The TBP cut point temperature for 20.16 volume percent is 302°F.
 - (d) Since the C_5^- material is defined in the crude assay and properties of the individual components are readily available, this material can be characterized completely on a componential basis. This is shown at the end of this example.
 - (e) Reflects slump material.
 - (f) Without slump material.
7. Obtain the estimated ASTM IBP and EP using the method described in Section 6.12 of the crude breakup procedure. Fill in columns (12) and (13) of the work table.

Using UOP Chart PD-544, connect the IBP and EP of each distillate cut with a straight line. Read the ASTM 50 percent temperature and record in column (14). See Figure 6.

(11)			(12)	(13)	(14)	(15)	
Correction for Range TBP °F	Correction for ASTM IBP, °F	Correction for ASTM EP, °F	Est ASTM IBP, °F	Est ASTM EP, °F	Est (b) ASTM 50 Pct Pt, °F	UOP K	UOP K from °API and Est 50 Pct Pt
IBP - C ₅	—	—	—	—	—	—	—
C ₆ -302	—	0	140 (a)	302	207	12.18	12.2
3 02 - 388	-15	+04	287	392	335	11.97	11.92
388 - 530	-15	+23	373	553	455	11.97	11.95
530 - 611	-15	+33	515	644	580	11.95	12.02
611 - 692	-15	+44	596	736	665	11.88	11.93
692 - 1000	-50	+50	642	1050	840	11.93	11.92
1000 +	-50	—	950	—	1080 (c)	11.42	—

Notes:

- (a) The IBP of this cut is difficult to define. The temperature shown is based on an average boiling point for C₆ paraffins. It should also be noted, the preceding cut (IBP-C₅) is 3.67 volume percent of the crude. This corresponds to a TBP distillation temperature of 120°F (see Figure 1).

- (b) The ASTM 50 percent point can be assumed equivalent to the CABP.
 - (c) Calculated from UOP K and °API. This entry should be verified by comparison with an estimated 50 percent point obtained from the TBP distillation curve. For the given example, the mid-volume point is located at 92 percent and the corresponding temperature is 1180°F (see Figure 1). The 1080°F shown is suspect.
8. From the data contained in the crude assay, calculate the UOP K for the distillate (assay Tables A-III and A-IV) and residual cuts (assay Table A-1). Plot the UOP K vs mid-volume percent for the distillate fractions. Plot the UOP K vs volume percent on crude for residual fractions. See Figure 5. Fill in column (15) of the work table.
 9. The UOP K obtained from the assay must be compared with a UOP K predicted from UOP Charts R.E B2 and B3. The °API gravity (column 9) and estimated ASTM 50 percent point (column 14) are used in conjunction with the B Charts. Small differences (± 0.05) in UOP K are typical. A gross discrepancy indicates an error. See last column in preceding table.
 10. Obtain and record the molecular weight of each cut as outlined in Section 6.16 of the breakup procedure. Enter in column (16) of the work table.
 11. Read the weight percent sulfur from Figure 4 for the distillate cuts and residual cut. Record these in column (17) of the work table.

The sulfur (lb/h) in the product fractions is equivalent to 1.73 weight percent of the total crude. The crude assay reports 1.7 weight percent sulfur. Recommend increasing the crude sulfur content to 1.73 weight percent for conservative metallurgy selection.

If the sulfur content of the crude, based on summing the product fractions, was less than that reported for the total crude; increase the sulfur content of the heavier fractions to achieve a sulfur balance.

12. Having completed the crude breakup, check the crude column receiver equilibrium to determine if a light ends spike should be introduced for the Crude Distillation Unit design. Refer to section 6.21 of the breakup procedure. A flash calculation at 5 psig and 100°F showed no receiver gas. Another calculation with triple the amount of reported propane also showed no gas. A third calculation reflecting an ethane spike of 0.25 volume percent in addition to the propane spike showed a receiver gas rate equal to 0.43 volume percent of the crude. This is an acceptable design gas rate and should be used for the Crude Distillation Unit design.

The crude column C_5^- light ends composition and rate are given in Table A-II of the assay. The information is summarized here on a "spike free" basis.

	°API Gravity	UOP K	Mol Wt	BPSD	Lb H	Mol H	Vol Pct
C ₃	147.2	14.70	44.094	170	1260	28.56	0.17
i-C ₄	119.8	13.81	58.120	170	1395	24.03	0.17
n-C ₄	110.6	13.50	58.120	1060	9040	155.49	1.06
CP	57.0	11.11	70.130	70	765	10.93	0.07
i-C ₅	95.0	13.05	72.146	730	6655	92.24	0.73
n-C ₅	92.7	13.03	72.146	1470	13535	187.62	1.47
Total	100.6	13.22	65.448	3670	32650	498.87	3.67

0-6647

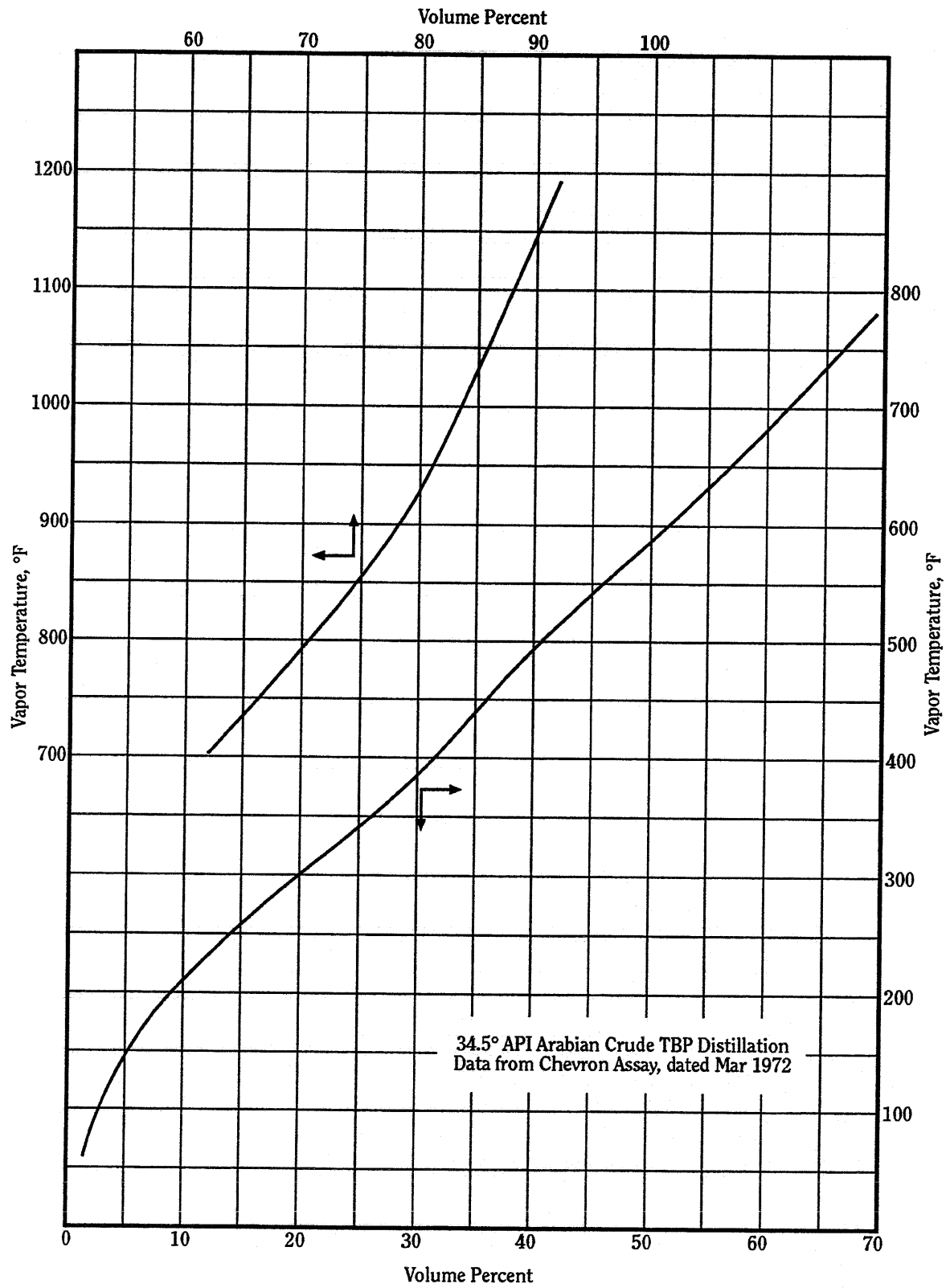
14.1045

WORK TABLE FOR SAMPLE PROBLEM

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
TBP Cut Pt °F	Cum Vol Pct	Nominal TBP Range °F	Cut Vol Pct	Correction Factor	Vol Pct for Properties	Cum Vol Pct	Mid Vol Pct Distilled	°API Gravity	Corr TBP Cut Pt °F
C5	3.67	IBP-	C5 3.67	1.00	3.67	3.67	-	-	
300	20.00	C6- 300	16.33	.99	16.49	20.16	11.92	65.90	302
385	29.80	300- 385	9.80	.99	9.90	30.06	25.11	50.60	388
525	43.60	385- 525	13.80	.97	14.23	44.29	37.18	42.90	530
600	51.60	525- 600	8.00	.94	8.51	52.80	48.55	36.30	611
675	59.50	600- 675	7.90	.94	8.40	61.20	57.00	31.10	692
1000	84.00	675-1000	24.50	(Diff)	22.80	84.00	72.60	24.20	1000
EP	100.00	1000+	16.00	1.00	16.00	100.00		8.50	

(1)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
TBP Cut Pt °F	Corr TBP Range °F	Est ASTM IBP °F	Est ASTM EP °F	Est ASTM 50 Pct Pt °F	UOP K	Molecular Weight	Weight Pct Sulfur
C5	IBP - C5	-	-	-	-		-
300	C6 - 302	140	302	207	12.18	99	0.03
385	302 - 388	287	392	335	11.97	137	0.05
525	388 - 530	373	553	455	11.97	185	0.40
600	530 - 611	515	644	580	11.95	245	1.08
675	611 - 692	596	736	665	11.88	297	1.67
1000	692 -1000	642	1050	840	11.93	390	2.40
EP	1000+	950	-	1080	11.42	580	4.30

