KUVLUM #1
(OCS-Y 0866)
- COCP Insp.
- WELL TEST

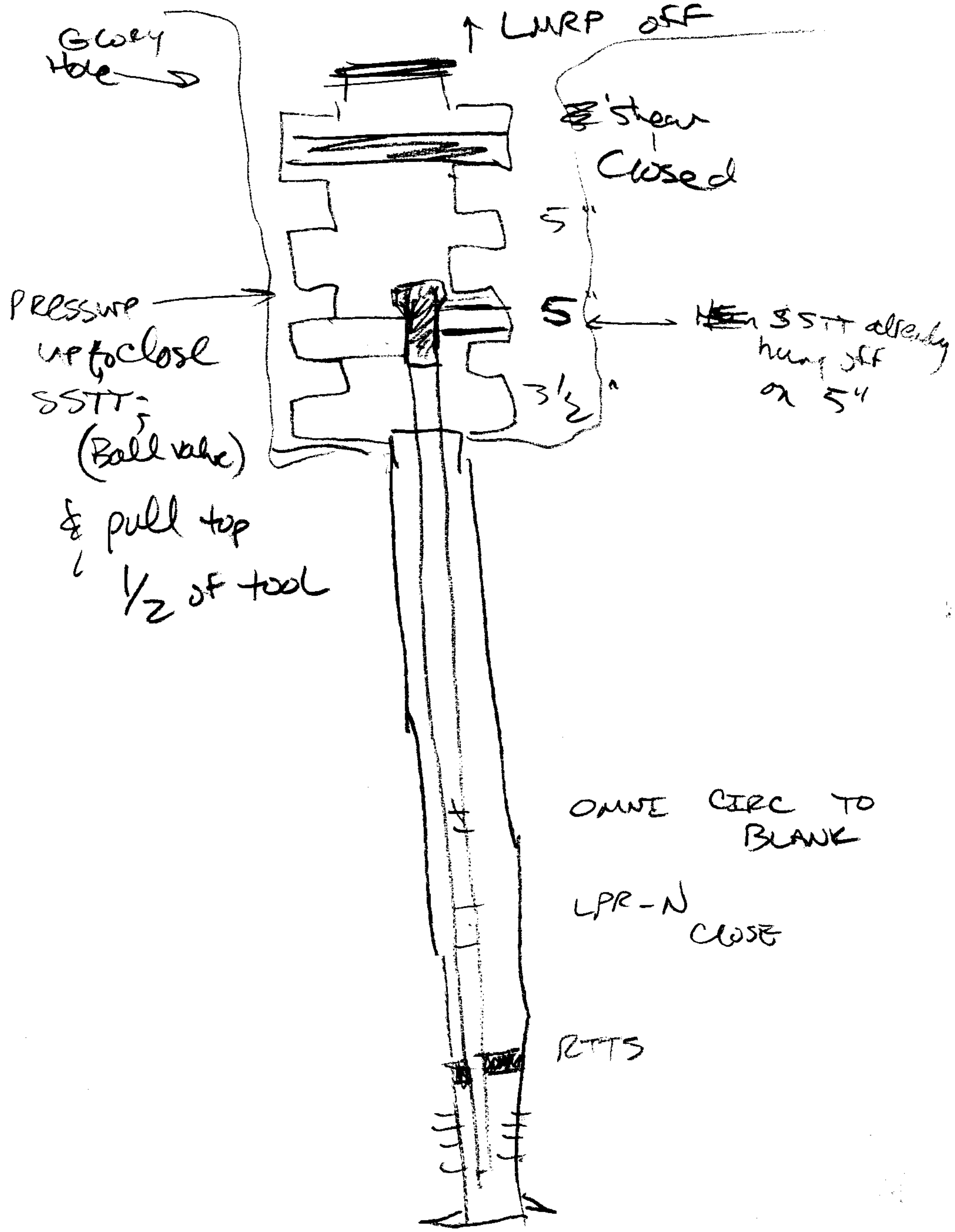
Confidential

7530-00-222-3521
FEDERAL SUPPLY SERVICE
(GPO)

JAMES B. REGG
PETROLEUM ENGINEER
MMS - ALASKA

(2B)

IF leave Stack



(5) Release RAMS

(6) Recover anchor lines

(5) SHEAR GUIDELINES

(3) Pull LMRP

(4A) Pull Stack

(7) Move off location

~~Strip Perf (wireline)~~

~~4SPF~~

~~12 Gram charge~~

~~"/16"~~

~~- useful for perfing tubing to establish communication w/ casing~~

~~- probably lower penetration thru casing if needed to kick on flow test~~

~~Nitrogen~~

Miscaroo back into flow near rig - better control backing than moving fwd.

~~ARC Production~~

~~Bridge Sal plug & X-link polymer designed to [illegible] wash out - will degrade over time~~

Secure During Test

① Bull head or reverse circulate to kill well.

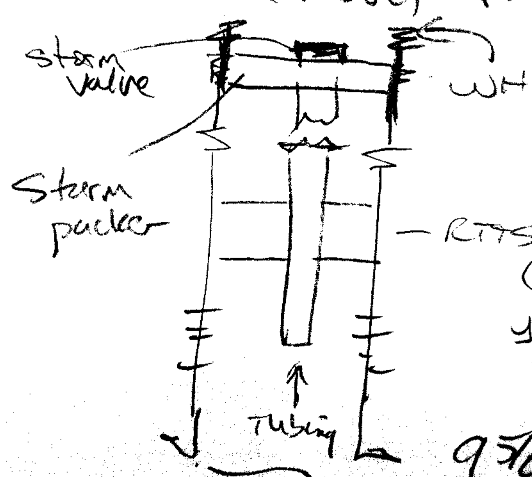
ⓩA SSTT must be pulled if pulling stack

? → (lands on lower 5" RAMS) (or on the wellhead)?

Replacing w/ Storm packer & storm choke (valve)

packer for annulus

choke (valve) for tubing



(NO gaurantee you can get this to pack off)

when running storm choke

~~Eleaser Anchorstring~~

(over)

Kulluk Inspection 9/16/92

Ice Observer - Bharat Dixit (Phd)

⟹ Send copy of paper ⟸ Done 9/24/92

- Anchor Tensions: must consider entire system (12 anchors); discussed global loads calculated based on various anchor tensions

Operating Tension
Pretension
Design Breaking Strength

- anchor lines are tested before beginning operations and inspected for any faulty sections. (Gary Pidcock)
  - replaced 2 lines prior to kuvlum
- Continuously monitored in control room
- Calculation routine used to assess global loads

sounds like they would work above pretension

- Ice Monitoring: dependent primarily on radar to track ice, & estimate hazards; also rely heavily on constant communication from ice breakers in response to direction from Kulluk to assess ice Conditions
  - Kulluk radar can reliably define ice conditions out to 6 miles; total range is ≈ 10-12 miles ice breakers extend range by "testing" areas directed by Kulluk & using their radar systems.

