1513 023 021

December 15, 1967

Mr. K. M. Elliott
Mobil Research & Development Corp.
150 East 42nd Street
New York, New York 10017

Dear Mr. Elliott:

Enclosed herewith are heat material balances for Cases 3, 4 and 5 of the engineering appraisal study.

Yours very truly,

K. L. Berry

K. L. Berry, Chairman
Engineering Appraisal Team

KLB:mtl
attachments

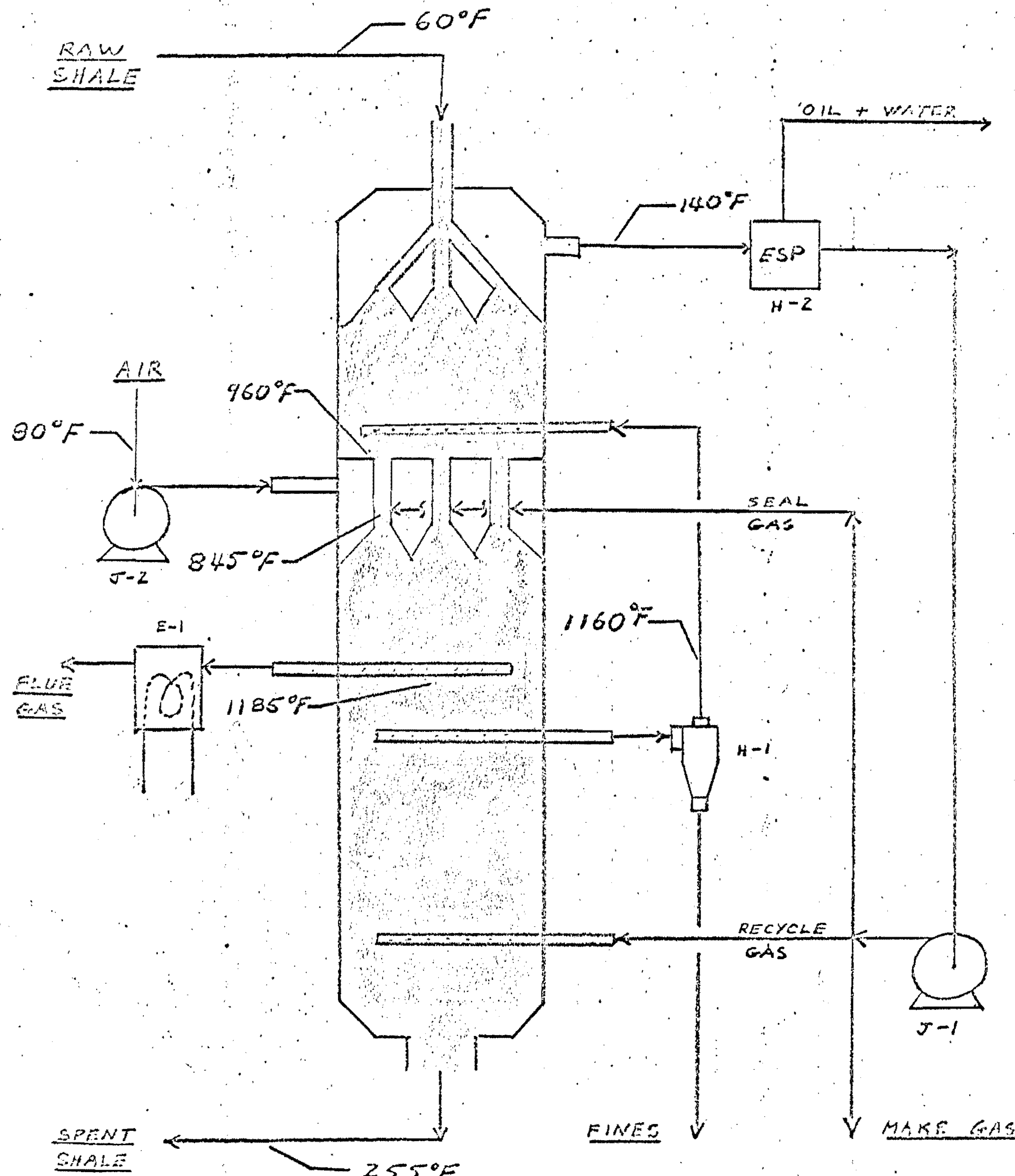
cc: Messrs. F. R. Conley
J. H. Smith
H. P. Dengler
W. O. Taff
S. L. Meisel
R. Mungen
R. T. Ellington
G. A. Blaine

Case 3

ENGINEERING CHART
(TRACING)

FILE
APP.
DATE 12-12-67
BY DFP

SUBJECT MOBIL NO. 2 FLOW DIAGRAM



FORM 33 2-57

PAN AMERICAN PETROLEUM CORPORATION

ENGINEERING CHART
(TRACING)

FILE 26

APP.

DATE 12-12-67

BY [illegible]

SUBJECT Mobil No. 2

BASIS: 1 TON RAW SHALE FROM CRUSHER
0"-2½", 30 GAL/TON

RAW SHALE, 0"-2½" WET	2000 #
FINES REJECT, 0"-¼"	66 #
FEED TO RETORT, ¼"-2½"	1934 #
MOISTURE IN RETORT FEED	19.3 #
AIR	4200 SCF
MAKE GAS (SAT. AT 140°F)	675 SCF
MAKE GAS (DRY)	493 SCF
MAKE GAS HEATING VALUE (MOIST), HHV	66.7 BTU/SCF
RAW SHALE OIL	27.2 GAL
RAW SHALE OIL RECOVERY - % F.A.	93.5
FLUE GAS	5324 SCF
RECYCLE GAS TO BOTTOM OF RETORT	11,067 SCF
SEAL GAS TO SPENT SHALE DOWNCOMERS	2009 SCF
SPENT SHALE	1,533 #

RETORT OVERALL MATERIAL BALANCE

IN	
RAW SHALE	1934 #
AIR	319 #
	2253
OUT	
OIL	206.4 #
MAKE GAS	48.0 #
WATER	29.3 #
SPENT SHALE	1533 #
FLUE GAS	436.3 #
	2253

RETORT OVERALL HEAT BALANCE

BASIS: BASE TEMPERATURE = 60°F
REACTION AT 60°F
1934 # OF RAW SHALE

IN	MBTU
RAW SHALE	0
AIR	3.9
RECYCLE GAS	36.5
SEAL GAS	6.4
COMBUSTION	384.0
	430.8

OUT	
RECYCLE GAS + SEAL GAS + MAKE GAS	32.9
OIL CONDENSED	− 28.1
MOISTURE FROM RAW SHALE	1.5
WATER OF REACTION CONDENSED	− 4.9
SPENT SHALE	63.0
FLUE GAS	108.0
HEAT OF REACTION	101.6
CARBONATE DECOMPOSITION	133.2
COOLING CO_2 OF DECOMPOSITION	23.6
	430.8

Case 4

PAN AMERICAN ... CORPORATION

ENGINEERING CHART
(TRACING)

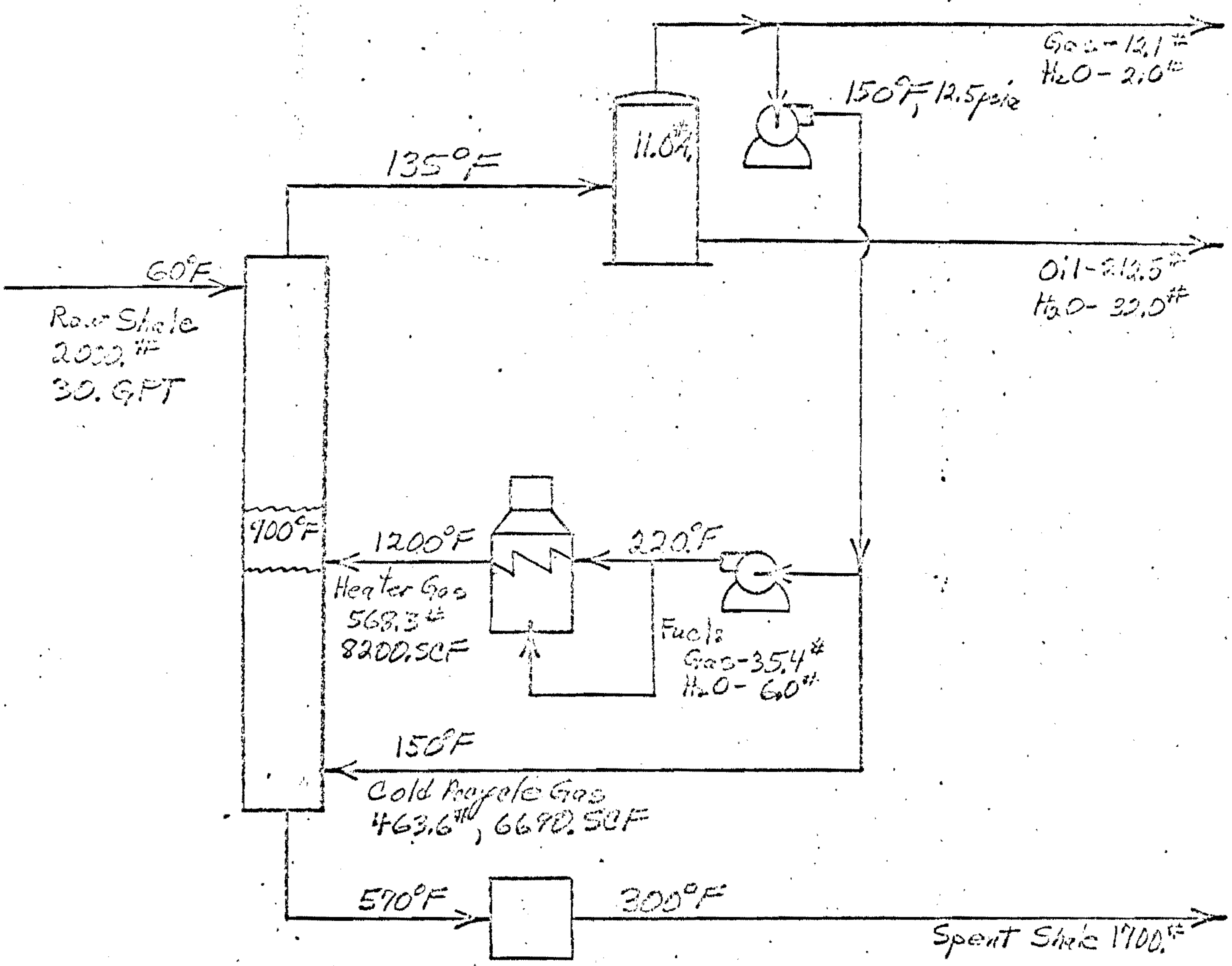
SUBJECT Indirect (Esso #4) Retort

FILE

APP.

DATE

BY



Indirect Retort Process
(Esso #4)
CEGe 12-14-67

PAN AMERICAN PETROLEUM CORPORATION

ENGINEERING CHART (TRACING)

SUBJECT Indirect (Fnop #4) Retort

FILE
APP.
DATE
BY

Predicted Yield: Basis - lose 5% F.A. oil due to reflux in top of retort, with 1% FA going to coke on spent shale, balance to gas of F.A. mol %.

	F.A. #/ton	Adjust. #/ton	Predicted Yield #/ton
Oil	228.	-11.	217.
Gas	34.	+9.	43.
H_2O	40.		40.
S.S.	1698.	+2.	1700.
	2000.	-0-	2000.

Final Yield: Basis - lose 15% of C_6 and heavier from gas flowing thru heater, all loss to gas, no coke.

	Predicted Yield #/ton	Heater Adjust. #/ton	Final Yield #/ton
Oil	217.	-4.5	212.5
Gas	43.	+4.5	47.5
H_2O	40.		40.0
S.S	1700.		1700.0
	2000.	-0-	2000.0

Oil Yield & Quality:

#/ton - 212.5
GPT - 27.8 (92.7% F.A.)
#/G - 7.641
API - 23.1°

ENGINEERING CHART (TRACING)

SUBJECT: Indirect (Case "4") Retort

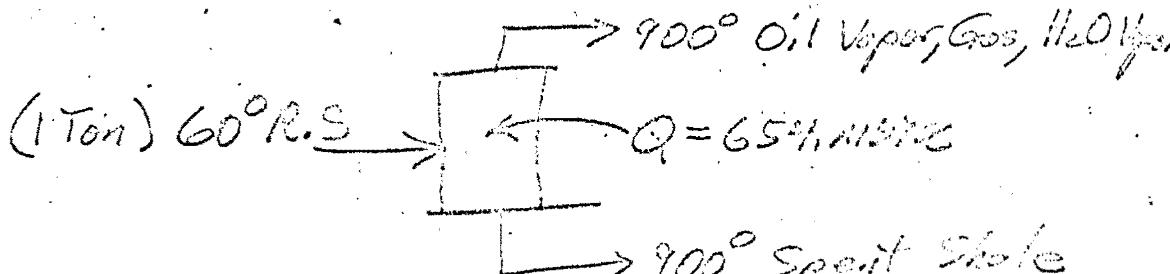
APP. ______ DATE ______ BY ______

HEAT & MATERIAL BALANCES

Basis 1. Ton (per hour) of Raw Shale

Ht. of Retorting = 900°F Retort temperature.

		MBTU/Hr
Sensible Heat - 275 BTU/lb x 2000#	→	550.0
"Ht. of Reaction"	→	104.0
Total Ht. of Retort,		654.0

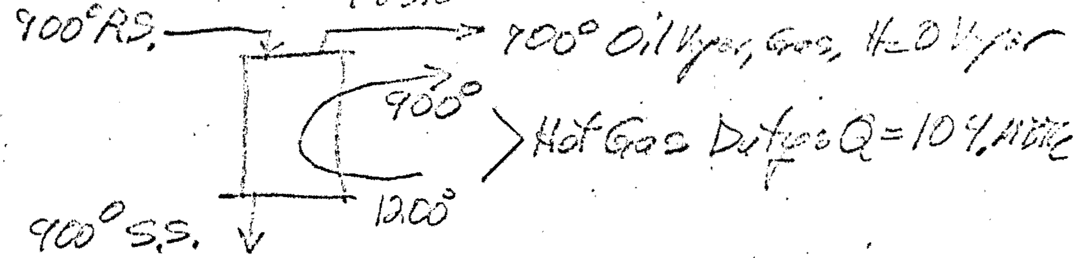


Hot Gas Rate for "Ht. of Reaction"

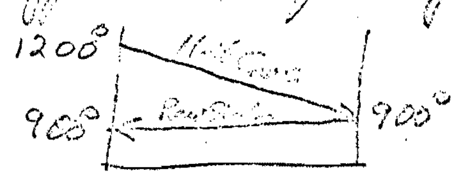
"Ht. of Reaction" - 104.0 MBTU

Hot Gas - 1200°F - 872.6 BTU/#
900°F - 689.6
Duty - 183.0 BTU/# of Hot Gas

Circulation = $\frac{104.0 \text{ MBTU}}{183.0}$ = 568.3 # Hot Gas



Note - zero approach OK for long retort zone



PAN [illegible] CORPORATION

ENGINEERING CHART (TRACING)

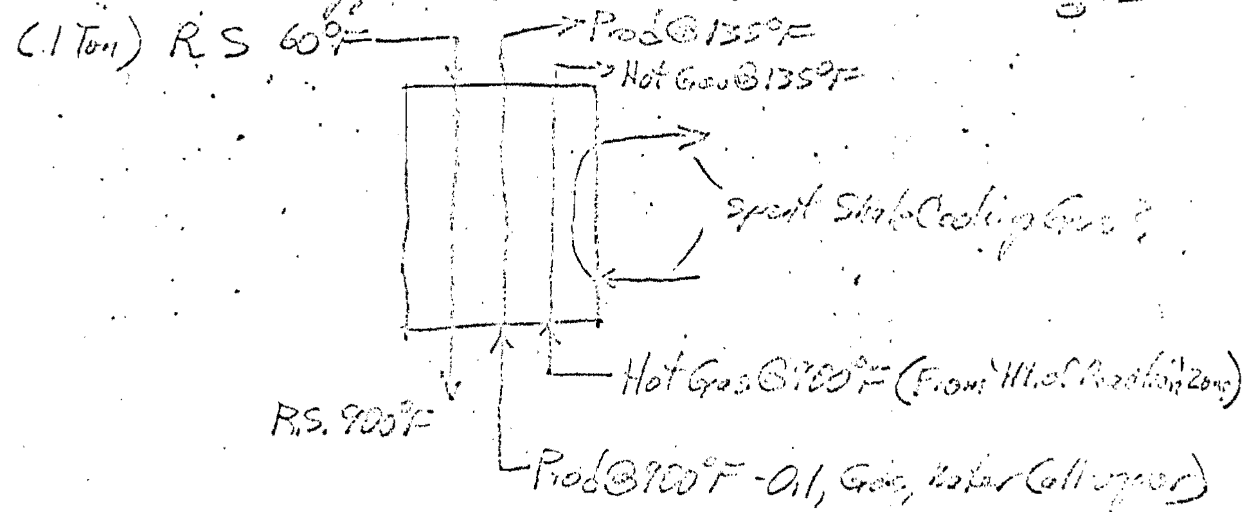
FILE
APP.
DATE
BY

SUBJECT Indian Y (E200 [illegible]) Retort

Ht. & Mat. Bal. - cont'd

Balance around top section for heat recoverable from spent shale

Assume 75°F approach ie 60°RS vs 135° Off-gas



OUTs	#	°F	BTU/#	MMBTU
R.S.	2000.	900°	275.	550.0 (prev. sensible)
Hot Gas	568.3	135°	320.	181.8 (# by 'Ht. of React.')
Prod - Oil (L)	216.8	✓	58.1	12.6
- Gas (V)	43.2	✓	169.0	7.3
- H_2O (V)	8.1	✓	1086.	8.8
- H_2O (L)	31.9	✓	103.	3.3
	2868.3			763.8

INs	#	°F	BTU/#	MMBTU
R.S.	2000.	60°	-0-	-0-
Hot Gas	568.3	900°	689.6	391.9
Prod - Oil & G (V)	260.	✓	619.	161.0
- H_2O (V)	40.	✓	1482.	59.3
Spent Shale - Cooling Gas Diff. (to bal.)				151.6
	2868.3			763.8

ENGINEERING CHART (TRACING)

SUBJECT Indirect (Esso #4) [illegible]

FILE
APP.
DATE
BY

HT. & MAT. BAL. - cont'd

SS. Cooling

SS. Cooling Gas Duty to R.S. (prev. bal) 151.6 MBTU

(15° App. @ Hot end) Gas from SS - 825°F - 647 BTU/#
Gas from R.S. - 135°F - 320
Duty to R.S. = 327 BTU/# per # SS.

Circulation = $\frac{151.6 MBTU}{327}$ = 463.6 # per # SS.

Gas from SS - 825.°F - 647. BTU/#
✓ to SS - 150.°F - 325.8
Duty from S.S. = 321.2 BTU/# per × 463.6# = 148.9 MBTU

(900°F) S.S. from Retort Zone 1700# × 202.BTU/# = 343.4 MBTU
Duty from SS. to gas 148.9 ✓
570°F S.S. from Retort 1700# 114.4 BTU/# 194.5 ✓

(300°F) S.S. from Retort 1700# 194.5 MBTU
✓ ✓ S.S Cooler ✓ 51. BTU/# 86.7 ✓
Duty of S.S. Cooler 107.8 ✓

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ENGINEERING CHART
(TRACING)

FILE
APP.
DATE
BY

SUBJECT Indirect (Exp 94) Patent

HT. & MAT. BAL. - cont'd

Heater Duty

Gas from - 1900° - 872.6 BTU/#
" to - 220° - 354.8 "
Duty - 517.8 × 568.3# → 294.3 MBTU

Heater Fuel

Assume 70% T.E.

Input = 294.3 MBTU / .70 → 420.4 MBTU

HHV of Gas (dry) ≐ 11827. BTU/lb

Fuel = 420.4 MBTU / 11,827 MBTU/# = 35.4 # of Methane Gas
associated H_2O = 6.0 #
Fuel, Wet Basis 41.4 #

Gas Rates, Wet Basis - 26.30 Mol. Wt.

	#	SCF (per Ton)
Heater Gas	568.3	8200.
Fuel Gas	41.4	597.
Heater Gas Blower Cap.	609.7	8797.
Cold Recycle	463.6	6690.
Total Gas Blower Cap.	1073.3	15487.

PAN AMERICAN PETROLEUM CORPORATION

ENGINEERING CHART (TRACING)

SUBJECT: Indirect (Fero #4) Retort

FILE
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DATE
BY

Blower Summary

Basis: 1. ton (per hour) of Raw Shale
Gas Quality (135°F Vapor, wet): 26,30 M.W.
"k" value = 1.230
System ΔP's: Cold recycle system (GCR Dec Off) = 1.50 psi
Heated system (for "conventional" heater) = 1.00 psi

Service	#/hr	SCF	P_2 (psia)	P_1 (psia)	R	T_2 (°F)	T_1 (°F)	Hp	BHP (per ton per hr)
Heater Gas	607.7	8777.	22.5	12.5	1.8	220.	150.	22805.	10.032
Total Gas	1073.3	15487.	12.5	11.0	1.136	150.	135.	4527.	3.506

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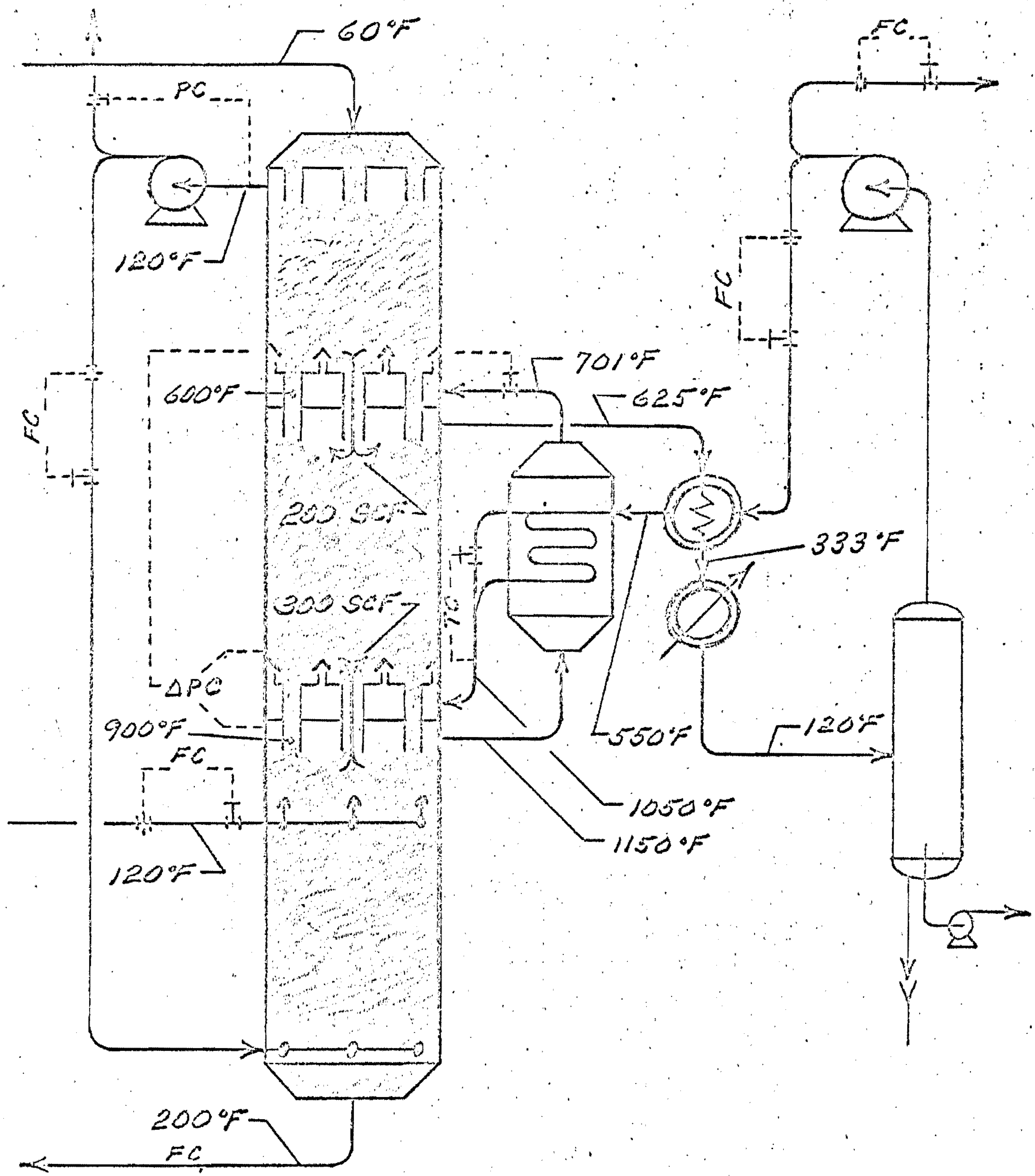
ENGINEERING CHART
(TRACING)

FILE
APP.
DATE 12-11-67
BY JHL

SUBJECT Flow Diagram
Continental Scheme II



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ENGINEERING CHART
(TRACING)

FILE
APP.
DATE 12-11-67
BY J.H.

SUBJECT UNIT RATES & DUTIES
CONTINENTAL SCHEME II

BASIS: 1 TON RAW SHALE, 1/4-2½", 30 gal. F.A.

RAW SHALE (DRY)	1980 #
MOISTURE	20 #
RAW SHALE (MOIST)	2000 #
AIR	5980 SCF
FLUE GAS VENT	5959 SCF
FLUE GAS SEAL LEAK TO PROCESS	500 SCF
FLUE GAS GENERATED	6459 SCF
FLUE GAS DEW POINT (11.0 PSIA)	123 °F
PROCESS GAS YIELD (SAT'D. AT 120°F & INCL. SEAL LEAK)	1054 SCF
PROCESS GAS HHV (MOIST)	392 Btu/SCF
RAW SHALE OIL	29.7 GAL.
PROCESS WATER DRAIN	1.88 GAL.
FLUE GAS RECYCLE	20,794 SCF
PROCESS GAS RECYCLE	19,345 SCF
FLUE GAS - PROCESS GAS EXGR.	283,000 Btu.
PROCESS GAS EXGR.	218,000 Btu.
PROCESS GAS COOLER	159,000 Btu.
COST	HEAP PLENTY

EQUIPMENT DESIGN FACTORS

1. 84,000 TPCD raw shale from mine.

2. Assume 90% on stream efficiency for all cases.

3. 93,333 TPSD feed to crushing plant.
   90,253 TPSD 1/4" - 2-1/2" feed to retorts.
   3,080 TPSD 1/4" fines.

4. Size all equipment without overdesign factors.

5. Use 1966 NGPSA data book, page 54, for calculation of blower horsepower. Assume 70% overall efficiency for blower and motor. Calculate temperature rise assuming isentropic compression.

6. Assume 70% furnace efficiency.

7. Calculate overall heat transfer coefficient and pressure drop for each exchanger.

KLB - 12-12-67