Figure 1



EDS-R00-0801

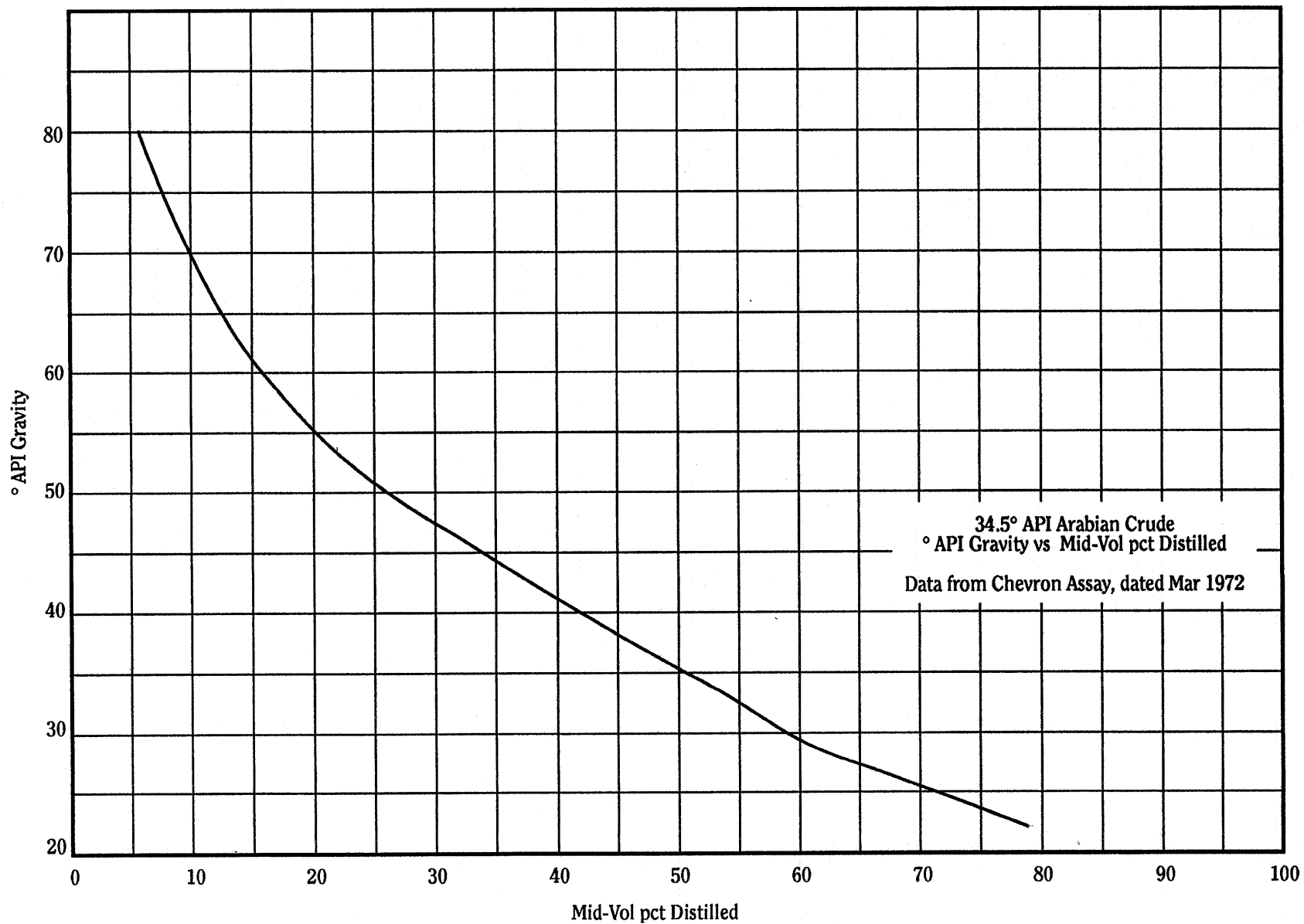


Figure 2

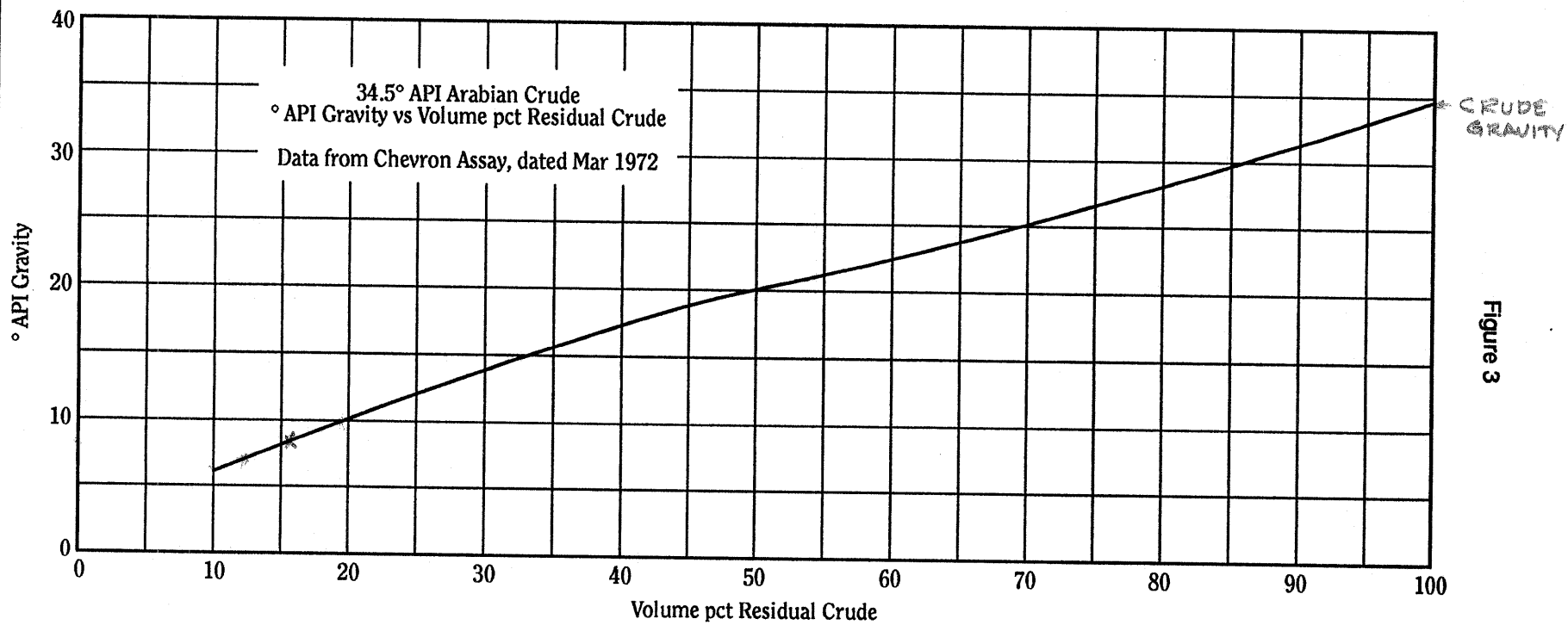


Figure 3

EDS-R00-0803

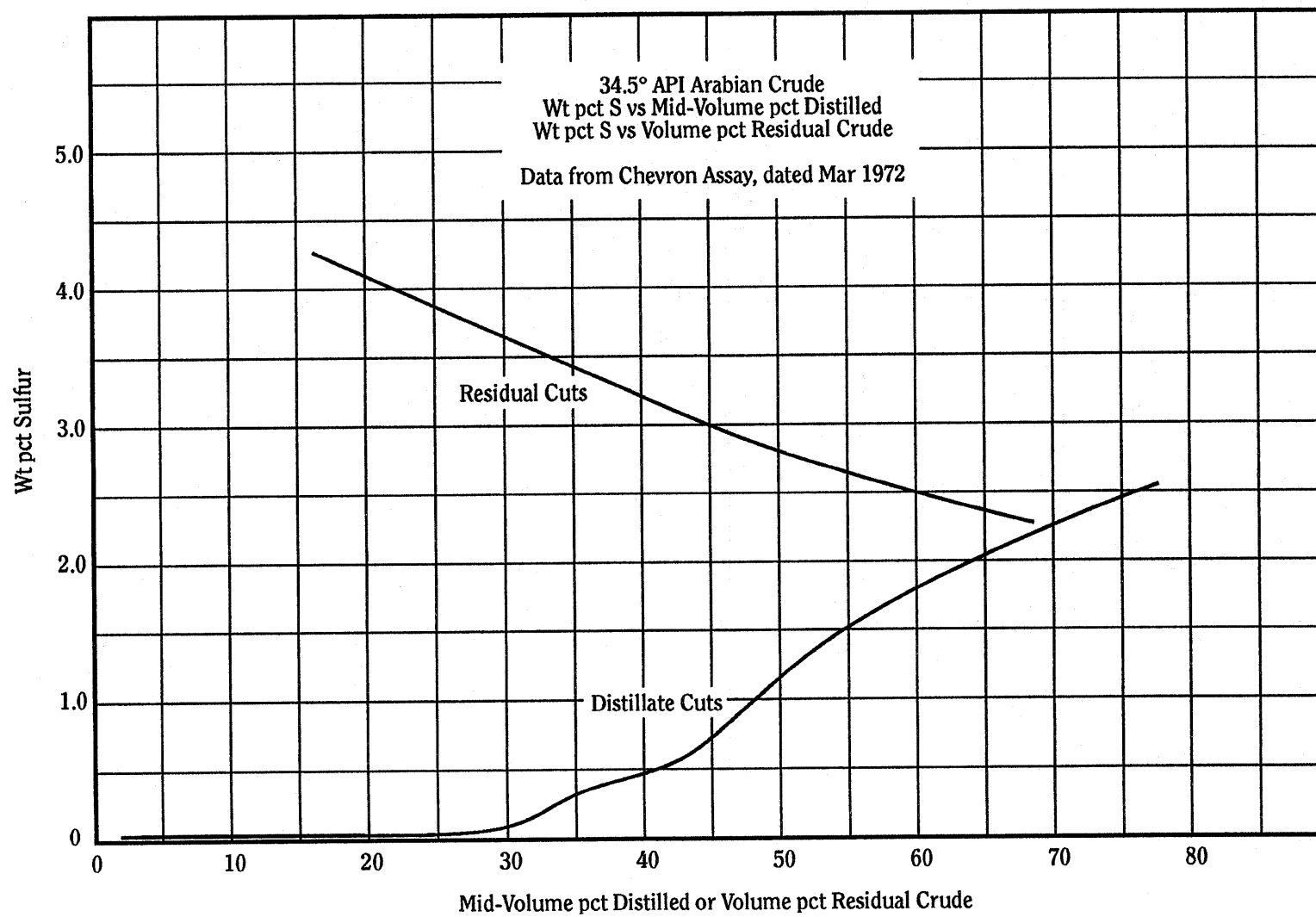


Figure 4

EDS-R00-0804

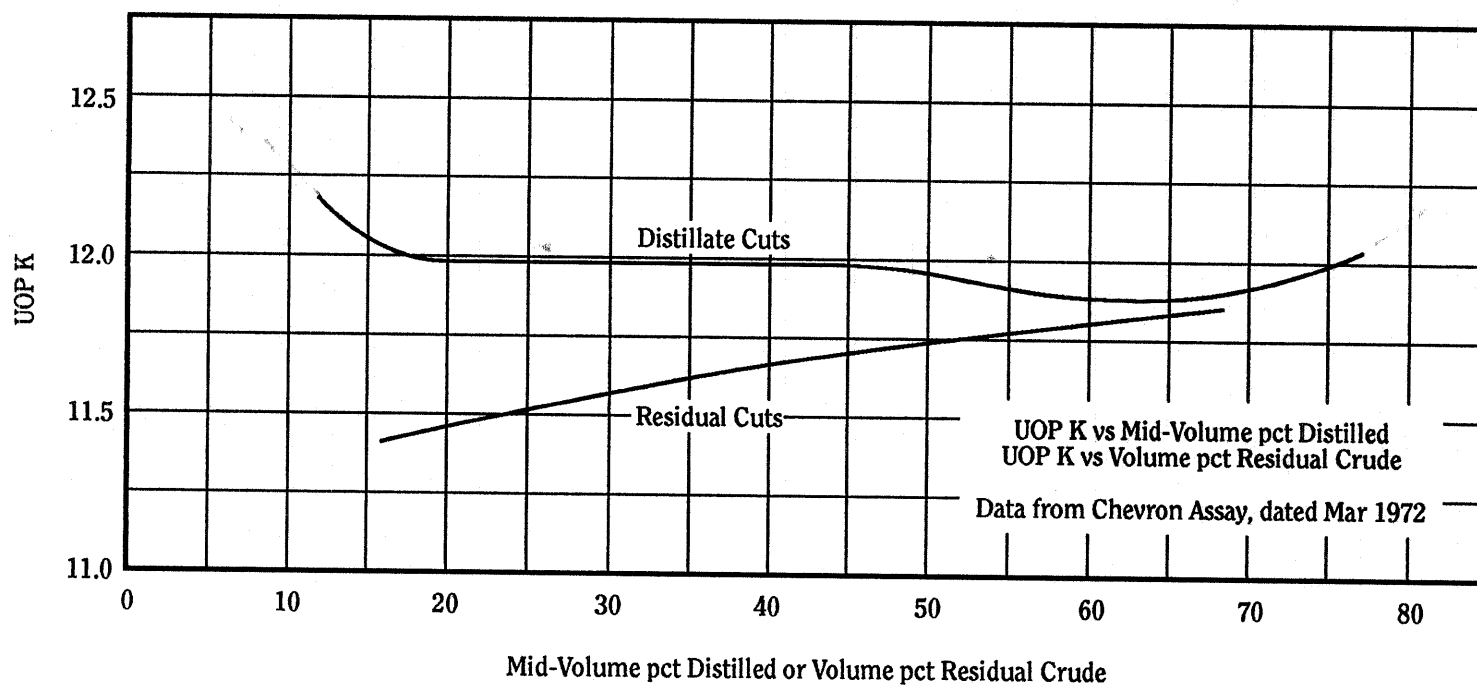
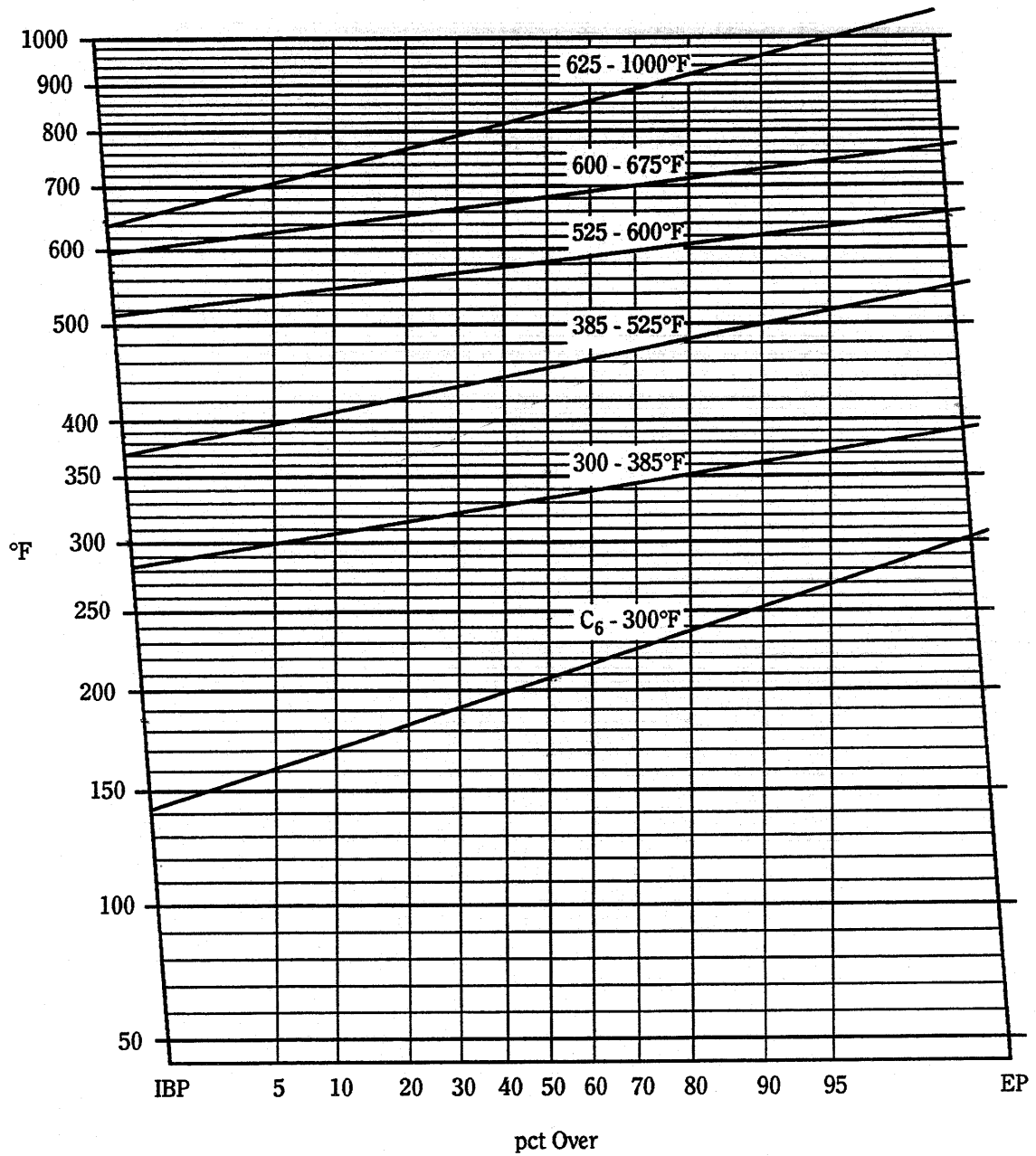


Figure 5

EDS-R00-0805

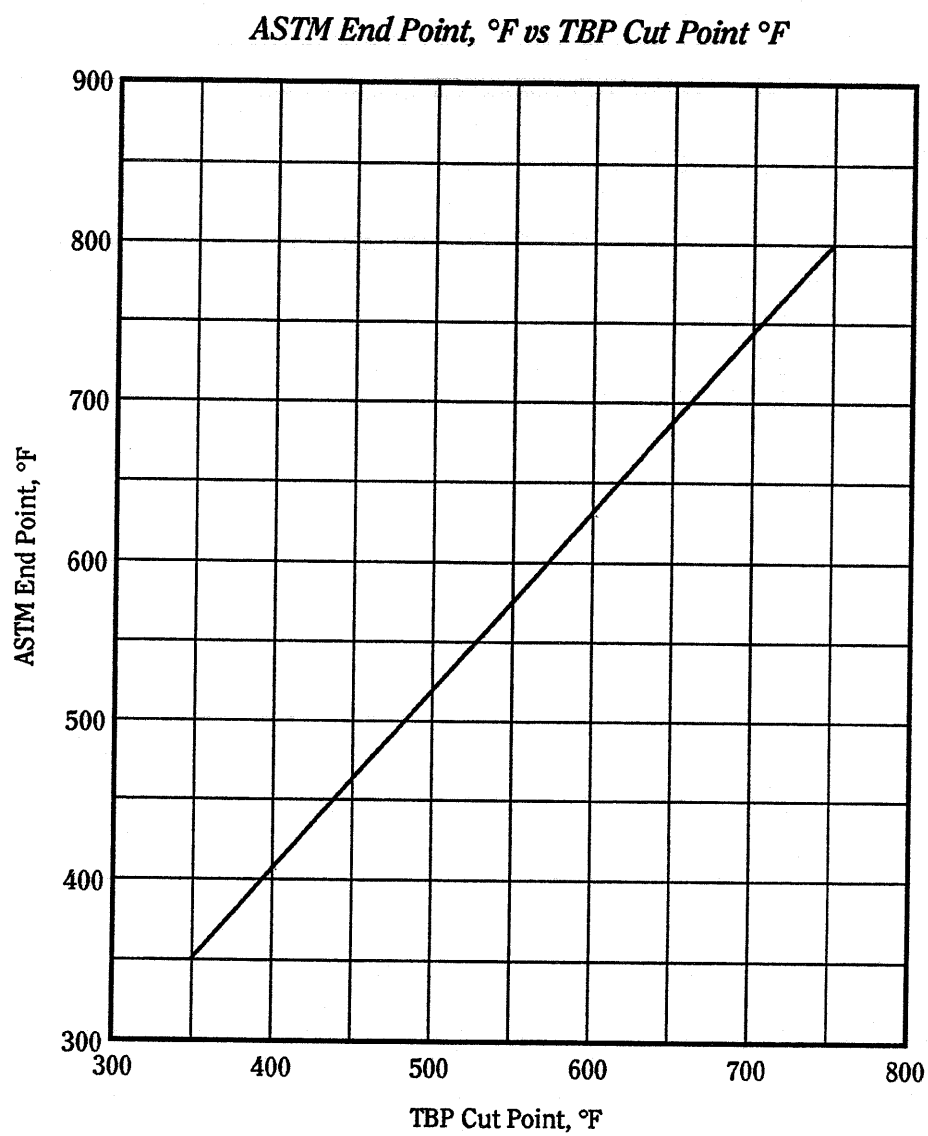
Figure 6

Estimate ASTM Distillations



EDS-R00-0806

Figure 7



EDS-R00-0807

$K = \frac{COIBP}{Sp-gr}$

APPENDIX 2

Crude Oil Break Up Procedure

TABLE A-1
 34.5°API ARABIAN CRUDE OIL
 CRUDE AND RESIDUA PROPERTIES

	Crude	400°F+ (204°C+)	600°F+ (315°C+)	800°F+ (427°C+)	1000°F+ (538°C+)
Yield from Crude, Vol. %	100	68.6	48.4	29.2	16.0
Yield Range from Crude, Vol. %	0.0-100.0	31.4-100.0	51.6-100.0	70.8-100.0	84.0-100.0
Gravity, °API	34.5	24.7	19.4	13.6	8.5
Specific Gravity at 60°F	0.8524	0.9059	0.9377	0.9752	1.017
Sulfur, Wt. %	1.7	2.3	2.9	3.7	4.3
H ₂ S, ppm	2				
Nitrogen, Wt. %	0.08	0.11	0.15	0.23	0.31
Wax, Holde, Wt. %	2.8	3.8	5.2		
Pour Point, °F	-15	+10	+40	+50	+80
Pour Point, °C ¹	-26	-12	+4	+10	+27
Fluidity, °F		-15	+20	+35	+80
Fluidity, °C ¹		-26	-7	+2	+16
Viscosity, cs at 100°F	5.5	28.5	155	2200	
Viscosity, cs at 130°F	4.0	16.5	70	700	14,000
Viscosity, cs at 210°F		5.5	14.5	65	470
UOP K		11.85	11.72	11.55	11.42
Total Acid No., mg KOH/g	0.08				
Saponification No., mg KOH/g	0.34				
Dielectric Constant ²	2.2				
Ramsbottom Carbon, Wt. %	2.6	3.7	5.6	8.7	12.1
Conradson Carbon, Wt. %	3.1	4.4	6.7	10.5	14.5
Ash, ASTM, Wt. %	0.01	0.01	0.02	0.03	0.05
Metals					
Vanadium					66
Nickel					24
Sodium					24
Iron					7
Copper					1.1
Chromium					0.5
Flash, Cleveland Open Cup, °F		230	395	525	610
Flash, Cleveland Open Cup, °C ¹		110	202	274	321
Vapor Pressure, psi Reid	3.5				
ASTM Dist. D 86, °F					
St	115				
10%	220				
20%	302				
30%	395				
40%	477				
50%	558				

¹Converted from observed, °F.

²Specific inductive capacitance at 23°C (77°F), ASTM D 924

TABLE A-II
34.5°API ARABIAN CRUDE OIL
LIGHT HYDROCARBON ANALYSIS
(SULFUR FREE BASIS)

TBP Temperature Range, °F TBP Temperature Range, °C		St-60 St-16		60-160 16-71	
Yield from Crude, Vol. %		1.5		4.8	
Yield Range from Crude, Vol. %		0.0-1.5		1.5-6.3	
Light Hydrocarbons, Vol. %	Total In Crude	In Cut	In Crude	In Cut	In Crude
Propane	0.17	11.3	0.17		
Isobutane	0.17	11.4	0.17		
Normal Butane	1.06	64.0	0.96	2.1	0.10
Cyclopentane	0.07	1.3	0.02	1.0	0.05
Isopentane	0.73	8.0	0.12	12.7	0.61
Normal Pentane	1.47	4.0	0.06	29.4	1.41
2-Methylpentane	0.62			12.9	0.62
3-Methylpentane	0.42			8.7	0.42
2,2-Dimethylbutane	0.01			0.2	0.01
2,3-Dimethylbutane	0.06			1.3	0.06
Normal Hexane	1.44			23.8	1.14
Methylcyclopentane	0.22			3.3	0.16
Cyclohexane	0.16			1.5	0.07
Benzene	0.07			0.8	0.04
C7's and Heavier	93.33			2.3	0.11
Totals	100.00	100.00	1.50	100.0	4.80

Correct analysis is required to design overhead system of Crude unit.

TABLE A-III
34.5°API ARABIAN CRUDE OIL
GASOLINES AND NAPHTHAS

TBP Temperature Range °F TBF Temperature Range °C	St - 60 St - 16	60 - 200 16 - 93	60 - 300 16 - 149	60 - 400 16 - 204	200 - 300 93 - 149	200 - 400 93 - 204	300 - 400 149 - 204
Yield from Crude Vol % Yield Range from Crude Vol %	1.50 0.0 - 1.5	8.10 1.5 - 9.6	18.50 1.5 - 20.0	29.90 1.5 - 31.4	10.00 9.6 - 20.0	21.80 9.6 - 31.4	11.40 20.0-31.4
Mid Volume % Gravity °API Specific Gravity at 60°F		5.60 76.90 0.6693	10.80 67.80 0.7100	16.50 59.00 0.7428	14.80 61.30 0.7339	20.50 54.50 0.7608	25.70 50.20 0.7788
Sulfur Weight % Hydrogen Sulfide ppm Mercaptan Sulfur ppm Doctor Test Corrosion Copper Strip Test		0.02 ≤ 200 Positive Negative	0.03 ≤ 180 Positive Negative	0.04 ≤ 160 Positive Negative	0.03 ≤ 160 Positive Negative	0.04 ≤ 150 Positive Negative	0.06 ≤ 130 Positive Negative
Octanes: F-1 Clear		58.00	45.30	36.10	38.30	29.50	19.50
F-1 + 1ml TEL/Gal		69.50	59.00	50.50	52.50	44.10	34.80
F-1 + 3ml TEL/Gal		79.70	70.00	62.80	64.60	57.50	49.00
F-2 Clear		56.70	44.30	36.20	38.10	31.50	25.00
F-2 + 1ml TEL/Gal		69.20	58.30	50.10	52.00	45.00	38.80
F-2 + 3ml TEL/Gal		79.30	69.50	62.30	64.10	57.50	51.70
Paraffins Volume % Naphthenes Volume % Aromatics Volume %		87.00 10.00 3.00	75.00 19.00 6.00	67.00 20.00 13.00	70.00 19.00 11.00	65.00 19.00 16.00	61.00 20.00 19.00
Vapor Pressure psi Reid		8.90	4.40	3.50	1.50	1.00	0.50
ASTM Distillation, D 86 °F							
St		90	120	140	212	227	308
10%		112	152	185	224	249	318
20%		122	168	207	231	263	325
30%		132	184	227	237	275	330
50%		148	211	263	250	299	343
70%		164	238	302	265	327	357
80%		174	253	324	273	343	365
90%		184	272	351	283	362	377
End Point		198	293	385	295	387	389
UOP K (From °API & Distillation Data)		12.64	12.32	12.07	12.16	12.00	11.94

2c dist 2-1

**TABLE A-IV
34.5°API ARABIAN CRUDE OIL
KEROSENES AND GAS OILS**

TBP Temperature Range °F TBF Temperature Range °C	300-400 143-204	300-500 149-260	300-600 149-316	400-500 204-260	400-600 204-316	500-600 260-316	600-800 316-427	800-1000 427- 553	
Yield from Crude Vol %	11.40	21.20	31.60	9.80	20.20	10.40	19.20	13.20	9.50
Yield Range from Crude Vol %	20.0-31.4	20.0-41.2	20.0-51.6	31.4-41.2	31.4-51.6	41.2-51.6	51.6-70.8	70.8-84.0	24.0-33.5
Mid Volume %	25.20	30.60	35.80	36.30	41.50	46.40	61.20	77.40	
Gravity °API	50.20	46.80	43.60	43.30	40.30	37.30	23.80	22.70	13.80
Specific Gravity at 60°F	0.7733	0.7935	0.8061	0.8095	0.8236	0.8383	0.8327	0.9175	0.9736
Sulfur Weight %	0.06	0.12	0.39	0.20	0.56	0.90	1.90	2.60	
Hydrogen Sulfide ppm	<5								
Mercaptan Sulfur ppm	130	115	100	100	90	80			
Nitrogen ppm	2	9	30	16	44	72	350	1050	2700
Viscosity: cs at 0°F	2.30	3.60	5.27	5.35	12.00				
cs at 100°F	0.97	1.28	1.75	1.77	2.60	3.60	10.90	112.00	
cs at 130°F	0.75	0.93	1.23	1.30	1.88	2.57	7.30	40.00	
cs at 210°F	0.57	0.64	0.77	0.78	1.00	1.25	2.68	9.80	95.00
Pour Point °F/°C*	B-60/6-62	-65/-54	-30/-34	-40/-40	-10/-23	+10/-12	+65/+22	+110/-57	
IP Cold Test °F/°C*	B-60/6-62	-50/-46	-17/-27	-26/-32	+5/-15	+10/-12	+65/+22	+105/-41	
Cloud Point °F/°C*					+5/-15	+10/-12	+65/+22	+105/-41	
Smoke Point mm ASTM/IP	26/28	25/27	24/26	23/24	20/21	17/18			
Smoke Tendency Lamp mm	47	40		38					
Naphthalenes (PNA) Vol %	0.70	1.60	3.60	2.50	5.00	7.50			
Luminosity Number	57	51	20	46	50	36			
Small Burner Coke ppm	1	1		1	70	400			
Color Saybolt	27	24	7	21		Below -16			
Color Stability 16 hrs at 212°F	21	19		16					
Corrosion Cu Strip at 210°F	Negative	Negative	Negative	Negative	Negative	Negative			
Aniline Point °F/°C*	133/56	142/61	143/64	151/65	156/65	161/72	171/77	182/83	
Cetane Number Determined	44	43	51	53	55	57			
Diesel Index	67	66	64	65	63	60	49	41	
Characterization Factor	11.97	11.96	11.97	11.97	11.93	11.97	11.87	12.03	
UOP K:									
(From °API & Viscosity Data)	11.85	11.88	11.90	11.90	11.98	11.92	11.80	11.85	
(From °API & Distillation Data)	11.94	11.92	11.92	11.92	11.92	11.91	11.89	12.05	
Paraffins Volume %	61.00	56.00	50.00	59.00	44.00	40.00	34.00	26.00	
Naphthenes Volume %	20.00	23.00	27.00	28.00	32.00	38.00	51.00	54.00	
Aromatics Volume %	19.00	21.00	23.00	23.00	24.00	22.00	15.00	20.00	
Flash Pensky Martens °F/°C*	108/42	116/47	127/53	179/82	190/88	250/121			
Flash Closed Tag °F/°C*	110/43	122/50	134/57	182/83	195/91	252/122			
ASTM Distillation °F	D86	D86	D86	D86	D86	D86	D1160	D1160	
Start	308	318	328	402	415	493	616	814	
10%	318	337	357	412	435	508	627	824	
20%	325	350	377	420	450	515	639	851	
30%	330	350	393	426	460	521	653	885	
50%	343	383	430	437	487	534	692	928	
70%	357	413	477	451	517	549	732	950	
80%	365	430	502	460	532	555	754	973	
90%	377	452	536	470	552	556	776	1000	
End Point	389	480	573	483	576	578	800		

*Converted from Observed °F

TABLE A-V
34.5° API ARABIAN CRUDE OIL
YIELDS IN VOLUME PER CENT DISTILLED
VERSUS TRUE BOILING TEMPERATURE (FAHRENHEIT)

(SEE ALSO FIGURES A-1, A-2, A-3 AND A-4)

True Temperature °F	0	10	20	30	40	50	60	70	80	90
100	2.8	3.2	3.7	4.3	4.9	5.6	1.5	1.8	2.1	2.4
200	9.6	10.5	11.5	12.5	13.5	14.5	6.3	7.1	7.9	8.7
300	20.0	21.1	22.3	23.5	24.7	25.9	15.6	16.7	17.8	18.9
400	31.4	32.4	33.5	34.5	35.5	36.5	27.0	28.1	29.2	30.3
500	41.2	42.2	43.1	44.1	45.2	46.2	37.5	38.4	39.3	40.3
600	51.6	52.7	53.8	54.9	56.0	57.0	47.2	48.3	49.4	50.5
700	61.9	62.9	63.8	64.7	65.6	66.5	58.0	59.0	60.0	61.0
800	70.8	71.7	72.5	73.2	74.0	74.8	67.4	68.2	69.1	70.0
900	78.2	78.9	79.5	80.1	80.7	81.3	75.5	76.2	76.9	77.6
1000	84.0						81.8	82.4	82.9	83.4

YIELDS IN WEIGHT PER CENT DISTILLED
VERSUS TRUE BOILING TEMPERATURE (CENTIGRADE)

True Temperature °C	0	10	20	30	40	50	60	70	80	90
100	8.3	9.8	11.4	13.0	14.7	16.5	3.7	4.7	5.9	7.1
200	26.0	27.7	29.5	31.3	33.0	34.6	18.4	20.4	22.3	24.2
300	43.5	45.4	47.4	49.4	51.3	53.2	36.2	37.9	39.6	41.5
400	62.0	63.7	65.3	66.9	68.5	69.9	54.0	56.8	58.6	60.4
500	76.7	77.9	79.0	80.1	81.2		71.4	72.8	74.1	75.4

CRUDE OIL BREAKUP

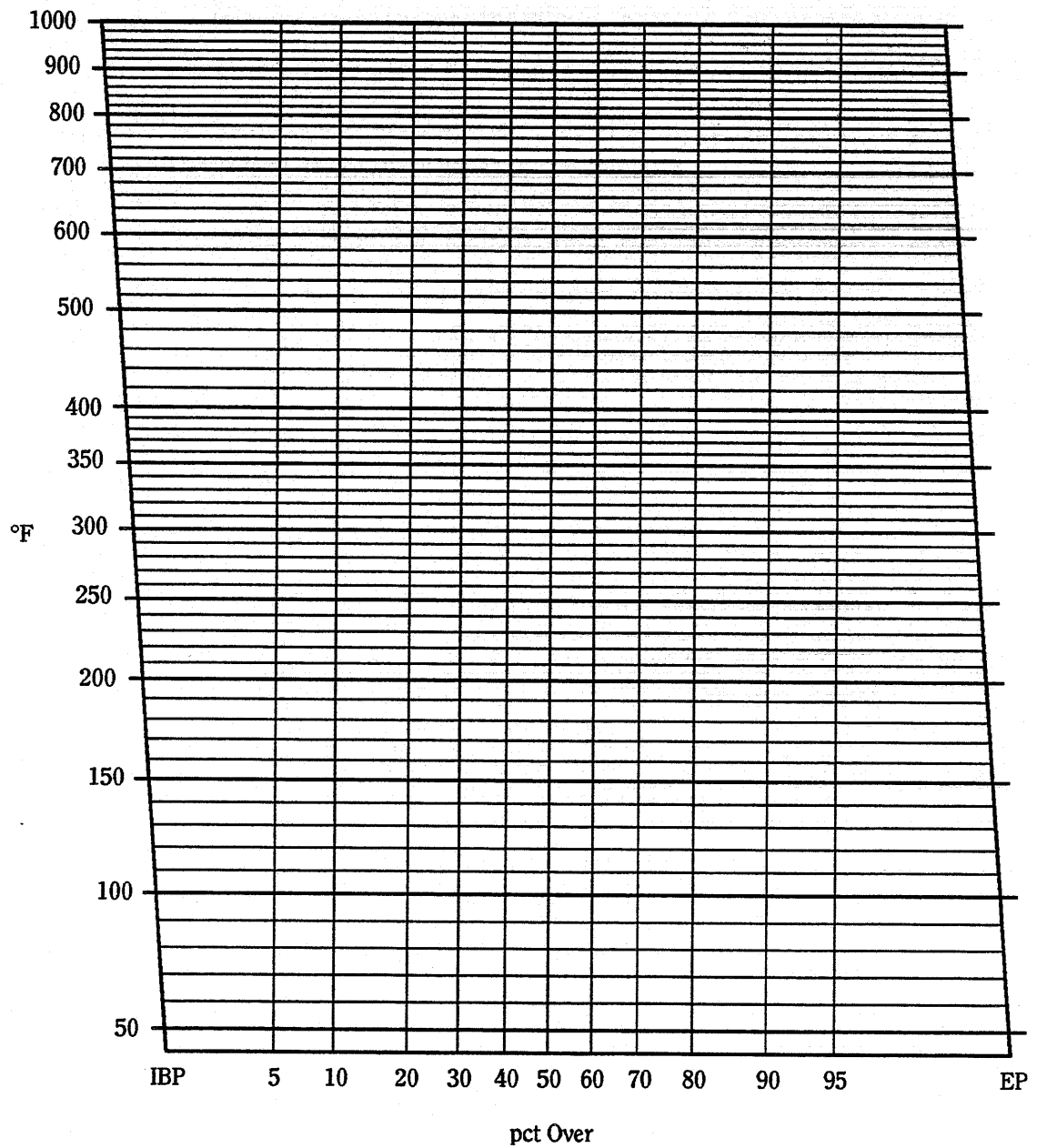
Class Problem

Break up the Light Arabian crude as defined in Chevron Oil Trading Company assay, March 1972, into the following cuts. Determine properties for each cut. Total crude charged to unit is 100,000 BPSD.

	<u>Nominal TBP Range. °F</u>
C ₅	IBP - C ₅
Light straight run gasoline	C ₆ - 250
Naphtha	250 - 375
Jet fuel	375 - 540
Diesel	540 - 625
Atmospheric gas oil (AGO)	625 - 700
Vacuum gs oil (VGO)	700 - 1000
Vacuum resid	1000 +

The total VGO shown above should be broken into the following cuts:

	<u>Approximate Volume Percent</u>
Light vacuum gas oil (LVGO)	20
Heavy vacuum gas oil (HVGO)	70
Slop Wax	<u>10</u>
	100



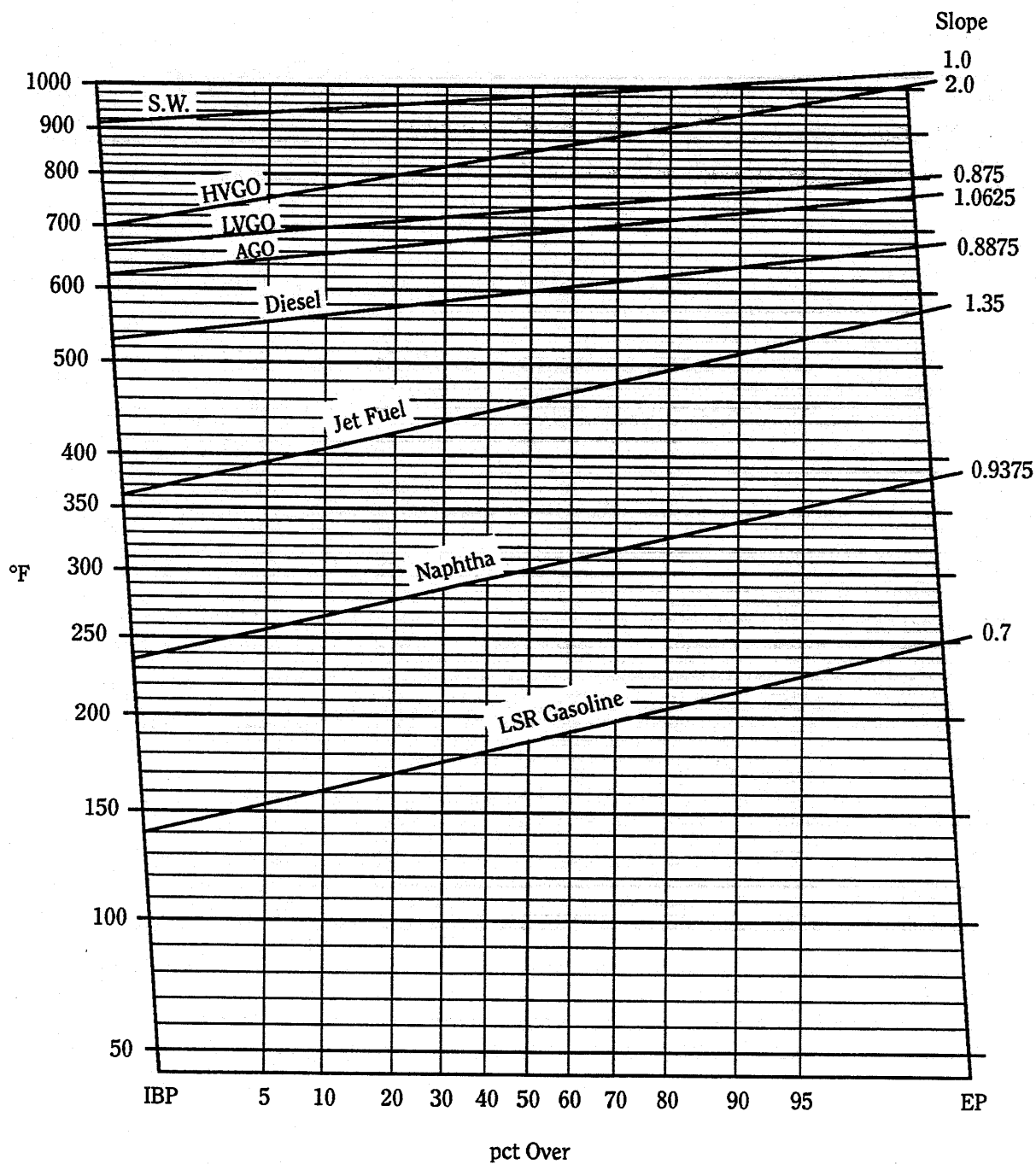
EDS-R00-0817

CRUDE OIL BREAKUP

Solution To Class Problem

	°API Gravity	UOP K	Mol Wt	BPSD	Lb/Hr	Mol/Hr	Vol Pct
Crude	34.5	11.84	212.0	100000	1243700	5866.32	100.00
Estimated Yields							
C ₃	--	14.70	44.094	170	1260	28.56	0.17
i-C ₄	--	13.81	58.120	170	1395	24.03	0.17
n-C ₄	--	13.50	58.120	1060	9040	155.49	1.06
CP	--	11.11	70.130	70	765	10.93	0.07
i-C ₅	--	13.05	72.146	730	6655	92.24	0.73
n-C ₅	--	13.03	72.146	1470	13535	187.62	1.47
LSR Gasoline	70.6	12.35	95	10830	110640	1164.63	10.83
Naphtha	53.3	11.97	125	14150	158085	1264.68	14.15
Jet fuel	42.8	11.97	187	16550	196035	1048.32	16.55
Diesel	35.0	11.93	258	9150	113460	439.77	9.15
AGO	29.5	11.87	312	7550	96815	310.30	7.55
LVGO	31.4	11.90	274.9	4600	58295	212.06	4.60
HVGO	23.5	11.96	435	15300	203800	468.51	15.30
Slop wax	20.7	12.05	570	2200	29845	52.36	2.20
Resid	8.5	11.42	580	16000	235955	406.82	16.00
	35.6	11.92	210.6	100000	1235580		

Calculated Properties of Yielded LVGO							
LSR Gasoline	70.6	12.35	95	110	1125	11.84	0.11
Naphtha	53.3	11.97	125	140	1565	12.52	0.14
Jet Fuel	42.8	11.97	187	510	6040	32.30	0.51
Diesel	35.0	11.93	258	580	7195	27.89	0.58
AGO	29.5	11.87	312	480	6155	19.73	0.48
LVGO	27.0	11.87	336	2780	36215	107.78	2.78
Total	31.4	11.90	274.9	4600	58295	212.06	4.60



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**CRUDE OIL BREAKUP
SOLUTION TO CLASS PROBLEM**

	← For Commercial Yields →					← For Properties →												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
	TBP Cut Pt °F	Cum Vol Pct	Nominal TBP Range °F	Cut Vol Pct	Corr Factor	Vol. Pct. for Prop.	Cum Vol Pct	Mid Vol Pct Distilled	°API Gravity	Corr TBP Cut Pt °F	Corr TBP Range °F	Est ASTM IBP °F	Est ASTM EP °F	Est ASTM 50 Pct °F	UOP K	Mol Wt	Wt Pct Sulfur	(5) UOP K
C3		0.17		0.17		0.07	0.17	-	-			-	-	-	14.70	44.094	-	-
i-C4		0.34		0.17		0.17	0.34	-	-			-	-	-	13.81	58.120	-	-
nC4		1.40		1.06		1.06	1.40	-	-			-	-	-	13.50	58.120	-	-
CP	250	1.47		0.07	1.00	0.07	1.47	-	-	251		-	-	-	11.11	70.130	-	-
i-C5		2.20	IBP - 250	0.73		0.73	2.20	-	-			-	-	-	13.05	72.146	-	-
n-C5		3.67		1.47		1.47	3.67	-	-			-	-	-	13.03	72.146	-	-
LSR Gaso		14.50		10.83	0.99	10.94	14.61	9.14	70.6			140	251	188	12.35	95	0.03	12.35
Naphtha	375	28.65	250 - 375	14.15	0.99	14.29	28.90	21.76	53.3	377	251 - 377	236	381	302	11.97	125	0.06	12.93
Jet fuel	540	45.20	375 - 540	16.55	0.97	17.06	45.96	37.43	42.8	548	377 - 548	362	574	460	11.97	187	0.42	11.98
Diesel	625	54.35	540 - 625	9.15	0.94	9.73	55.69	50.83	35.0	637	548 - 637	533	676	600	11.93	258	1.28	11.99
AGO ¹	700	61.90	625 - 700	7.55	0.94	8.03	63.72	59.71	29.5	719	637 - 719	622	767	690	11.87	312	1.82	11.91
LVGO	750	66.50	700 - 750	4.60 ³	-	2.78 ²	66.50	65.11	27.0	750	719 - 750	669	800	730	11.87	336	2.10	11.85
HVGO	960	81.80	750 - 960	15.30	1.00	15.30	81.80	74.15	23.5	960	750 - 960	700	1010	850	11.96	435	2.47	11.97
SW	1000	84.00	960 - 1000	2.20	1.00	2.20	84.00	82.90	20.7	1000	960 - 1000	910	1050	980	12.05	570	2.8	12.11
Resid ⁴	EP	100.00	1000 ⁺	16.00	1.00	16.00	100.00	-	8.5	EP	1000 ⁺	-	-	1080	11.42	580	4.3	-

- Notes: (1) Total VGO arbitrarily split: LVGO 20.8 %; HVGO 69.2%; Slop Wax 10.0%
 (2) Without "Slump" Material
 (3) With "Slump" Material
 (4) Estimated Slope = 3.7
 (5) From UOP R.E. Charts B-2 and B-3. Used as a check on values in column 15.

EDS-R00-0819

OUTLINE

Introduction

Crude Assay Review

Objectives of Crude Breakup

Crude Breakup Procedure

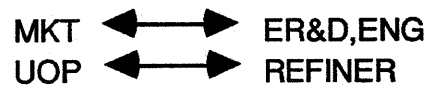
Class Problem

INTRODUCTION

History of crude breakups

Need to

Avoid Misinterpretation



Be **Consistent**

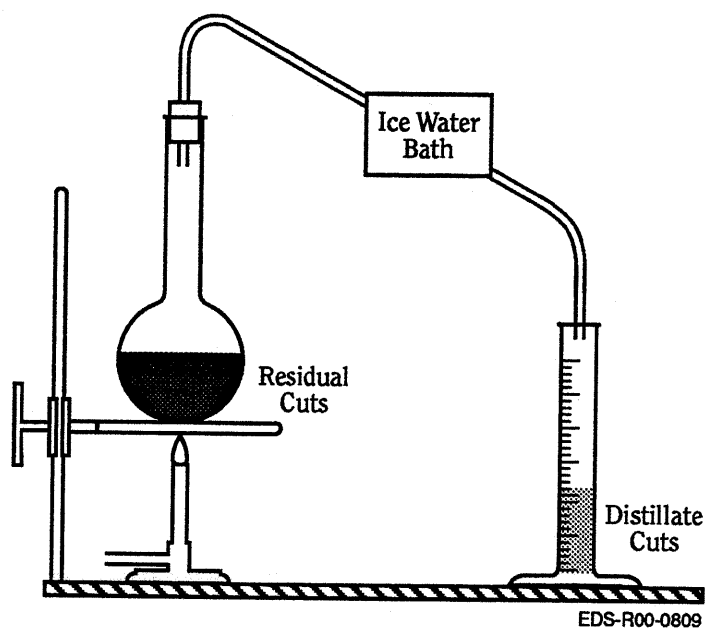
Provide Sound **Design** Basis

Experience Factors

Crude Assay

What Is It?

Information On:



Data in Tabular/Graphic Form

Crude Assays

By: UOP/Others

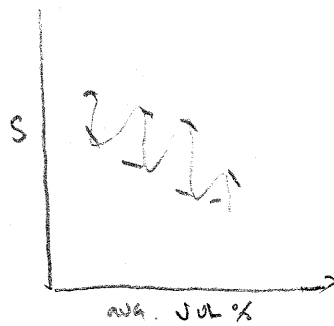
Understand Information

Read **Carefully**

Recheck Data

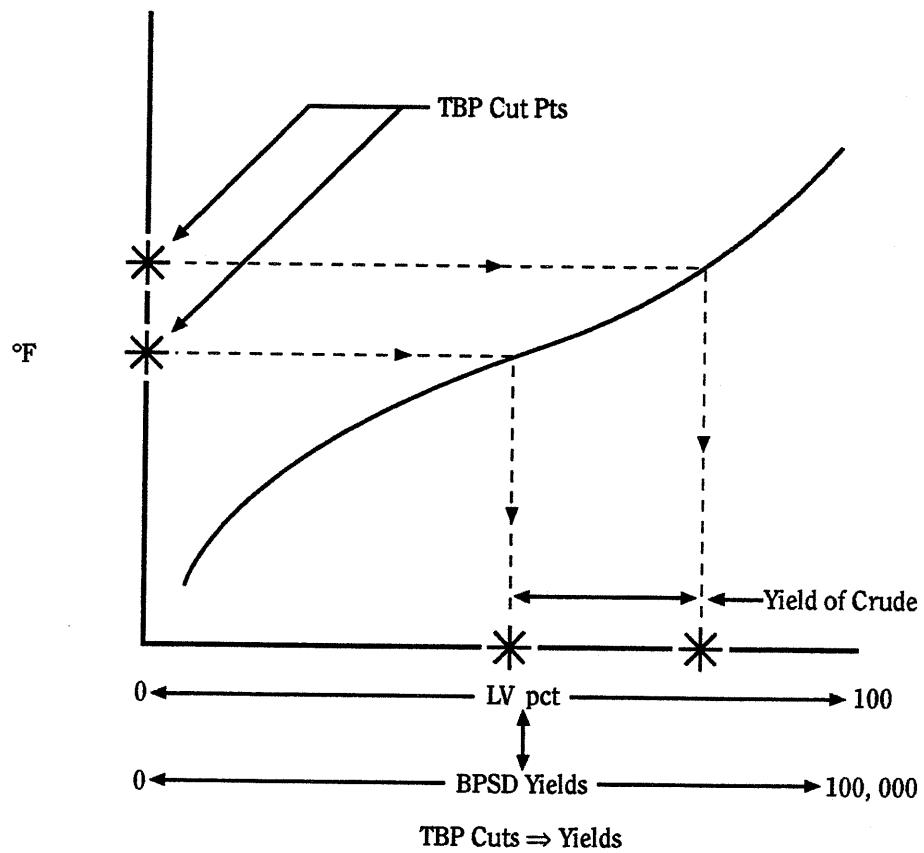
Supplement Data

△ (Operating Data)



OBJECTIVES

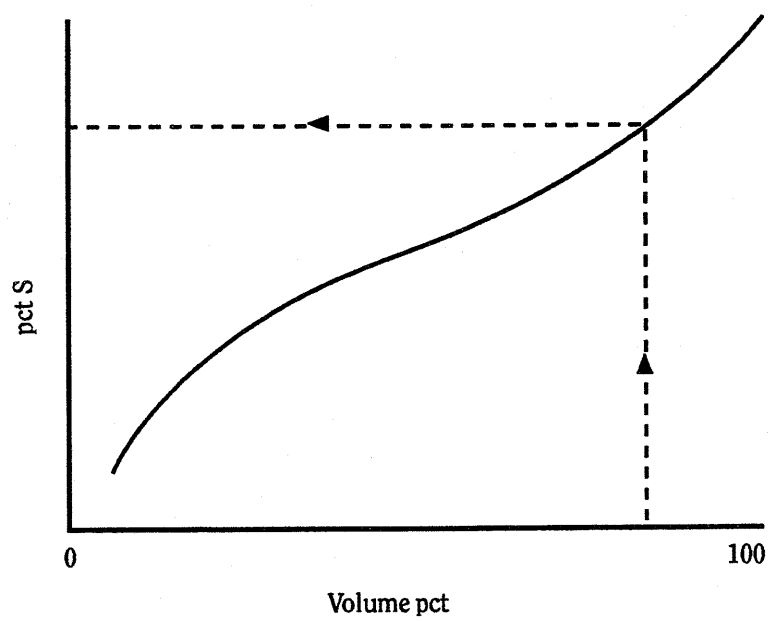
"Predict": Yields and Properties



EDS-R00-0810

OBJECTIVES

"Predict": Yields and Properties



EDS-R00-0811

OBJECTIVES

Typical Properties Required For Crude And Vacuum Design

API	BOILING PT.	SLOPE
K	MOL WT	
SULFUR	H ₂ S	SALT
ACID NO		
VISCOSITY	POUR POINT	

OBJECTIVES

Typical Properties Required For "Other" Units

API	BOILING RANGE	
SULFUR	H ₂ S	MERCAPTAN S
PONA	OCTANE NO.	SMOKE POINT
NITROGEN	VISCOSITY	METALS
CON CARBON	C ₇ -INSOL.	

PROCEDURE

GUIDELINE ONLY

USE COMMON SENSE

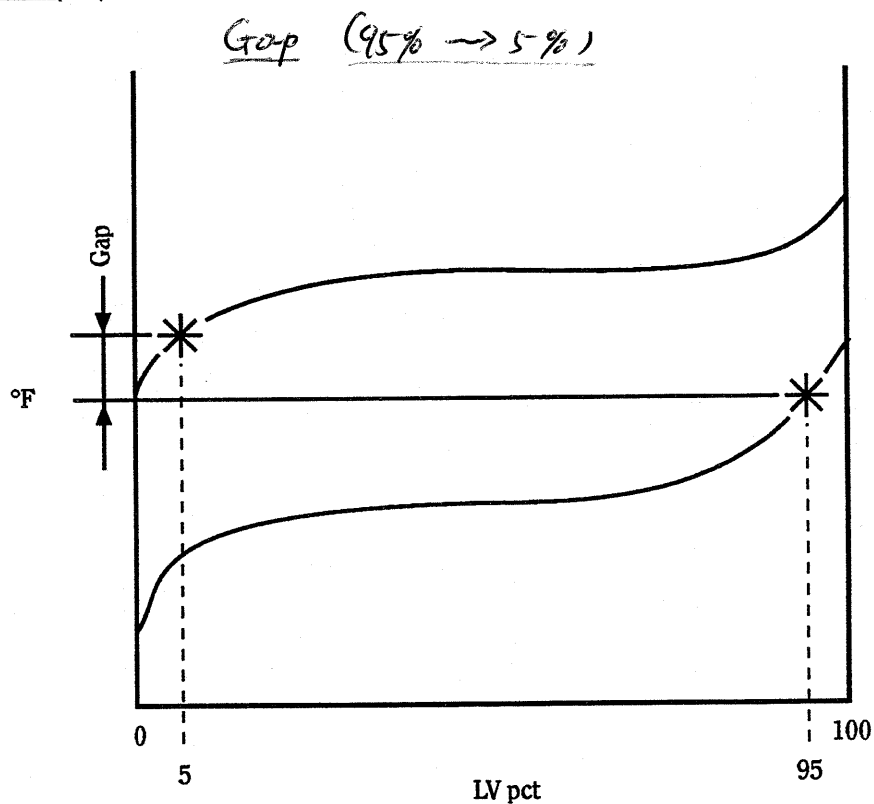
CONFLICTING DATA??

RECHECK DATA

PROCEDURE

Definitions:

GAP (95 pct - 5 pct)



ASTM
Gap ⇒ Degree of Fractionation

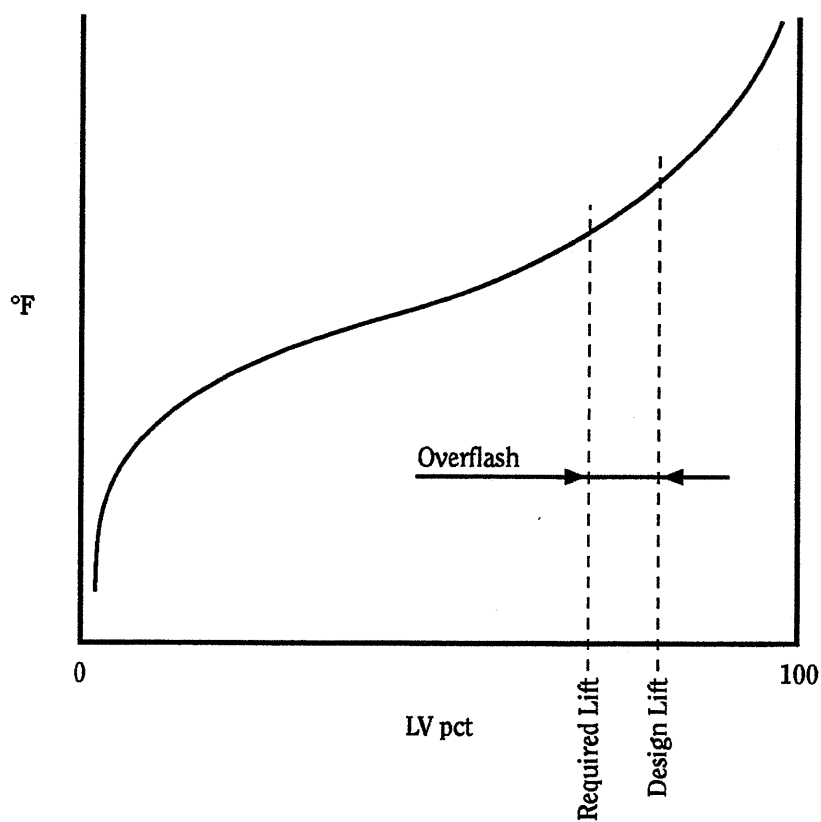
EDS-R00-0812

negative Gap = overlap

PROCEDURE

Definitions:

Overflash (3-5 pct)



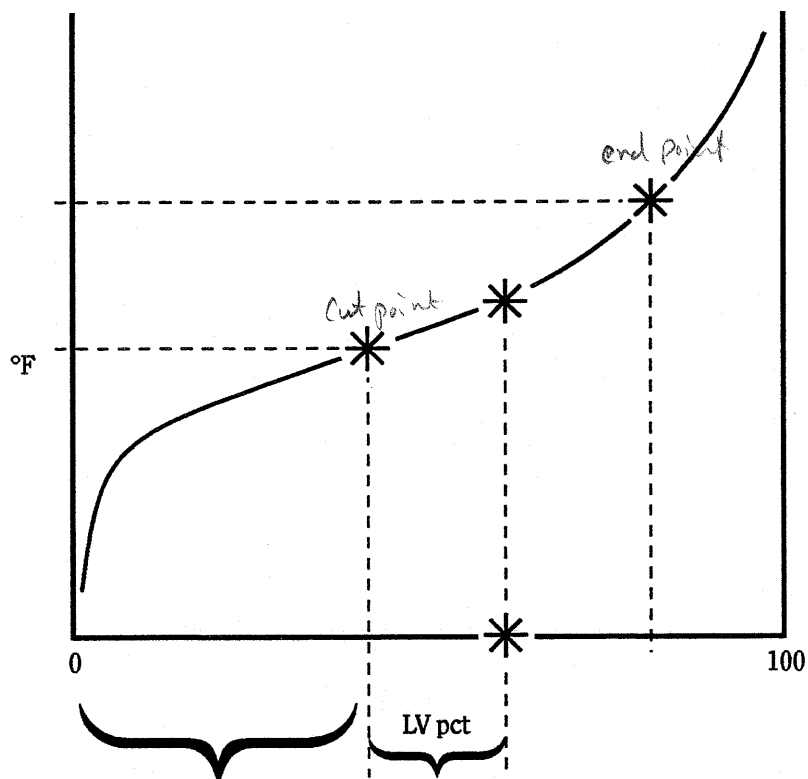
TBP
Overflash $\Rightarrow$ Internal Reflux

EDS-R00-0813

PROCEDURE

Definitions:

Mid Volume pct

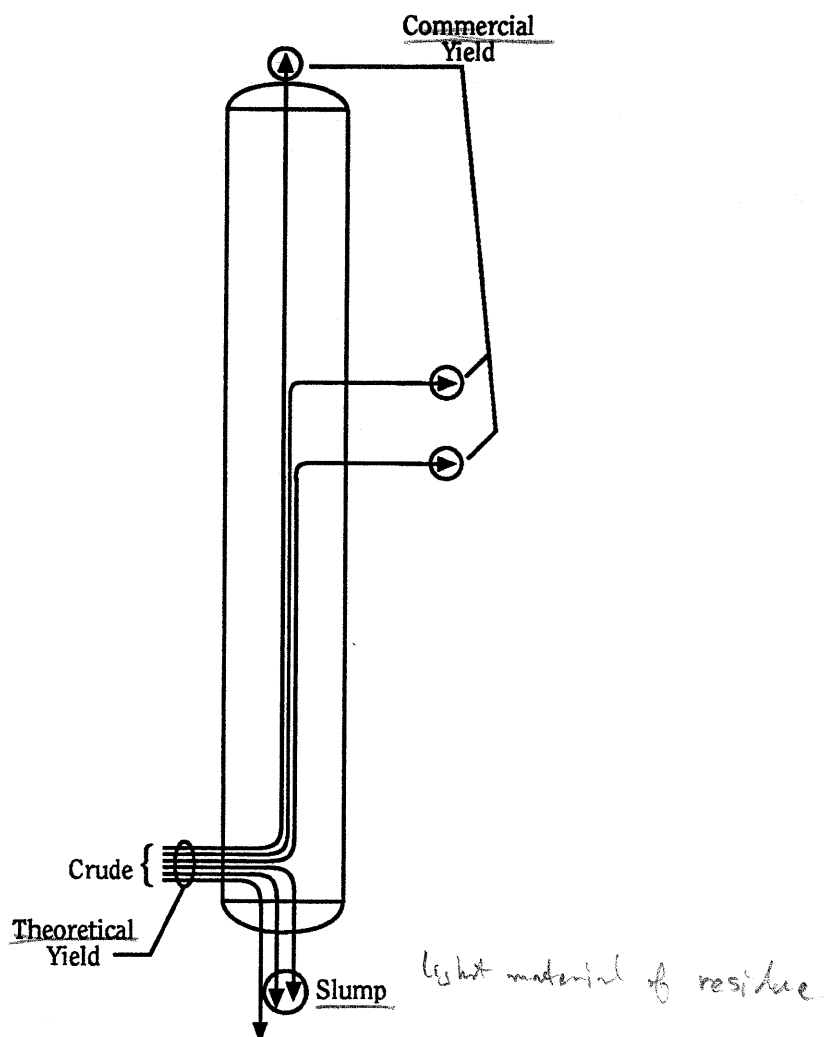


Mid Volume pct $\Rightarrow$ Distillate Cuts

EDS-R00-0814

PROCEDURE

Definitions:



EDS-R00-0815

PROCEDURE

DESIGN CRITERIA:

• NO. TRAYS	6-10	8 ~ 12 trays
• OVERFLASH	0 - 5 LV Pct.	
• REFLUX	1.0 R/D	
• STRIPPING STEAM	8 - 10 lb/bbl	incoming to side stripper.
side cut stripper	typical	

PROCEDURE

CHECK BS & W

PLOT DATA

DISTILLATES - Mid Vol Pct
RESIDUALS - Vol Pct

START WITH:

YIELDS OR PROPERTIES???

"SET" SLUMP

FIND MID VOL Pct

FIND PROPERTIES

0.5 Vol %
of total crude.

Bottom sludge & water content
Settling water at Crude Tank
Storage

PROCEDURE

"SET" ASTM DISTILLATION

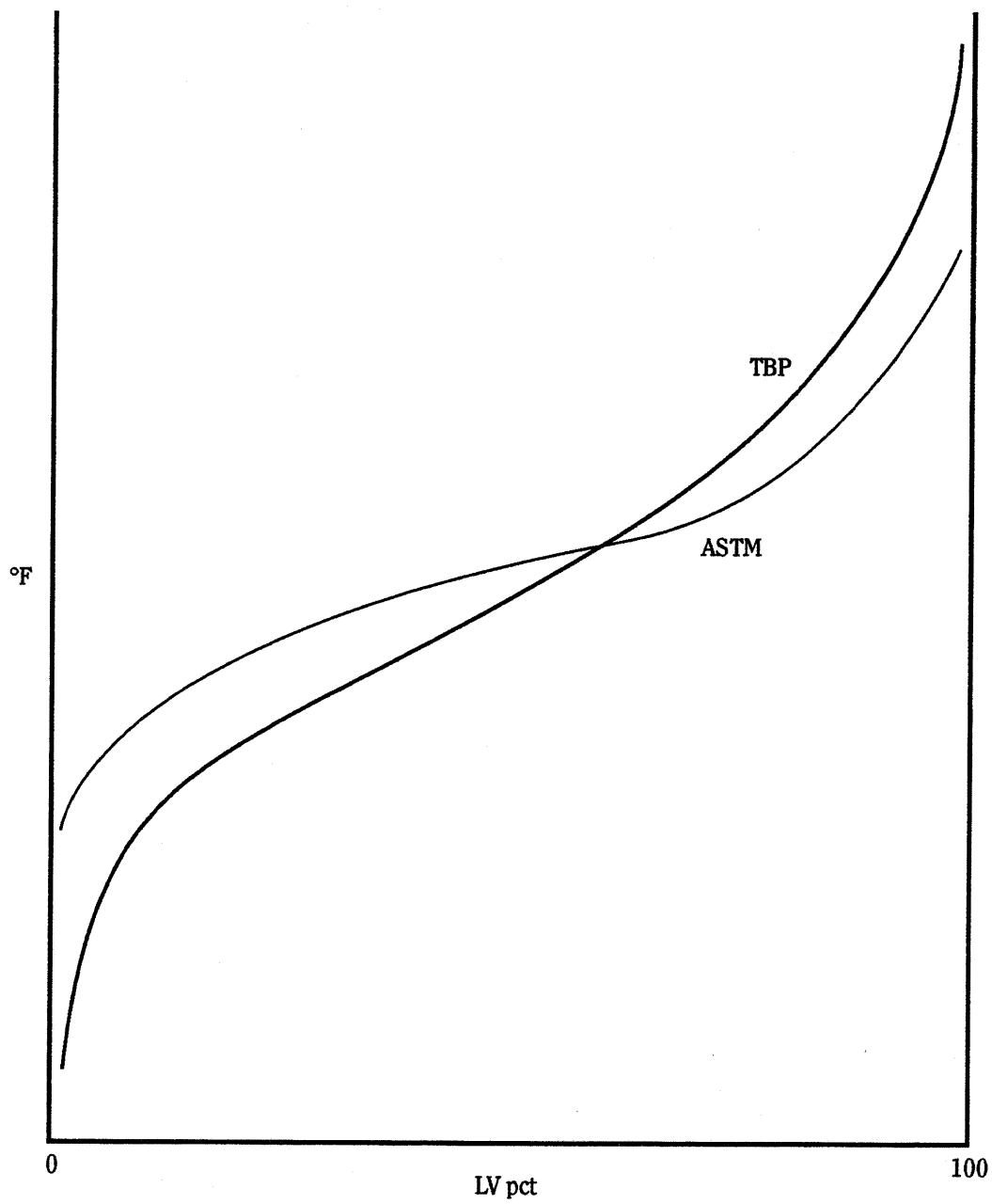
BREAK-UP VGO

FIND "K" FROM ASSAY INFORMATION

CALCULATE "K" VIA 50 Pct POINT

FIND MOL WT

PROCEDURE



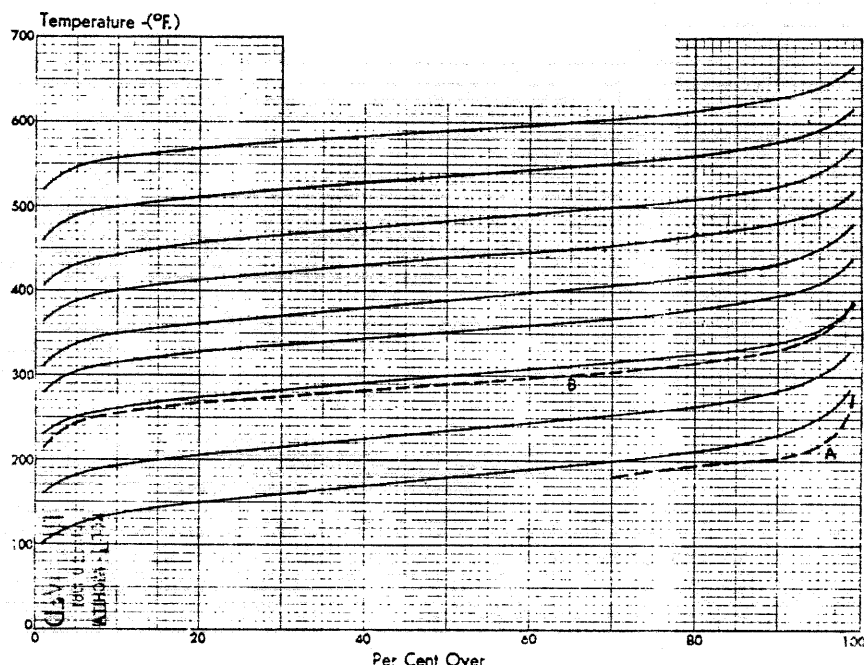
EDS-R00-0816

New tool puts finger on faulty crude-tower distillation...

Probability chart helps pinpoint the cause of trouble

BY G. C. THRIFT

Koch Engineering Co., Inc.,
Wichita, Kans.



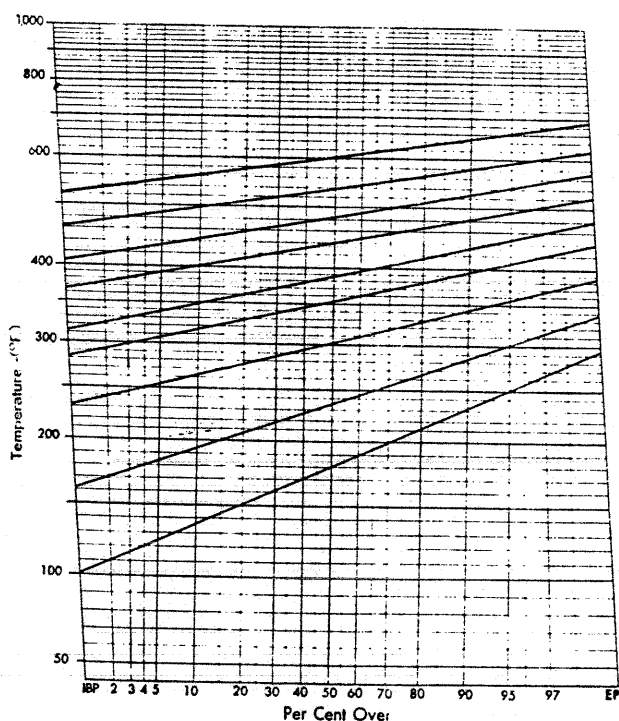
SUPERIMPOSING DISTILLATION CURVES from a problem unit over ideal distillation curves helps the operator to analyze the trouble. Fig. 1

MOST STARTUP operators and trouble shooters have accumulated a morgue of typical operating data and product tests. Invariably this morgue contains numerous ASTM distillation curves of products from familiar, well-designed, and well-operated units.

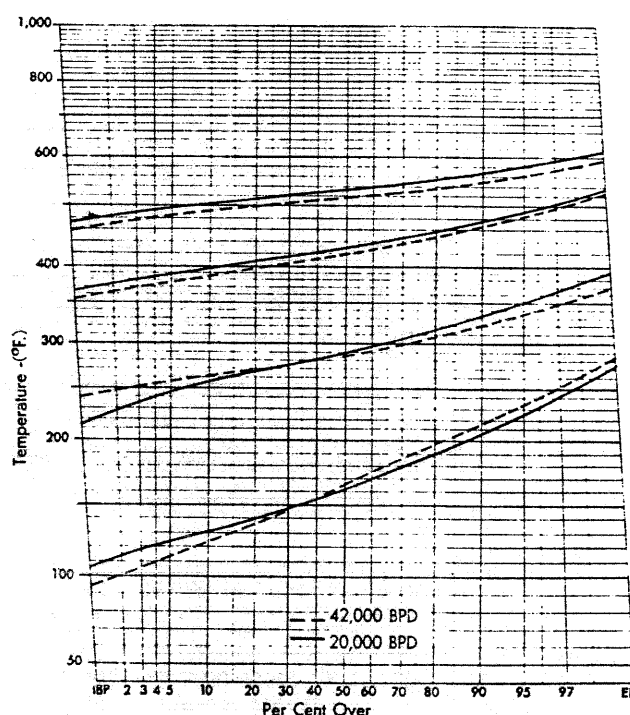
Many have those ASTM's idealized and plotted similar to those in Fig. 1. By using these plotted ASTM's as "par" and superimposing the plots of ASTM's from problem units, much can be gained by comparing the character or curve shapes of the two sets of ASTM's.

Such a superimposition is shown

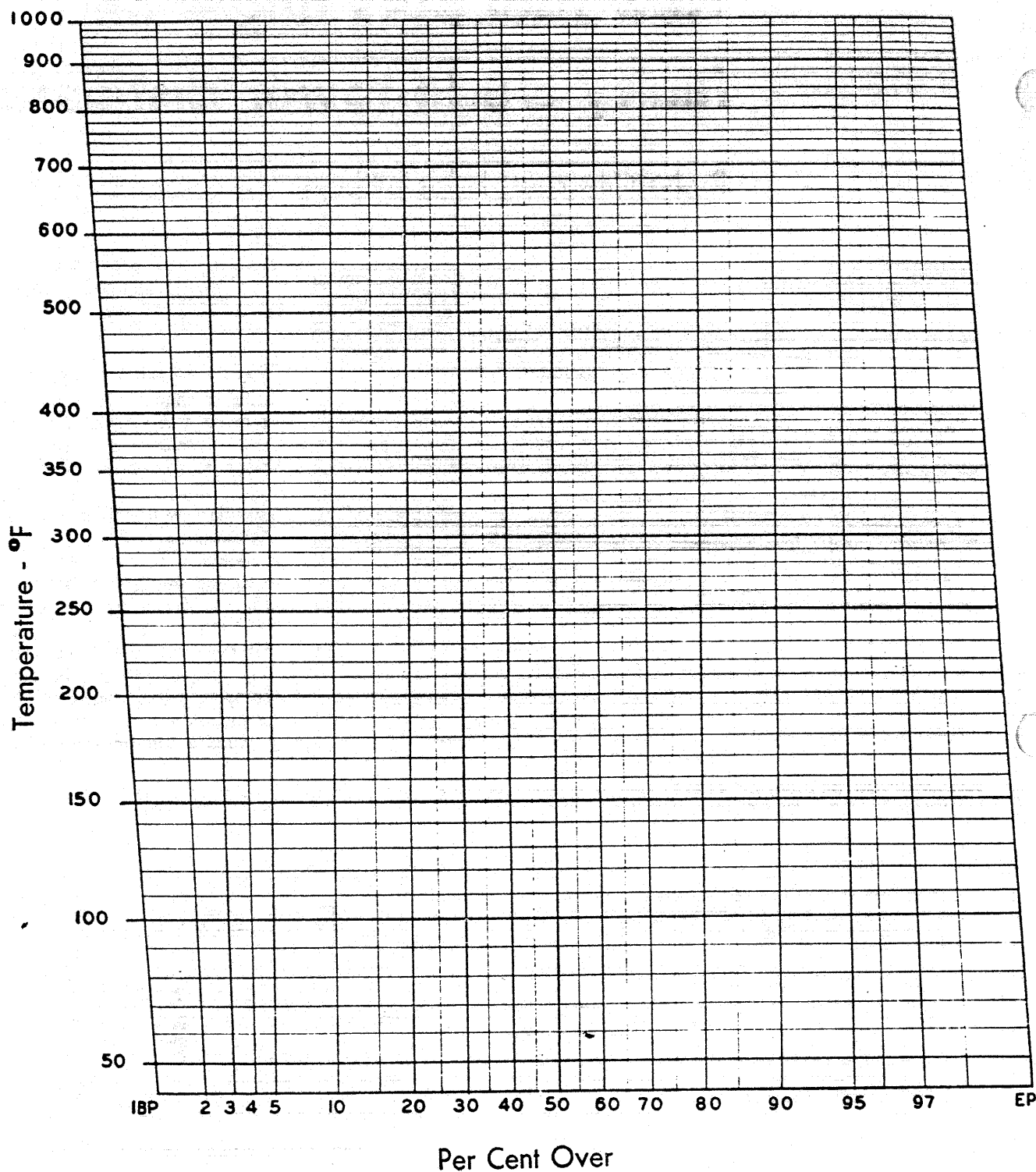
A paper presented to WPKA, Wichita, Kans., May 1961.



NOTE THAT ALL of the ASTM's plotted here are straight lines. These are the same idealized ASTM's that show up as curves in Fig. 1. Fig. 3.



IDENTICAL OPERATING conditions produced naphthas of different boiling ranges. Inspection showed installation errors in the tower zone. Fig. 4.



PROBABILITY CHART is based on over 100 ASTM's of stripped products from well-designed units. Fig. 2.

by dashed lines A and B in Fig. 1. The abrupt curve near the end point of the lowest-boiling material (point A) is positive evidence that it is contaminated with heavier-boiling material. It was found that a leaky valve in a pump manifold was to blame. B is simply a poorer-than-average fractionated product.

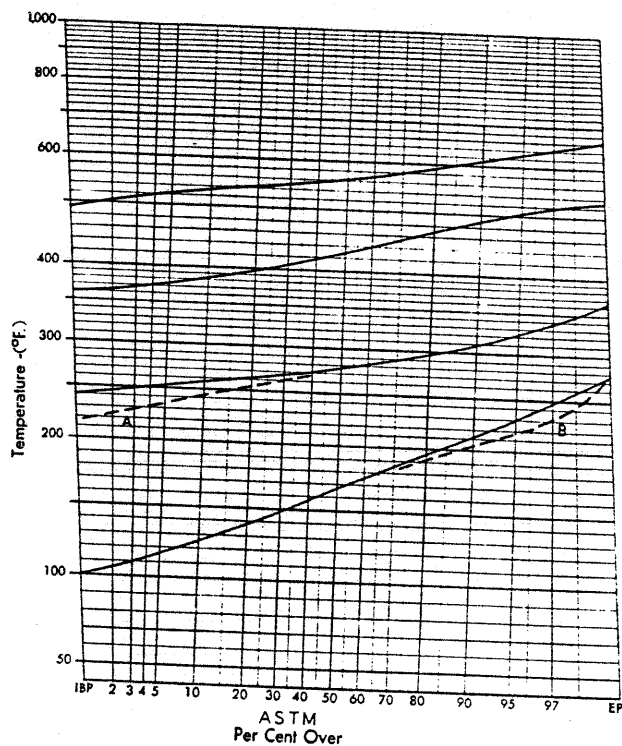
Considerable experience is help-

ful, and even necessary, to get the most out of comparing a curve with a straight line. The departure of the "sport" or problem ASTM from par, or a straight line, is obvious and graphic. Much more will be obvious to the untrained observer.

With empirical scales, ASTM's of stripped crude-unit products can be plotted as essentially straight lines.

Fig. 2 is such a scale. It is based on more than 100 ASTM's of stripped products from units of good design and well within their efficient operating range. Similar methods were used many years ago on the development of the viscosity-temperature relationship chart for petroleum oils.

Fig. 3 includes the same idealized



LINE A reveals an ~~overstripped~~ naphtha. Line B shows a contaminated gasoline. Fig. 5.

ASTM's as are plotted in Fig. 1. Note that all of the ASTM's plot as straight lines.

Typical uses of the probability chart are shown in Figs. 4 to 7.

By preparing such a chart as Fig. 3 for each new unit, on each typical duty, any subsequent tray damage or efficiency deterioration can be readily spotted. Experience with the chart will teach the analyst or operator a great deal.

Here are some general observations and what they mean:

Curved down near i.b.p. = poor stripping.

Curved up near i.b.p. = overstripping.

Curved up near e.b.p. = contamination or entrainment.

Curved down near e.b.p. = contamination or abnormal fractionation or stripping of next higher boiling cut.

Lines with greater slope than normal = generally poorer fractionation.

Lines with lesser slope than normal = abnormally good fractionation.

While this chart is meant for crude distillation alone, it will assist in other relatively wide-boiling-range product evaluations.

Acknowledgment

The writer thanks Koch Engineering Co., Inc., for permission to publish these data.

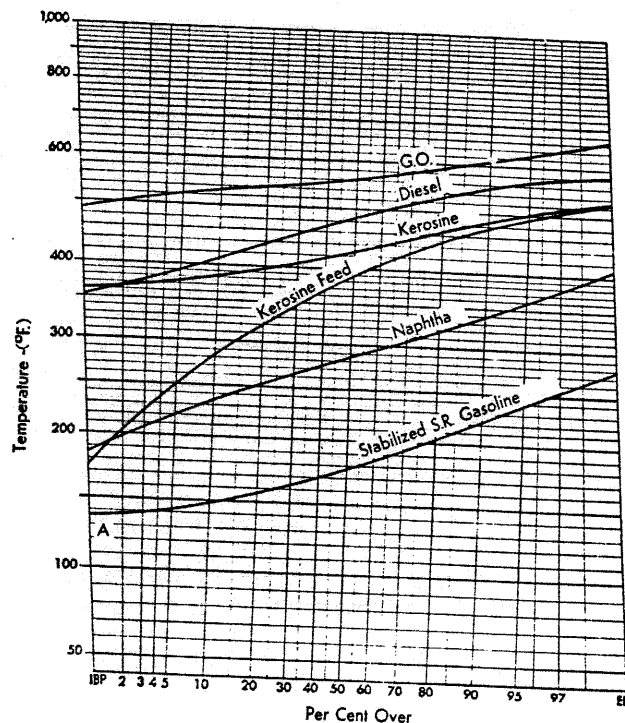
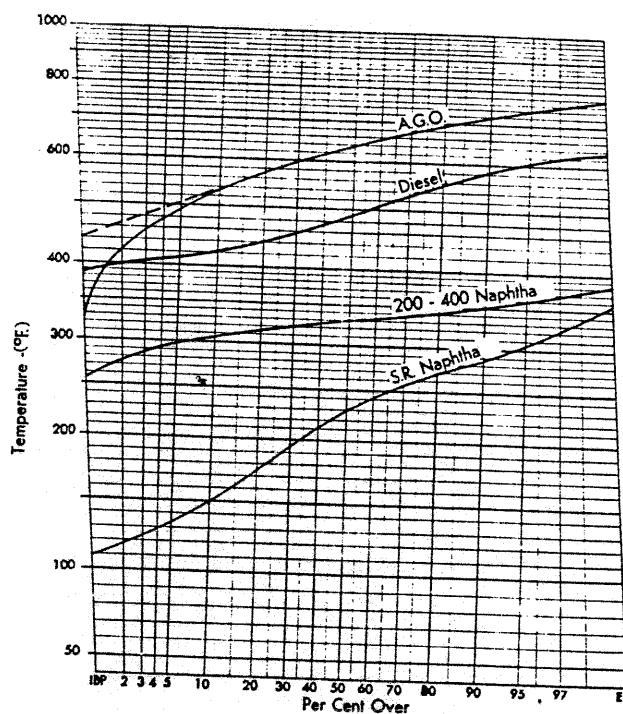


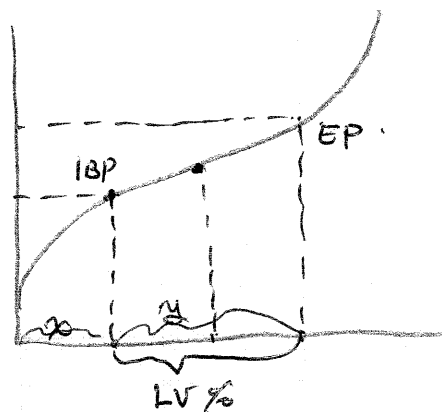
CHART SHOWS a straightrun naphtha stabilized to lower-than-average vapor pressure (point A). Fig. 6.



BADLY CORRODED TRAYS gave these operating results. The gas oil was unstripped in this case. Note the abnormal character of the lines. These "galloping" ASTM's frequently result on manual equipment and should be checked before analysis. Fig. 7.

(1) (1)	(2) (2)	(3) (3)	(4) (4)	(5) (5)	(6) (6)	(7) (7)	(8) (8)	(9) (9)	(10) (10)
IBP Cut Pt	Cut Vol %	Named TBP Range °F	Cum Vol %	Correction factor	Vol % for properties (4)/(5)	Cum Vol %	Mid Vol % Distilled	API Gravity	Corr TBP Cut Pt
C ₅	3.67	1BP ~ 45	3.67	1.00	3.67	3.67	-	-	-
LSR 300	16.33	46 ~ 300	20.00	0.99	16.44	20.16	11.92	65.9	302
Naph 385	9.80	300 ~ 385	29.8	0.99	9.90	30.06	25.11	50.6	388
Kero 515	13.80	385 ~ 525	43.6	0.97	14.23	44.29	37.19	42.9	530
Diesel 600	8.0	525 ~ 600	51.6	0.94	8.51	52.80	48.55	36.3	611
AGO 675	7.8	600 ~ 675	59.4	0.94	8.40	61.20	57.00	31.1	642
V ₆₀ 1000	24.5	675 ~ 1000	84.00	(Diff)	22.80 (4)	84.00	72.6	24.2	1000
Residue 1000+	16.00	1000 +	100.00	1.0	16.00	100.00	-	8.5	-
Total	100.00								
C ₅									
LSR									
NAPH									
KERO									
DIESEL									

Light End	Vol %
C ₃	0.17
1 BP	0.17
2 BP	1.06
CP	0.07
2 C ₅	0.73
7-65	1.47
	<u>3.67</u>



$$\text{Mid. Vol \%} = x + \frac{y}{2}$$

	(11) CORR TBP Range °F	(12) Est ASTM IBP, °F	(13) Est. ASTM EP, °F	(14) Est. ASTM 50% Pt	(15) HOP ± Assay ASTM	(16) Mol Wt	(17) Wt % Sulfur	API
C ₅	-	-	-	-	-	-	-	-
LSR	6 ~ 302	140	302	207	12.18 12.18	99	0.03	
NAPH	302 ~ 388	287	392	335	11.97 11.92	137	0.05	
KERO	388 ~ 530	373	533	455	11.97 11.95	185	0.4	
DIESEL	530 ~ 611	515	644	580	11.95 12.02 12.02	245	1.08	
AGO	611 ~ 692	596	786	665	11.88 11.93	297	1.67	
VGO	692 ~ 1000	642	1050	840	11.93 11.92	390	2.40	
VAC RESID.	1000+	950	-	1090 (1)	11.42	580	4.30	

most reliable

fig. 4

$$K = \frac{(207 + 460)^3}{\left(\frac{141.5}{131.5 + 05.9} \right)} = 12.1389$$

$$12 = \frac{(CIBP)^3}{0.8433}$$

$$CIBP = \left\{ (12)(0.8433) \right\}^{\frac{1}{3}} - 460$$

$$= 576$$

API BPSD lb/hr m³/hr Vol % sp. GR. MW

(100000)

Cs-		3670	32650	448.87	3.67	0.6097	65.448
LSR	65.9	16460	172626	1743.7	16.48	0.7163	99
NAP	50.6	9900	112342.5	820.	9.4	0.7777	137
KERO	42.9	14230	168626.8	911.5	14.23	0.8114	185
DIESEL	36.3	8510	104809.	427.8	8.51	0.8433	245
AGO	31.1	8460	106754	359.4	8.40	0.8702	297
VGO	26.1	22800	310358 302812.4	776.4	22.8	0.9097	390
Residue	8.5	16000	236172.3	407.2	16.00	1.0107	580

Correct specific gravity of VGO to adjust total mass flow rate to meet it.

Crude API = 34.5

Flow = 100 000 BPSD

Max Flow = 1243,700 lb/hr.

Class Problem

Page 10

	(1) TBP Cut pt °F	(2) Cum Vol. %	(3) Nominal TBP Range, °F	(4) Cut Vol. %	(5) Correction factor	(6) Vol % for properties (4)/(5)	(7) Cum Vol. %	(8) Mid. Vol % Distill	(9) °API Gravity
C5	C5	3.67	BP-C5	3.67	1.00	3.67	3.67	-	100.6
LSR	250	14.5	C6-250	10.83	0.99	10.94	14.61	9.14	71.5
NAPH	375	28.7	250-375	14.20	0.99	14.34	28.95	21.98	53.5
JET FUEL	540	45.2	375-540	16.50	0.97	17.01	45.96	37.46	43.0
DIESEL	625	59.3	540-625	9.10	0.94	9.68	55.64	50.80	35.0
AGO	700	61.9	625-700	7.60	0.94	8.09	63.73	59.70	29.5
LVGO (20%)	750	60.3	700-750	4.42	*(By diff.)	2.59	66.32	65.03	27.5
90% HVGO VGO HVGO	1000 960	81.8	750-960	15.47	1.0	15.47	81.79	74.06	23.0
10% W Vac. Resid.	1000 + 1000	84.0	960-1000	2.21	1.0	2.21	84.00	82.90	21.0
RESID	+1000	16.0	1000+	16.00	1.0	16.00	100.00	92.00	8.5

	(10) Corr TBP Cut pt, °F	(11) Corr TBP Range °F	(12) Est. * ASTM IBP, °F	(13) Est. ASTM EP, °F	(14) Est ASTM 50% Pt	(15) UOP K	(16) Mid. Wt % Sulfur	(17) Wt % Sulfur	Sp. Gr.
C5		BP-C5				8.32			
LSR	251	C6-250	140	251	188	12.35	2.35	95	0.697
NAPH	377	251-377	236	380	302	11.87	11.93	85	0.7689
JET FUEL	550	377-550	362	575	425 460	11.87	11.94	187	0.8109
DIESEL	635	550-635	535	675	577 600	11.93	11.90	250	0.8498
AGO	722	635-722	620	760	685	11.87	11.91	312	0.8789
LVGO	750	722-750	672	800	728 735	11.87	11.85	36	0.8879
90% HVGO	960	750-960	700	1010	877 895	11.96	11.97	435	0.9159
10% W Vac. Resid	1000	960-1000	910	1050	965 980	12.05	12.11	520	0.9209
RESID	1000+	1000+				11.42	12.13		1.0107

* VGO shall contain slump.

* * C6+ TBP ≤ 350°F ⇒ use as ASTM EP
* ASTM IBP = initial TBP cut point - 15°F except VGO

* ASTM EP = from Fig. 7

* For VGO ; ASTM IBP = initial TBP cut point - 50°F

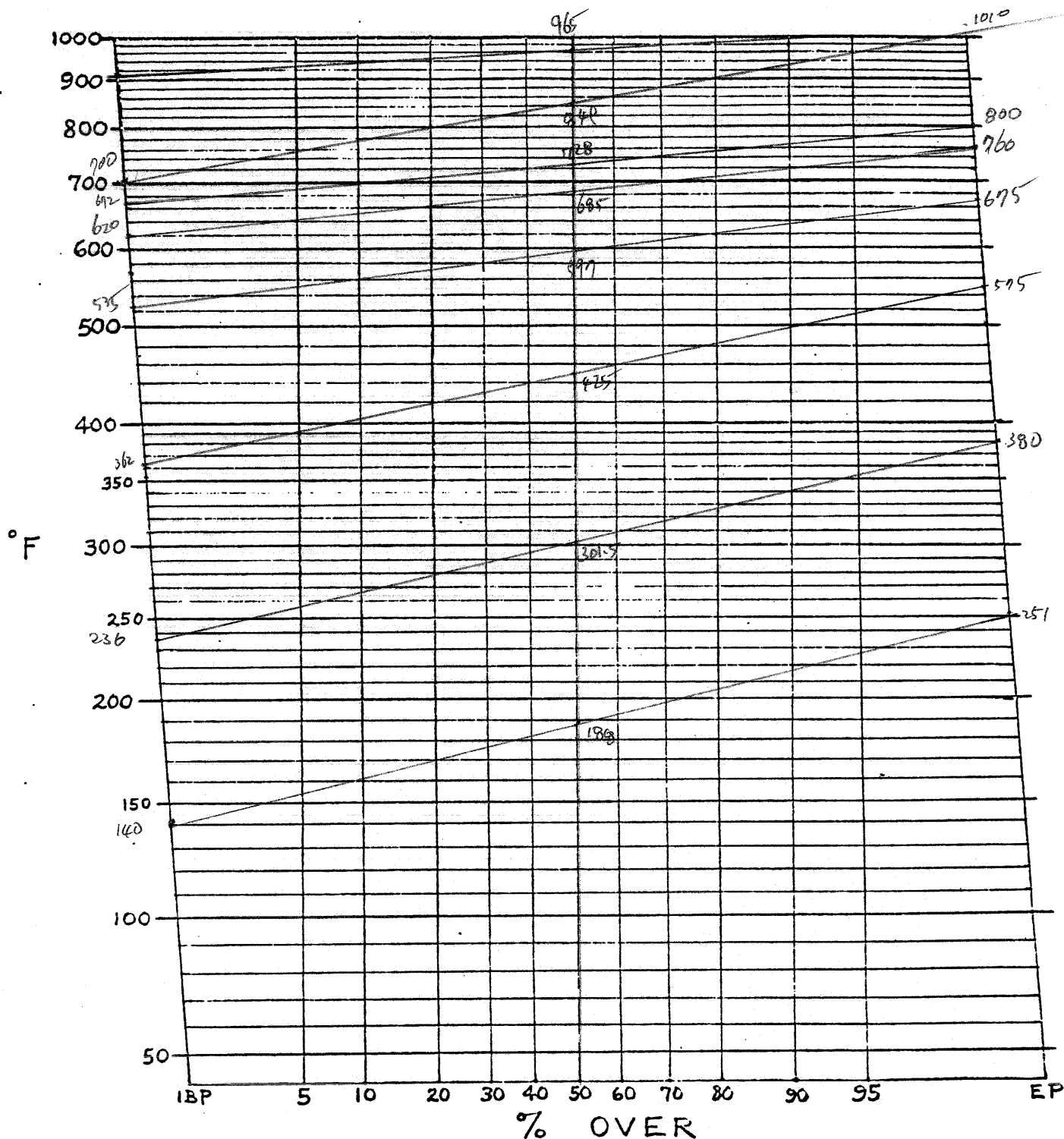
ASTM EP from fig. 9 or 50°F higher than its TBP EP.

B-2,3
with
mean Ave
BP

SUBJECT Probability Chart
 FOR ASTM Plots (stripped Products)

DATE _____
 BY _____

Ref. - O & G J 9/4/61 p. 180



PD-544

1-31-73

FNMSW

Outline.

Introduction

Crude Assay Review

Objective of Crude Breakup

Crude Breakup Procedure.

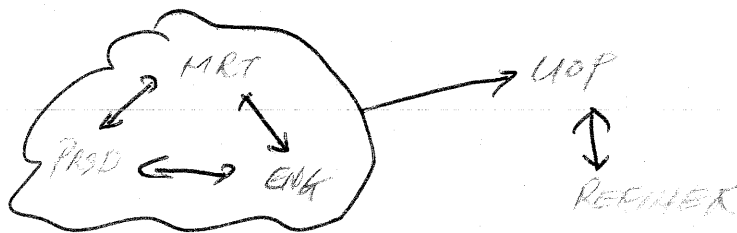
Class Problem

Introduction.

History of Crude Breakup

Need to ;

Avoid misinterpretation

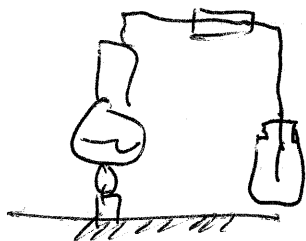


Crude Assay.

What is it?

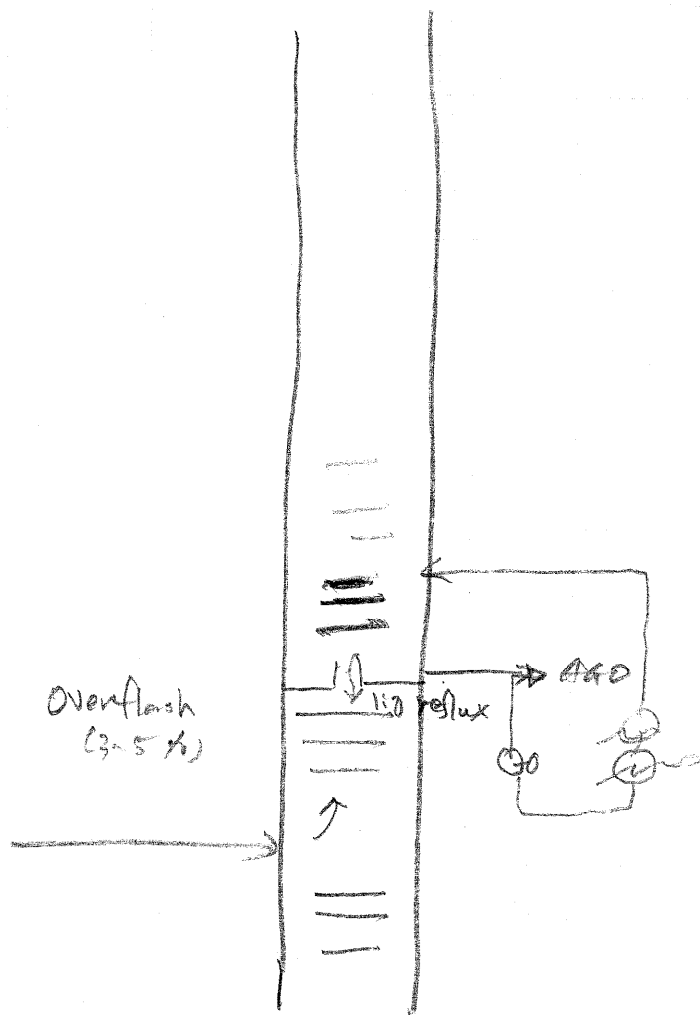
Information on

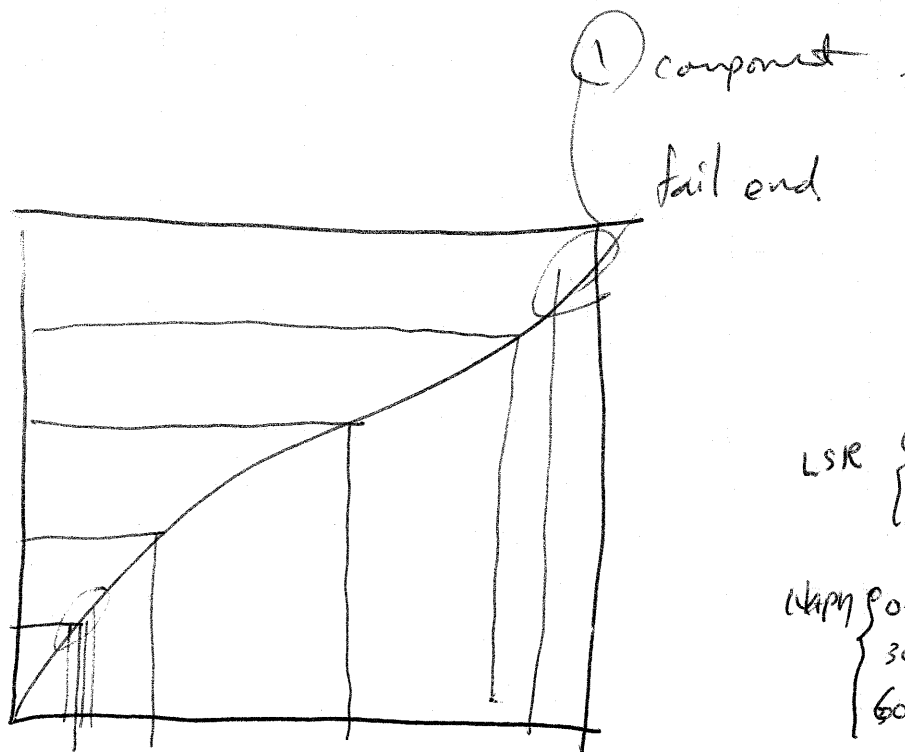
Distillate cuts



Residue Cuts

Data 14





LSR $\begin{cases} 0 \sim 60 = 1 \text{ component} \\ 60 \sim 100 = 5 \text{ components} \end{cases}$

Wap $\begin{cases} 0 \sim 30 = 5 \\ 30 \sim 60 = 1 \\ 60 \sim 100 = 5 \end{cases}$

• 10 ~ 20°F of component cut.

Book: Gutf, 1982

- Petroleum Refinery Distillation,
- Charles Holland.
- Working

Lighter stream = 10 °F

Heavier stream = 20

30 ↓

3/ BT
KF - (SPOR)

(K) (SPOR)