JK

Kulluk Inspection 9/16/92

- Very obvious during my observation time that there is extensive communication w/ ice breakers

- Miscaroo is very maneuverable boat ∴ it is used relatively close to Kulluk to clear ice which has the potential for fouling in anchor & lines (because of smaller size and lower hp)

Kalvik used further out

- Review SAR imagery received on rig to I.D. floes which pose a hazard - Regional focus of monitoring effort; rely on radar for alert levels; STAR is on retainer with daily calls to operator of plane to identify the need for such flights.
  - none to date { high confidence in existing monitoring
  - image sent in w/ Randy Howell on 9/16 shows the event which forced a move from location
  - Helicopter recon used to verify locale ice (often times video taped).
  - rely extensively on I/B GPS to track floe movements

Color code (prioritize) floes based on ability to manage, risk to vessel, etc

- Tour of rig w/ Gary Pidcock (BeauDrill)
  - diverter system, storage, rig floor
  - 2 BOP stacks; 10,000 & 15,000 psi WP; using 15,000 psi stack

16"

k Inspection 9/16/92

- test backup BOP at beginning of well & would test only if necessary to replace stack in use.

- problems w/ glory hole bit; sediments too hard @ location; took longer than anticipated; only ran ½ of glory hole caisson - future applications may not use caisson in U.S. due to soil consolidation - Idea was conceived) for Canadian Beaufort ops.

- BeauDril had no experience prior to Kuvlum drilling riserless; procedure was put forward by Arco based on lack of gas @ site & stability of soils.
  → two primary concerns are gas and "fill" in glory hole; the ability to air lift sediments from glory hole enabled Arco to drill riserless the 30" & 20" strings.
  - Arco had drilled riserless in GOM
  - Gary Pidcock says they probably saved several days rig time.

Icebreakers: Miscaroo, Kalvik, Supplier, Kigoriak

Kulluk Inspection 9/16/92

Suspension & Securing During Well Test

1. what procedures will be used to determine suspension & secure?
2. what would constitute a suspension & a secured well?
3. Concern is that if had to suspend & secure there could be oil in drill / test string? How will that effect HT-ST = OT?
4. what criteria will be evaluated & what situation must be in available before initiating the well test?
5. How will testing in presence of ice affect the alert levels?
6. What if there is a likelihood that the rig will not get back on location?

Kuvlum Location:

Lat 70° 18' 57.38"
Long 145° 25' 10.97"

Off Location 9/17/92 @:

70° 9.4'
144° 57.8'

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k Inspection 9/16/92

n Hall - COPAC

- concerned about data flow from BWASP; feels they need info. real-time from BWASP to supplement Kuvlum aerial program
- have not deployed passive acoustic array due to ice and availability of ice breakers; did try to deploy using Miscaroo but found it to be too hard to hold station for deployment; boats supplied by ARCO too small and unstable (20' flat bottom river boats) - Hall not willing to risk personnel safety
- aerial surveys are going smoothly, according to Hall - have not done multiple flights in 1 day - doesn't find any merit in this
  → he contradicts himself by saying this then stating that they know most whales are submerged so could not see - perhaps more flights would detect more whales
- shifted aerial flights by 2 transect lines to east - continue to fly those west lines also

- Hall says that concerns about aerial flights team leader are unfounded
  - he objects to having to fly transects & believes Maryanne Gallager is well qualified (not sure where NMFS & NMFS NML staff are coming from)

- Hall said Janet Clarke & Sue Moore were not available due to contractual obligations this year.

- will attempt to put instrumentation for passive acoustics program in water to catch what he calls the "second pulse of whales"
  - dependent on ice/weather

- passive acoustic equipment did not arrive at location until early September - not enough time to install & calibrate everything before start of migration

Kulluk Operations Manual -

Anchor Tensions -

① calculate the anticipated global load based on floe size, drift rate (velocity), winds etc. ; an algorithm in computer does calculation

② based on information and anticipated global load, assess whether anchor line tensions are adequate for anticipated load - what if not adequate?
- would alert level be elevated?

③ unexpected ice interactions can lead to high and rapidly increasing loads on the Kulluk ; in situations where increasing anchor line tensions are occurring with potentially hazardous ice conditions around the Kulluk, frequent communication between ice breakers & Rig are essential
- emphasis is placed on detection of such situations & transmitting info to ice breakers for ice management.

④ Major incentive for using ice management is to reduce global loads & anchor line tensions

* ⑤ generating rubble around the rig by ice management can cause the formation of pressured ice & ridges which in turn cause higher forces on the mooring system

- probably one of the best reasons to monitor anchor line tensions

* - ice management functions by breaking & pushing ice into open areas; once there are no open areas left, it becomes difficult to break the ice, and even when broken, there is NO REDUCTION IN ICE FORCES ON the Kulluk.
- maneuverability of ice breakers significantly reduced

→ - most effective way to deal w/ internal ice pressure is recognition that pressure is imminent:

a) offshore winds drive ice toward land fast ice edge & ice coverage increases
b) open water leads become fewer
c) ice drift slows while wind speed stays constant or increases
d) difficulty in maneuvering ice breakers

ICE RECON SHOULD BE CONDUCTED

) stationary or semi-stationary first year ice will partially freeze in the Kulluk (very noticeable in areas where paint from hull is lost); will increase loads

Observations / Concerns:

① Above discussions show importance of monitoring anchor line tensions, but no indication as to how it will affect alert levels

② operation above pretension values; pretensions should be max allowable unless operator can somehow demonstrate operating tension can reasonably exceed pretension w/o affecting the integrity of the mooring system (dragging anchor, breaking line, etc)

→ ③ WHAT CONTROLS ANCHOR PRETENSION TEST (TO WHAT VALUE TESTED) ??

Ice floes are color coded on ice map, identifying the priority of the hazard WRT ICE Management

- ice maps generated by helicopter recons, imagery, ship based observations, and radar

Kulluk Inspection 9/16/92

COLOR CODE ICE MAP -

G - GREEN : Ice has been managed, ice easily managable, or is not a threat

B - BLUE : Ice is longterm consideration; may threaten rig & will require management

Y - YELLOW : Ice is short term concern; will require management based on current drift implemented on a priority basis

R - Red : Difficult ice that poses an imminent hazard to the Kulluk and should be managed on a high priority basis

BL - Black : "Red" hazards that are not feasible to manage or cannot be managed in time

- Coding established by Ice Advisor in consultation w/ Marine Supt. & in discussions w/ ice breakers

- Coding system in addition to Alert Levels for Well & Vessel.

LUM 9/28/92

WELL TEST ANALYSIS

BUILD UP -

LOG - LOG : $P_{ws} - P_{wf}$ vs. $\Delta t_{SHUT IN}$ (t; hrs)

HORNER : P_{ws} vs. $\frac{t + \Delta t}{\Delta t}$ (semi log)

Skin : $S = 1.1513 \left[\frac{P_{1hr} - P_{wf}}{-m} - \log\left(\frac{k}{\phi \mu c r_w^2}\right) + 3.2275 \right]$

Permeability : $k = \frac{-162.6 \, B_o \, \mu_o \, q_o}{m_H \, h_o}$ md

μ_o ; cp
q_o ; BBL/day
m_H ; HORNER PLOT SLOPE (psi/cycle)

DRAWDOWN : q_o vs. t (hrs)

P_{wf} vs. $\log t$

RES. LIMIT : P_{wf} vs. t

calculate slope & intercept

Kuvlum 9/29/92

- Tour Test facilities 7:00pm w/ ARCO TEST ENGINEER & HRS REP
- DATA COLLECTION ON RIG FLOOR & IN TESTING DOG HOUSE ON 10M DECK
- P, T, BS&W ; Choke size?
  - SAMPLES AFTER HEATER
- 10 - 400 barrel Tanks ; TEST FLUIDS HEATER TO SEPARATOR, THEN COMMINGLE OIL & WATER INTO TANKS (10)
- METHYNOL INJECTION AVAILABLE IF NEEDED
- BRINE SOLUTION USED BECAUSE ~~of~~ OF NEEDED 9.5 ppg fluid and concerns for Barite fallout ; SLIDES TAKEN OF FILTRATION UNIT
- CONCERNS ABOUT SAND PRODUCTION ; WILL BE USING SAND DETECTOR (SOLIDS) -

- FINISHED STRAPPING & CONFIRMATION OF SPACE OUT ; RIGGING UP SUBSEA TEST TREE & REST OF TUBING THIS EVENING ; TESTED SUBSEA TREE BEFORE RUN

vlum 9/29/92

TEST PROCEDURE - BRAD BERG ; ARCO TEST ENGINEER

1. FLOW 10 Minutes - CLEANUP PERFS
2. SHUT IN TO RUN PRESSURE READOUT TOOL (SRO) SURFACE READ OUT PROBE ASSEMBLY
3. FLOW 12 HOURS (maybe ~~$~~ longer) FOR DRAWDOWN
4. SHUT-IN FOR BUILD UP (T=?)
5. OPEN FLOW VARYING DRAWDOWN TO OPTIMIZE DRAWDOWN FOR FORMATION AND TO FIND WHEN SAND PRODUCTION BECOMES PROBLEM.
6. SHUT IN & BULL HEAD FLUIDS INTO FORMATION

- TESTING BEING CONDUCTED BY HALLIBURTON RESERVOIR SERVICES (HRS)

- REPRESENTATIVES FROM ARCO, PHILLIPS, TOTAL, AND UNION TEXAS PETROLEUM

9/30/92

- Discussed ice conditions w/ ARCO engineers
- Discussed COCP actions WRT testing - plans in place based on leaving tools & BOP stack pulling test string @ subsurface tree (SSTT) and (MRP) - RTTS packs off annulus ; SSTT closes tubing w/ Flapper valve - Close shear rams

hung off 5" pipe ram

ICE : S. Columbia moving 0.5Kts due West
∴ 6 miles away - present trajectory
carries to North of N. Columbia (grounded)

Kuvlum 9/30/92

TEST -

Underbalance by pumping diesel down tubing ; well displaced to 9.5ppg brine previous to running tools
(brine wt assumed)
- brine tested - 9.5ppg 0850 hrs
- diesel tested @ 7.2ppg
- AMBIENT TEMP = 14.6°F

| 0845 hrs | guns fired, start 10min flow
| 0855 hrs | shutin LPR-N & lubricator
pressure up

RIH w/ wireline - SRO probe

| 1000 hrs | Problems w/ seating SRO; POOH ; 1125 hrs SRO @ surface

→ NOTE : RIG & ENV. ON YELLOW ALERT
HT = 10 hrs - S. Columbia moving due west ; N. Columbia and Panama grounded
ICE RECON 0900 hrs
- radar analysis before test

| 1140 hrs | Decision to flow test w/o SRO ; Target is stabilized rate ; open 12/64ths choke

ADJUSTABLE CHOKE

MONITOR SURFACE WH PRESSURE (TP)

| 1145 hrs | OPEN TO 16/64ths Choke
| 1200 hrs | OPEN TO 20/64ths choke
| 1224 hrs | OPEN TO 24/64ths choke

TANK CORRELATION VALUE = 1.6667 bbl/in

TANK RATE = $(ST_2 - ST_1)(1.667)(\frac{in}{hr})(24)$
STRAP

Kuvlum 9/30/92

| 1301 hrs | OPEN TO 28/64ths Choke
BS&W @ 1330 hrs 28% (water)

| 1335 hrs | OIL TO SURFACE
CASING PRESSURE @ [illegible] 1579 psi
TUBING PRESSURE @ WH 572 psi
FLOW 1000 BPD
TUBING TEMP (WH) 39°F

| 1405 hrs | SWITCH FLOW TO SURGE TANK
(surge tank not operable)
DUE TO GAS (FLARING)
BACK TO TEST SEPARATOR

| 1445 hrs | TP = 750 ± 10 psi
~~BS&W = 25%~~ BS&W 25% H2O 2.00% solids
gas head fluctuating pressure

| 1507 hrs | TP begin stabilizing @ 785 psi
@ 1500 hrs TANK STRAP = 38¼"

| 1515 hrs | TANK STRAP 3'9" → 45"
Flow = 1080 BPD
TP = 784 psi ; CP = 1490 psi
BS&W = 0.75% TOTAL
T_{WH} = 37.6°F

| 1518 hrs | TP increasing after 11 minutes to 788 psi ; fluctuating +/- 4 psi around 784 psi

| 1530 hrs | TANK STRAP = 50½"
TP = 782.25 psi ; T_{WH} = 37.6°F
RATE = 880 BPD

| 1545 hrs | Adding demulsifier @ data header
BS&W = .75% ~~water~~ total
TANK STRAP - 60¾"
DUMP VALVE ON SEPARATOR STUCK OPEN → REASON FOR HIGH FLOWRATE
FLOW RATE = 1640 BPD
TP = 780 psi ; T_{WH} = 35.6°F

| 1600 hrs | STRAP - 64¾"
TP = 781 psi ; T_{WH} = 37.5°F
GAS RATE = 702 MCFD
FLOW RATE = 638 BPD

STOP USE OF DEMULSIFIERS @ ?
-CAUSING GEL TO FORM @ bottom OF centrifuge sample

Kuvlum 9/30/92

1500 hrs — TP stabilized 780 psi +/- 2 psi (since 1525 hrs)

1615 hrs — TANK STRAP = 64 3/4"; SAME DUE TO FILL UP OF SURGE TANK
TP = 780 psi; T = 37.6°F
FLOW RATE = N/A

1630 hrs — TANK STRAP = 64 3/4"
TP = 779.25 psi; T = 37.6°F
FLOW RATE = N/A

CALC. GAS RATE = 775.11 MSCFD — AVE. SINCE 1600 hrs

~~1635 hrs~~ 1645 hrs — ORIFICE PLATE CHANGE FROM 1.000 in to 1.500 in FOR GAS METERING

FILL SURGE TANK

1645 hrs — TP = 758.5 psi; T_{WH} = 37.6°F

1648 hrs — change choke from 28/64" adj. to 28/64ths positive
TP = 722.25 psi; T_{WH} = 37.4°F

1650 hrs — TO SURGE TANK; DUMP OUT OF SURGE TANK TO TANK FARM (STORAGE)

1700 hrs — TANK STRAP = 5'5" ⇒ 65"
TP = 713 psi; T_{WH} = 37.8°F

→ Tubing Pressure @ wellhead; Temp @ wellhead

TANK RATE = (70.75 − 65)(1.667)(4/Hr)(24 hrs) = 920 BPD
(15 min; increments)

Kuvlum 9/30/92

1715 hrs — TP = 705.25 psi; T = 38.1°F
TANK STRAP = 5'10 3/4" ⇒ 70.75"
TANK RATE = 920 BPD

1730 hrs — TP = 703 psi; T = 38.4°F
TANK STRAP = 7'2"
TANK RATE = 2440 BPD

1745 hrs — TP = 701 psi; T = 38.7°F
TANK STRAP = 8'4 3/4"
TANK RATE = 2360 BPD

1745 hrs — BEGIN INJECTING DEFOAMER
1800 hrs — TP = 698.25 psi; T = 38.9°F
TANK STRAP = 8'4 3/4"; FLOW RATE = 0
BS&W = 0
GAS Meter = 1079.4 MSCFD
OIL METER = 1445 BPD

1815 hrs — TANK STRAP = 10'5 3/4"
TP = 697.75 psi; T = 39.2°F

- Discuss options regarding foaming — may be affecting oil meter values
- GAS RATE CALCULATED BASED ON METERED DIFFERENTIAL PRESSURE OVER PAST 30 minutes (30 samples — 1 per minute) on HRS Data Sheet
- Oil Rates based on turbine meter reported on HRS Data Sheet
- STABLE FLOW THRU SEPARATOR / SURGE TANK CHECK FOR SHRINKAGE & METER CORRECTION AFTER 1900 hrs (?)

28/64ths POSITIVE CHOKE

Kuvlum 9/30/92

1830 hrs METERED OIL RATE = 1629 BPD
METERED GAS RATE = 1073.45 MSCFD
WATER = 0
TP = 695.75 psi ; T = 39.3°F
TANK STRAP = 11'5¼" ; TANK RATE = 4000 BD

< PRELIM. API GRAVITY = 34° >
AVERAGING 34° API w/ SAMPLES FROM FLOOR

1845 hrs TP = 694. psi ; T = 39.73°F
TANK STRAP = 12'5¼" ~~[illegible]~~
TANK RATE = 1912 BPD

1900 hrs TP = 692.75 psi ; T = 39.99°F
TANK STRAP = 13'6" ; TANK RATE = 2040 BD
ACTUAL GAS GRAVITY = 0.712 (measured)
METERED OIL RATE = 1609.92 BPD
" GAS RATE = 1085.41 MSCFD
WATER = 0

1915 hrs TP = 691.25 psi ; T = 40.21°F
TANK STRAP = 14'7¼"
TANK RATE = 2120 BPD

1930 hrs TP = 690 psi ; T = 40.5°F
TANK STRAP = 15'6¼"
TANK RATE " 1760 BPD
METERED OIL RATE = 1583.19 BPD
" GAS RATE = 1107.25 MSCFD
TANK GOR: 629 SCF/BBL
WATER = 0

API GRAVITY = 34.2° (34° from RFT)
GAS GRAVITY = 0.700 (assumed)

1900 hrs - South Columbia Flow moving to north east of RIG ; current trajectory poses no problem

28/64ths choke (positive)

9/30/92

1938 hrs - 5 gal defoamer pumped (total)

[illegible] hrs TANK STRAP = 16'6½"
TP = 688.75 psi ; T = 40.6°F
TANK RATE = 490.1 BPD

~~[illegible]~~

[illegible] hrs TP = 687.25 psi ; T = 40.9°F
TANK STRAP = 17'5½"
LAST STRAP TANK #1
TANK RATE = 440.1 BPD
METERED OIL RATE = 1585 BPD
" GAS RATE = 1092 MSCFD
WATER = 0
~~[illegible]~~ GOR = 690 SCF/BBL (METER BASED)

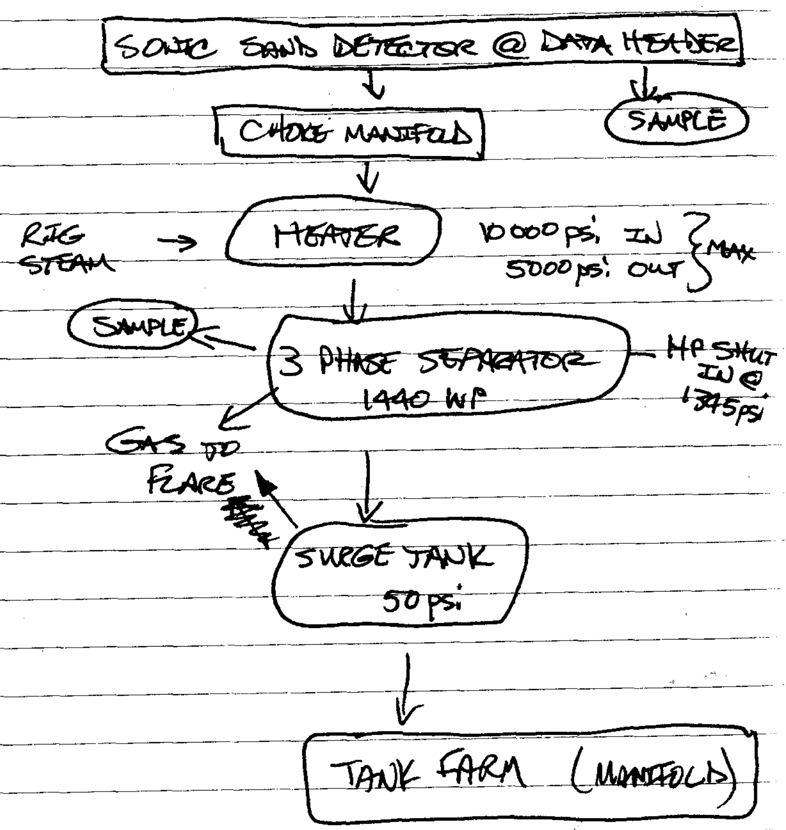
* CHANGE TANKS FROM #1 TO #3 ***
- Do single strap after min's, let set to get shrinkage & meter correction
EXISTING TANK #3 STRAP = 2"
STRAP AFTER 1 HR FLOW = 51" (49" corrected) 51-2
STRAP AFTER ~~#~~1 HRS STATIC = 51"

- 15 minute straps to continue on TANK #1 until value levels off. - shrinkage (correction factor)
- Flow into TANK #3 for 1 HOUR ; STRAP EVERY ~~15 MINUTES UNTIL~~ HOUR
- SWITCH TO TANK #10 AFTER 1 HOUR TANK #3 FLOW - PRE STRAP #10 = 1.25"

KUVLUM 9/30

PIPING & INSTRUMENTATION — TEST

- GET COPY OF DRAWING FROM ARCO



28/64 POSITIVE CHOKE

KUVLUM 9/30/92

STRAPS FOR SHRINKAGE / METER CORRECTIONS

TANK #1 STRAPS

2000 hrs	17' 5¼"	80% full
2315 hrs	17' 5¼" ;	NO FOAM PER SAMPLE.

⟹ TANKS FILLED TO APPROX. 80% MAX

TANK #3 STRAPS

		NET
00 hrs (START)	2"	—
15 hrs	—	—
30 hrs	—	—
45 hrs	—	—
100 hrs	5[illegible]"	[illegible]9"
115	5[illegible]"	
130	5[illegible]"	
2145	5[illegible]"	
2200	5[illegible]"	

NO GAS BREAKOUT

28/64ths → POSITIVE CHOKE

Kuukuu 9/30/91

2015 hrs	TP = 686 psi ; T = 41.2°F
	~~TANK #3 STRAP =~~
	API GRAVITY = 34.2°
2030 hrs	TP = 685 psi ; T = 41.4°F
	~~TANK #3 STRAP = ; TANK RATE = BPD~~
	METER OIL RATE = 1565.6 BPD
	METER GAS RATE = 1110.9 MSCFD
	WATER = 0
2045 hrs	TP = 683.8 psi ; T = 41.7°F
	~~TANK #3 STRAP =~~
	~~TANK RATE =~~

*** SWITCH TO TANK #10 *** (after 2100 hrs)

2100 hrs	TP = 682.75 psi ; T = 41.9°F
METER GOR = 700 SCF/BBL (?)	METER OIL RATE = 1557.5 BPD
	METER GAS RATE = 1087.8 MSCFD
	TANK #3 STRAP = 4' 3" ; TANK RATE = 1960 BPD
2115 hrs	TP = 681.5 psi ; T = 42.1°F
	~~TANK #10 STRAP~~ =
2116 hrs	→ DUMP VALVE ON SURGE TANK STUCK OPEN ; WILL AFFECT NEXT RATE @ 2200 hrs
2130 hrs	TP = 680.5 psi ; T = 42.3°F
	SEP. P_S = 99.1 psi ; SEP. T = 127.7°F
DIFF. PRESS = 60.15 psi	METER OIL RATE = 1559 BPD
	METER GAS RATE = 1089 MSCFD
	~~TANK #10 STRAP =~~ GOR = 700 SCF/bbl (?)

→ SURGE TANK @ OPERATING LEVEL ; OPEN DUMP VALVE TO TANKS (STORAGE)

28/64ths → POSITIVE CHOKE

Kuukuu 9/30/92

...hrs	TP = 679.5 psi ; T = 42.6°F
...hrs	TP = 678.25 psi ; T = 42.7°F
	TANK #10 STRAP = 2' 6 3/4" (INITIAL 1 1/4")
	TANK RATE = 1160 BPD
	METER OIL RATE = 1534 BPD
	METER GAS RATE = 1059.8 MSCFD
	SEP. – { P_{STATIC} = 98.2 psi ; P_{DIFF} = 59.8 psi ; T = 122.3°F }
	API GRAVITY = 34°
	METERED GOR = 690 SCF/bbl (?)
	TANK GOR = 910 SCF/bbl
...3 hrs	TP = 676 psi ; T = 43.2°F
	~~METER OIL RATE = BPD~~
	~~METER GAS RATE = MSCFD~~
	SEP. { P_{STAT} = 98 psi ; P_{DIFF} = ~~54.2~~ 55.5 psi ; T = 123.8°F }
	API GRAVITY = 34°
	0.3% CO_2 , Ø H_2S
...00 hrs	TANK #3 STRAP = 8' 3"
	TANK RATE = 1920 BPD
...15 hrs	TP = 672.75 psi ; T = 43.8°F
...30 hrs	TP = 672.3 psi ; T = 44.0°F
	METER OIL RATE = 1528 BPD
	METER GAS RATE = 1005.7 MSCFD
	METER GOR = 660 SCF/BBL (?)
	SEP. { P_{STAT} = 98.5 psi ; P_{DIFF} = ~~55.5~~ 55.3 psi ; T = 127.9°F }

28/64ths POSITIVE CHOKE

TANK FACTOR = 1.667 bbl/in

KUVLUM 9/30/92 – 10/1/92

1900 hrs → 2300 hrs GOR = 510 SCF/bbl

(CALC. BY HRS @ 2330 hrs) – based on TANK STRAPS & METERED GAS

* – PREVIOUS GOR's SUSPECT SINCE BASED ON UNPROVED OIL METER

$\boxed{\text{2400 hrs / 000 hrs}}$

TP = 670.5 psi ; T = 44.4°F

METER OIL = 1539.7 BPD

METER GAS = 991.8 MSCFD

METER GOR = 640 SCF/bbl (?)

SEP. { P_{STATIC} = 98.4 psi ; P_{DIFF} = 53 psi
T = 130.3°F

→ actual gas gravity = 0.730 (measured)

measured by RanaRex Sp.GR. TESTER

TANK # 10 STRAP = 6' ½"

TANK RATE = 1690 BPD

TANK GOR = $\frac{991.8\,M}{1690}$ = 587 $\frac{SCF}{bbl}$

$\boxed{\text{0030 hrs}}$

TP = 668 psi ; T = 44.0°F

METER OIL = 1496.6 BPD

METER GAS = 1001.1 MSCFD

METER GOR = 670 $\frac{SCF}{BBL}$ (?)

SEP. { P_{STAT} = 118.7 psi ; P_{DIFF} = 43.5 psi
T = 129.1°F

KUVLUM TANK STRAPS – #3 & #10

– ALTERNATING USE – EACH 1 HR FLOW

TANK # 3			TANK # 10
2000 hrs	2" ← PRE STRAP →		—
2100 hrs	5"		2100 hrs 1.25"
2200 hrs	5"		2200 hrs 30.25"
	99"	2300 hrs	—
	—	10/1 2400 hrs	72.5"
	144"	0100 hrs	—
	—	0200 hrs	117"
	184.5"	0300	—
	—	0400	154.5"
		0500	—
	—	0600	

→ SWITCH TO TANK #4 @ 0600 hrs

28/64ths POSITIVE CHOKE

KUVLUM

10/1/92

0100 hrs

TP = 665.8 psi ; T = 45.1 °F

Meter oil = 1521.2 BPD

Meter gas = 1012.7 MSCFD

Meter GOR = 670 SCF/BBL (?)

TANK #3 STRAP = 12' 0" ; TANK RATE = 1800 BPD

TANK GOR = 563 SCF/bbl

SEP. { P_{STAT} = 106.6 psi ; P_{DIFF} = 51.7 psi

T = 127.4 °F

OIL GRAVITY = 34° ; 0.3% CO_2

0130 hrs

TP = 664 psi ; T = 45.4 °F

Meter oil = 1500.7 BPD

Meter gas = 1014.5 MSCFD

METER GOR = 680 SCF/bbl (?)

0200 hrs

TP = 662.8 psi ; T = 45.7 °F

Meter oil = 1494.4 BPD

Meter gas = 991.2 MSCFD

CALC. GOR = 991.2M / 1780 = 557 SCF/bbl

METER GOR = 660 SCF/bbl (?)

TANK #10 STRAP = 117" ; TANK RATE = 1780 BPD

SEP. { P_{STAT} = 106.7 psi ; P_{DIFF} = 52.2 psi

T = 128.4 °F

TANK GOR = $\frac{991.2M}{1780}$ = 557 SCF/bbl

28/64ths - POSITIVE CHOKE

[illegible]um

10/1/92

[illegible]30 hrs

TP = 660.8 psi ; T = 46.0 °F

Meter oil = 1486.9 BPD ; Meter gas = 1009.6 MSCFD

METER GOR = 680 SCF/bbl

SEP. { P_{STAT} = 106 psi ; P_{DIFF} = 50.6 psi

T = 128 °F

[illegible]250 hrs - Meter factor calculated @ 1.19 ←

[illegible]300 hrs

TP = 658.8 psi ; T = 46.2 °F

Meter oil = 1761.8 BPD ; meter gas = 1018.5 MSCFD

METER GOR = 580 SCF/bbl

TANK #3 STRAP = 184.5" ; TANK RATE = 1620 BPD

CALC. GOR (TANK) = 629 SCF/bbl

0330 hrs

TP = ~~[illegible]~~ 657.3 psi ; T = ~~[illegible]~~ 46.5 °F

Meter oil = ~~[illegible]~~ 1751.9 BPD ; Meter gas = ~~[illegible]~~ 1041.3 MSCFD

METER GOR = ~~5[illegible]~~ 590 SCF/bbl

SEP. { P_{STAT} = ~~[illegible]~~ 105.6 psi ; P_{DIFF} = ~~[illegible]~~ 58.7 psi

T = ~~[illegible]~~ 126.3 °F

0400 hrs

TP = 656 psi ; T = 46.7 °F

Meter oil = 1754.7 BPD ; Meter gas = 1045.9 MSCFD

METER GOR = 600 SCF/bbl

TANK #10 STRAP = 154.5" ; TANK RATE = 1500 BPD

TANK GOR = 697 SCF/bbl

0430 hrs

TP = 654.5 psi ; T = 46.9 °F

Meter oil = 1746.7 BPD ; Meter gas = 1043.7 M SCFD

METER GOR = 600 SCF/bbl

{ P_{STAT} = 105.4 psi ; P_{DIFF} = 54.8 psi

T = 128 °F

28/64ths POSITIVE CHOKE

KUVLUM 10/1

0500 hrs
TP = 652.5 psi ; T = 47.2 °F
meter oil = 1806.2 BPD ; meter gas = 1037.8 MSCFD
METER GOR = 570 SCF/bbl
(TANK# STRAP = ; TANK RATE = BPD
TANK GOR = SCF/bbl

0530 hrs
TP = 651.5 psi ; T = 47.4 °F
meter oil = 1764.8 BPD ; meter gas = 1047.8 MSCFD
Meter GOR = 580 SCF/bbl

SWITCH TO TANK #4 @ 0600 hrs

0600 hrs
TP = 650.5 psi ; T = 47.7 °F
meter oil = 1739.2 BPD ; meter gas = 1023.6 MSCFD
METER GOR = 590 SCF/bbl
TANK #4 STRAP BEFORE FLOW = 1.8"
~~TANK RATE = BPD~~
~~TANK GOR = SCF/bbl~~

0630 hrs
TP = 649.3 psi ; T = 47.9 °F
TANK STRAP = 22.6" ; TANK RATE = 1756 BPD
METER OIL = 1808.8 BPD
METER GAS = 1024.6 MSCFD
METER GOR = 570 SCF/bbl
WATER = ∅
SEP. { P_{STAT} = 104.3 psi, P_{DIFF} = 52.9 psi, T = 129.3 °F

0700 hrs
STRAP TANK #4 = 3'8½" (44.5) ; TANK RATE = 1780 BPD
TP = 647 psi ; T = 48 °F
METER OIL = 1833 BPD
METER GAS = 1012.5 MSCFD
METER GOR = 550 SCF/BBL ; TANK GOR = 569 SCF/bbl
WATER = ∅ API = 34°

28/64ths POSITIVE CHOKE
→ FLUCTUATING RATES DUE TO SEPARATOR PROBLEMS (SURGE TANK)

KUVLUM 10/1

0700 hrs
METER CUM. gas = 672 MSCF
METER CUM. oil = 893 BBL (?)

0730 hrs
TP = 645.5 psi ; T = 48.3 °F
meter oil = 1785.3 BPD ; meter gas = 1005.2 MSCFD
METER GOR = 560 SCF/bbl
SEP. { P_{STAT} = ~~[illegible]~~ 104 psi ; P_{DIFF} = 51.7 psi
T = 130.1 °F

0750 hrs
START ANOTHER 5GAL INJ. OF DEFOAMER

0800 hrs
TP = 644.3 psi ; T = 48.5 °F
Meter oil = 1757.3 BPD ; meter gas = 982.2 MSCFD
METER GOR = 560 SCF/bbl
TANK #4 STRAP = 95" ; TANK RATE = 2020 BPD
TANK GOR = 486 SCF/bbl
WATER = ∅
°API = 34° ; BS&W = ∅
CUM. oil (meter) = 967 BBL
CUM. gas (meter) = 714 MSCF
SEP. P_{STAT} = 98.2 psi, T = 123 °F, P_{DIFF} = 47.8 psi

0830 hrs
TP = 642.8 psi ; T = 48.6 °F
Meter oil = 1775.5 BPD
meter gas = 937.9 MSCFD
} Meter GOR = 530 SCF/bbl
SEP. { P_{STAT} = 97.1 psi ; P_{DIFF} = 47.3 psi
T = 117.1 °F

DUMP VALVE ON SURGE TANK SCREWED UP @ 0800 hrs

28/64ths POSITIVE CHOKE FOR FLOW TEST

Kuvlum 10/1

0900 hrs TP = 641.5 psi; T = 48.8°F

Meter oil = 1809.9 BPD; meter gas = 959.1 MSCFD

Meter GOR = 530 SCF/bbl

TANK #4 STRAP = 127 1/2"; TANK RATE = 1300 BPD

TANK GOR = 738 SCF/bbl

CUM. oil (metered) = 1042 BBL

CUM. gas (metered) = 743 MSCF

OIL GRAVITY = 34° ; ∅ BS&W

0700–0900 hrs TANK RATE AVE = 1660 BPD

0930 hrs TP = 639.7 psi; T = 49 °F

meter oil = 1815 BPD; meter gas = 933.3 MSCFD

Meter GOR = 510 SCF/bbl

SEP. P_{SEP} = 95 psi T = 114°F

TANK #4 STRAP = 146"; TANK RATE = 1480 BPD

TANK GOR = 630 SCF/bbl

Metered cum. oil = 1079 bbl ; 34° API @ 60°F

metered cum. gas = 773 MSCF

WATER = ∅ BS&W = ∅

→ ATTEMPT CLOSE IN WELL @ 0930 hrs @ LPR-N (DOWN HOLE)

– BLEEDING CASING PRESSURE FROM 1500 psi

0931 hrs TP = 638.7 psi

0932 TP = 638.0 psi

0933 TP = 638.5 psi

0934 TP = 638.5 psi

0935 TP = 638.8 psi

0936 TP = 638.8 psi

0937 TP = 638.8 psi

0938 TP = 638.8 psi

[illegible]lum 10/1

[illegible]9 hrs TP = 638.8 psi

[illegible]0 TP = 638.8 psi

[illegible]1 TP = 638.5 psi

[illegible]2 TP = 638.5 psi

[illegible]3 TP = 638.5 psi

[illegible]4 TP = 638.5

[illegible]45 638.5

[illegible]46 638.5

MAYBE ? LPR-N TOOL NOT CLOSED; TRY TO PRESSURE UP AGAIN < CONCERN IS OMNI VALVE – AVAIL. POSITIONS >

~~shifted~~ shifts positions when pressure up

– currently in position 3

[illegible]48 BEGIN PRESSURE UP AGAIN

MONITOR TUBING PRESSURE

[illegible]951 TP = 638 psi ; CP = 1457.3 psi

[illegible]952 " ; CP = 1739 psi

0953 " ; CP = 1723 psi

[illegible]954 INCREASE ANNULUS P (CP) TO 2000 psi

actual 2035 psi

0955 TP = 638.25 psi ; CP = 2002.5 psi

0956 TP = 638.75 psi ; CP = 1985.75 psi

0957.5 hrs TP = 638.75 psi ; CP = 0 BLEED OFF C. PRESSURE

0958 hrs TP = 637.5 psi

0959 hrs TP = 636.5 psi

1000 hrs TP = 637 psi

Kuvuu 10/1/92

[1000 hrs] TANK #4 STRAP = 13'9 3/4" => 165.75"
TANK FLOW RATE = 1580 BPD

1001 hrs TP = 637.5 psi
1002 TP = 637.3 psi
1003 TP = 636.5 psi
1004 TP = 636. psi
1005 636.5 psi
1006 637 psi
1007 637.5 psi
1008 637.3 psi
1009 637.3 psi
1010 637.3 psi ; q_o = 1776 BPD; q_g = 962.6 MSCFD

APPEARS THAT LPRN NOT SHIFTED INTO CLOSED POSITION - WELL STILL FLOWING

[1015 hrs] TP = 637 psi ; T = 48.9°F
METER q_o = 1794 BPD
METER q_G = 960.7 MSCFD } 540 SCF/bbl

[1016 hrs] PRESSURE UP ON CASING TO 1950 psi to open LPRN

[1020 hrs] TP = 637 psi; Metered q_o = 1783 BPD
q_G = 963 MSCFD

[1021 hrs] UP ANNULUS PRESS. TO 2500 psi
[1024 hrs] BLEED OFF ANNULUS

Kuvuu 10/1/92

[..5 hrs] TP = 635.5 psi Metered q_o = 1776 BPD
q_G = 974 MSCFD

[..30 hrs] TP = 635.0 psi Metered q_o = 1736 BPD
q_G = 952

TANK STRAP = 15'10" => 190"
TANK RATE = 1940 BPD
TANK GOR = 491 SCF/bbl

[1035 hrs] TP = 636 psi METERED q_o = 1783 BPD
q_G = 942.3 MSCFD

[1039 hrs] PRESSURE ANNULUS TO 1500 psi (cycle #1)
[1040 hrs] BLEED DOWN ANNULUS
TP = 635 psi q_o = 1733 BPD
q_G = 951 MSCFD

[1041.5] PRESSURE ANNULUS - CYCLE #2

[1043 hrs] PRESSURE CYCLE #3

[1044 hrs] CYCLE #4 - TO BLIND IN OMNI

[1045 hrs] TP = 617.5 psi ← 1046.0 558 psi
1046 hrs 357 psi
1047 hrs 160 psi SUBSEA LUBRICATOR CLOSED
1047.5 TP = 57.6 psi
1048 TP = 35.9 psi
1048.5 TP = 8.8 psi
1049 TP = 0

10/3/92 NOTE: 6PR-N VALVE PULLED ON 10/2/92 was partly open — choke downhole
- careful w/ P.I. calculations
- Affected drawdown

Kuvlum 10/1/92

~~1030 hrs~~ ~~BEGIN RIG UP OF SCHLUMBERGER SPINNER SURVEY~~

$\boxed{\text{1045 hrs}}$ BEGIN SHUT-IN; 12 HR +/- PLANNED; NO SURFACE READOUT; ALL P'S MEASURED BELOW OMNI VALVE

$\boxed{\text{1100 hrs}}$ — ARCO REPORTS SMALL (≤ 10 gal) discharge of Condensate from line leading to Flare @ End of flow period; was burning when hit Ice (Condensate accumulates in low spot on flare line — low gas rate not enough to carry to burner except when slug hits from separator shut down — Supplier is Monitoring affected ice; doesn't appear to be a problem — May try to recover ice

my estimate is less than 10 gal

Probably representative of fluid to ice

- Follow up surveys w/ boat helicopter — No evidence of sheening — wasted ice
- bled line to flare — 99% water; 1% Condensate (estimated)

Kuvlum 10/1/92

$\boxed{\text{..00 hrs}}$ — Decision made to suspend build up test; will circulate & reverse out fluids, thru separator — flare gas — Meter liquids & strap tank
- TANK #5 to catch fluids

..hrs

$\boxed{\text{1800 hrs}}$ Pick up 10th anchor and begin deployment w/ Miscaroo (9 deployed — existing as of 10/1)

$\boxed{\text{..35 hrs}}$ Anchor #1 on bottom w/ RAR

$\boxed{\text{1935 hrs}}$ Reverse out fluids, control @ Choke manifold before Separator; flow through adjustable choke — Current Setting 20/64ths

..ut in
..culate
position

WH Pressure 1000 psi @ data header prior to opening choke
- ~~well shut in~~ - well remains shut in

WH = TP

Kurlun 10/1/12

1940 hrs	Continue Reverse out; well shut in
	TP = 959 psi
	- dry gas to flare
1943 hrs	WH = 948 psi
1945 hrs	WH = 920 psi ← Begin Pump down annulus @ 1948, WH =
1950 hrs	WH = 1290 psi
	- BEGIN TO ROUTE FLOW THRU SEPARATOR (PREVIOUS PRECHARGE TANKS)
1952	WH = 1380 psi
	CP = 465
1953	WH = 1313 psi, CP = 450.0 psi
Pump shut in	engage pumps slow 1959 hrs
2000 hrs	Move to 24/64ths adjustable
	TP = 1261 psi; CP = 454 psi
	- dry gas
2000 hrs - 2054 hrs	WATCHED FLARE FOR fluids; NO BURNING ON WATER; POSSIBLY <1 gal water discharge
2015	WP = 920; CP = 107
2030	WP = 780; CP = 341
~~2045~~ 2045	WP = 410; CP = 297
2100	WP = 12.4; CP = 170

Kurlun 10/1

2104 hrs	Shut in choke
2105 hrs	Begin Cycle #1 OMNI valve
2108 hrs	1500 psi / 1500 psi
	WP = 0
2108 hrs	Begin cycle #2 OMNI
2110	WP = 1500; CP = 1500
	Bleed down
2110.5	WP/CP = 0
2111	Begin Cycle #3 OMNI
2112.5	WP/CP = 1500 psi
2113	Bleeddown
2113.25 hrs	WH = 560; CP = 0
	OMNI VALVE BLANK POSITION
2114.75	TP = 700 psi
2115 hrs	TP = 525 psi
2119 hrs	Bleed WH down to 150 psi
2119.5 hrs	TP = 29.6 psi
2121.5 hrs	OMNI IN WELL TEST POSITION
	CP = 1500 psi; TP = 0 psi

- 4 Seals around while rig flaring on 9/30 & 10/1

Kuvlum 10/1/92

2200 hrs Plans are to pull test string; replace ~~[illegible]~~ LPR-N & OMNI; retrieve perf guns & run in hole for retest of same zone
- Consideration due to no surface readouts during flow test & shut in - could not get SRO to seat after 10 minute clean up (junk in hole) & could not run prior to Build up (LPR-N failure).

3 attempts

uses a J-latch

- hole currently taking brine (lost circulation) & wellbore overbalanced.
  - trying to determine rate & will spot lost circulation plug, & control wellbore loss
- will not retrieve tools until wellbore ~~[illegible]~~ static

probably due to suspending Build up too soon

- expect 8-16 hrs to get tools out of hole; should be ready for retest within 24-48 hrs

- current ice conditions > No hazards other than grounded Parana & N. Columbia

COCP / TESTING 10/1/92

Kuvlum

2200 hrs - (CONT'D)

→ Discussed "what ifs" with Fred Johnson (ARCO Drilling Engineer) regarding ice & suspensions (similar discussions should have been done between ARCO office engineers & DS)

→ Question was what if coming out w/ test string & ice alerts increase (HT decreasing) - ARCO position is that well will be dead ~~first~~ ~~[illegible]~~ ~~packer (close off annulus) &~~ before pulling string, RIH w/ RTTS packer (close annulus) & storm choke (for tubing close)
- this would be secured by ARCO standpoint & would pull BOP stack because potential for damage if Parana and/or N. Columbia moved through location (15' scours) based on ROV surveys
- what would MMS position be? