Homework #3

Imagine that you have been hired to work at a small refinery. You’ve been asked to evaluate the contribution of 50,000 bpd of a new sour crude (see attached). Do the following:

1. Tabulate the yield data for all of the unique fractions (i.e., do not include the whole crude, the 369°-FBP Atm Resid, or the 509°-FBP Vac Resid). Include in your table:
   - Incremental yield for the cut (vol%)
   - Incremental yield for the cut (wt%)
   - Density @ 15°C (kg/L)
   - Sulfur content

2. Add the following calculated values to the table:
   - TBP at Start of Cut / IBP (°F)
   - TBP at End of Cut / FBP (°F)
   - Cumulative Yield at Start (vol%)
   - Cumulative Yield at End (vol%)
   - Density @ 60°F (kg/L)
   - Specific Gravity
   - °API
   - Cumulative yield at the middle of the cut (vol%)
   - TBP consistent with this mid-increment yield
   - Watson K Factor calculated from the mi-increment TBP

3. Plot the values of Cumulative Yield at start of cut (vol%) vs. TBP at start of cut (°F).

4. Plot the values of API gravity vs. the mid-increment Cumulative Yield (vol%).

5. Plot the values of sulfur content vs. the mid-increment Cumulative Yield (vol%).

6. A total gas oil in the boiling range 648 to 1022°F will be sent to the FCCU. Calculate as appropriate for this vacuum gas oil:
   - Specific Gravity
   - °API gravity
   - Watson K factor
   - Sulfur content (wt%)
   - The amount of total gas oil to the FCCU feed (in bpd & lb/day)
   - The mass amount of sulfur from the gas oil (in lb/day)
BP Oil International Ltd., a subsidiary of BP PLC, has re-issued an assay for Schiehallion crude oil to coincide with the May 2017 resumption of production from the Schiehallion area. Field redevelopment is part of the multibillion-pound Quad 204 project in the west of Shetland region offshore UK (OGJ Online, May 22, 2017).

The project included the construction and installation of the 130,000-boe/d Glen Lyon harsh-water floating production, storage, and offloading vessel (FPSO), replacement of subsea installations, and a drilling program of as many as 20 wells to enable full reserves development.

Following Quad 204’s approval in 2011, production of Schiehallion crude—the marketing name for the blended stream produced from Schiehallion and Loyal fields—was suspended in early 2013 to accommodate the mid-2014 decommissioning of the original Schiehallion FPSO. Works to return the fields to historical peak production rates last achieved in 2000-02 were also completed.

With seven new production system manifolds, overall subsea system capacity has been expanded beyond 75 wells. Equipped to store 800,000 bbl of oil, the new FPSO is connected to the seafloor via 21 new risers: 15 production, 3 gas, and 3 water injection. The 15 production risers are connected to production flowlines totaling 55 km in length. Gas risers and water injection risers are connected to existing infrastructure.

Designed to withstand winds in excess of 100 mph and waves that can reach more than 50 ft high, the FPSO is scheduled to ramp up to its plateau production rate of 130,000 boe/d by 2018.

The Glen Lyon FPSO is operated by BP with 36% interest alongside partners Royal Dutch Shell PLC 54% and Siccar Point Energy Ltd. 10%.

Schiehallion field interest is Shell 55%, BP 33%, and Siccar Point Energy 12%. Loyal field interest is split 50-50 between BP and Shell.

Schiehallion and the adjacent Loyal field have produced nearly 400 million bbl of oil since production started in 1998 (OGJ, Aug. 17, 1998, p. 38). The fields’ redevelopment through the Quad 204 project targets recovery of an additional estimated 450 million bbl, extending their life beyond 2035.
Whole crude
API gravity at 60/60° F: 25.2
Density at 15° C., kg/l.: 0.9025
Total sulfur, wt %: 0.458
Mercaptan sulfur, ppm (wt): 2
Total nitrogen, ppm (wt): 1,300.0
Basic nitrogen, ppm (wt): 418
Acidity, mg KOH/g: 0.310
Vis. at 20° C., cst: 67.41
Vis. at 30° C., cst: 38.55
Vis. at 40° C., cst: 23.96
Vis. at 50° C., cst: 15.930
Pour point, °C.: 6
Wax, wt %: 7.0
Carbon residue, wt %: 2.90
Asphaltenes, wt %: 0.30
Vanadium, ppm (wt): 8
Nickel, ppm (wt): 6
Iron, ppm (wt): 1
Ethane, wt %: 0.01
Propane, wt %: 0.02
Isobutane, wt %: 0.03
n-Butane, wt %: 0.06
Isopentane, wt %: 0.06
n-Pentane, wt %: 0.07
Cyclopentane, wt %: 0.02
C₆ paraffins, wt %: 0.26
C₆ naphthenes, wt %: 0.33
Benzene, wt %: 0.01

Light naphtha, C₆ to 95° C.
Yield on crude, wt %: 1.05
Yield on crude, vol %: 1.35
Density at 15° C., kg/l.: 0.7108
Total sulfur, wt %: 0.005
Mercaptan sulfur, ppm (wt): 12
Acidity, mg KOH/g: 0.030
Paraffins, wt %: 49.65
Naphthenes, wt %: 49.33
Aromatics, wt %: 1.02
n-Paraffins, wt %: 17.93
Research octane no.: 74.1

Heavy naphtha, 95-149° C.
Yield on crude, wt %: 2.55
Yield on crude, vol %: 3.00
Density at 15° C., kg/l.: 0.7743
Total sulfur, wt %: 0.006
Mercaptan sulfur, ppm (wt): 11
Total nitrogen, ppm (wt): 0.2
Acidity, mg KOH/g: 0.037
Paraffins, wt %: 21.63
Naphthenes, wt %: 67.18
Aromatics, wt %: 11.18
n-Paraffins, wt %: 3.17
Research octane no.: 72.0

149-175° C.
Yield on crude, wt %: 1.75
Yield on crude, vol %: 1.95
Density at 15° C., kg/l.: 0.8068
Total sulfur, wt %: 0.021
Mercaptan sulfur, ppm (wt): 23
Total nitrogen, ppm (wt): 0.5
Acidity, mg KOH/g: 0.037
Paraffins, wt %: 22.03
Naphthenes, wt %: 63.81
Aromatics, wt %: 14.15
n-Paraffins, wt %: 3.05
Research octane no.: -13.0

Kerosine, 175-232° C.
Yield on crude, wt %: 6.35
Yield on crude, vol %: 6.80
Density at 15° C., kg/l.: 0.8455
Total sulfur, wt %: 0.039
Mercaptan sulfur, ppm (wt): 5
Total nitrogen, ppm (wt): 1.1
Acidity, mg KOH/g: 0.029
Vis. at 40° C., cst: 1.40
Vis. at 60° C., cst: 1.081
Smoke point, mm: 17.5
Aromatics, vol %: 23.0
Naphthenes, wt %: 1.28
Freezing point, °C.: 74.5
Cetane index (ASTM D4737-90): 29.2
Refractive index at 70° C.: 1.4438

Light gas oil, 232-342° C.
Yield on crude, wt %: 25.75
Yield on crude, vol %: 26.55
Density at 15° C., kg/l.: 0.8757
Total sulfur, wt %: 0.189
Mercaptan sulfur, ppm (wt): 3
Total nitrogen, ppm (wt): 21.0
Basic nitrogen, ppm (wt): 16
Acidity, mg KOH/g: 0.100
Vis. at 50° C., cst: 3.266
Vis. at 100° C., cst: 1.459
Aromatics, wt %: 33.60
Smoke point, mm: 13.4
Aromatics, vol %: 29.7
Naphthenes, wt %: 9.81
Pour point, °C.: 21
Cloud point, °C.: 21
Freezing point, °C.: 21
Cetane index (ASTM D4737-90): 42.9
Refractive index at 70° C.: 1.4672

Heavy gas oil, 342-369° C.
Yield on crude, wt %: 6.60
Yield on crude, vol %: 6.65
Density at 15° C., kg/l.: 0.8917
Total sulfur, wt %: 0.416
Total nitrogen, ppm (wt): 150.0
Basic nitrogen, ppm (wt): 60
Acidity, mg KOH/g: 0.250
Vis. at 50° C., cst: 8.312
Vis. at 100° C., cst: 2.744
Pour point, °C.: 9
Cloud point, °C.: 7
Cetane index (ASTM D4737-90): 55.0
Refractive index at 70° C.: 1.4774
Aniline point, °C.: 74.8
Wax, wt %: 9.8

Light vacuum gas oil, 369-509° C.
Yield on crude, wt %: 30.55
Yield on crude, vol %: 30.10
Density at 15° C., kg/l.: 0.9165
Total sulfur, wt %: 0.464
Total nitrogen, ppm (wt): 7.480
Basic nitrogen, ppm (wt): 235
Acidity, mg KOH/g: 0.410
Vis. at 60° C., cst: 24.920
Vis. at 100° C., cst: 7.445
Pour point, °C.: 27
Refractive index at 70° C.: 1.4867
Aniline point, °C.: 86.4
Wax, wt %: 10.0
Carbon residue, wt %: 0.04

Heavy vacuum gas oil, 509-550° C.
Yield on crude, wt %: 5.70
Yield on crude, vol %: 5.55
Density at 15° C., kg/l.: 0.9322
Total sulfur, wt %: 0.654
Total nitrogen, ppm (wt): 2,000.0
Basic nitrogen, ppm (wt): 570
Acidity, mg KOH/g: 0.600
Vis. at 60° C., cst: 140.000
Vis. at 100° C., cst: 25.740
Vis. at 100° C., cst: 7.445
Pour point, °C.: 27
Refractive index at 70° C.: 1.4994
Aniline point, °C.: 97.9
Wax, wt %: 13.1
Carbon residue, wt %: 1.10

550-585° C.
Yield on crude, wt %: 4.05
Yield on crude, vol %: 3.90
Density at 15°C, kg/l.: 0.9404
Total sulfur, wt %: 0.759
Total nitrogen, ppm (wt): 2,700.0
Basic nitrogen, ppm (wt): 775
Acidity, mg KOH/g: 0.590
Vis. at 60°C, cst: 301.700
Vis. at 100°C, cst: 44.670
Aniline point, °C.: 101.4
Wax, wt %: 14.9
Carbon residue, wt %: 2.76

**Atmospheric residue, 369°F-BP**

Yield on crude, wt %: 55.85
Yield on crude, vol %: 53.50
Density at 15°C, kg/l.: 0.9422
Total sulfur, wt %: 0.679
Total nitrogen, ppm (wt): 2,400.0
Basic nitrogen, ppm (wt): 733
Acidity, mg KOH/g: 0.400
Vis. at 60°C, cst: 129.900
Vis. at 100°C, cst: 25.240
Vis. at 120°C, cst: 14.24
Pour point, °C.: 30
Wax, wt %: 10.7
Carbon residue, wt %: 5.11
Asphaltenes, wt %: 0.55
Vanadium, ppm (wt): 15
Nickel, ppm (wt): 10
Iron, ppm (wt): 2

**Vacuum residue, 509°F-BP**

Yield on crude, wt %: 25.30

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**Nelson-Farrar Cost Indexes**

**Refinery construction (1946 basis)**

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<td>Pumps, compressors, etc.</td>
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<td>777.3</td>
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<td>Misc. equip. average</td>
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**Refinery operating (1956 basis)**

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<td>Fuel cost</td>
<td>100.9</td>
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*These indexes are published in the first of each month and are compiled by Gary Farrar, OGJ Contributing Editor.

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**550°F-BP**

Yield on crude, wt %: 19.55
Yield on crude, vol %: 17.85
Density at 15°C, kg/l.: 0.9885
Total sulfur, wt %: 1.020
Total nitrogen, ppm (wt): 5,000.0
Basic nitrogen, ppm (wt): 1,556
Acidity, mg KOH/g: 0.330
Vis. at 100°C, cst: 329.000
Vis. at 120°C, cst: 204.50
Vis. at 150°C, cst: 67.77
Pour point, °C.: 45
Wax, wt %: 11.1
Carbon residue, wt %: 14.20
Asphaltenes, wt %: 1.50
Vanadium, ppm (wt): 43
Nickel, ppm (wt): 28
Iron, ppm (wt): 6

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**585°F-BP**

Yield on crude, wt %: 15.50
Yield on crude, vol %: 13.95
Density at 15°C, kg/l.: 1.0020
Total sulfur, wt %: 1.090
Total nitrogen, ppm (wt): 6,600.0
Basic nitrogen, ppm (wt): 1,761
Acidity, mg KOH/g: 0.260
Vis. at 100°C, cst: 747.600
Vis. at 120°C, cst: 281.10
Vis. at 150°C, cst: 67.77
Pour point, °C.: 54
Wax, wt %: 10.0
Carbon residue, wt %: 17.20
Asphaltenes, wt %: 1.90
Vanadium, ppm (wt): 53
Nickel, ppm (wt): 35
Iron, ppm (wt): 7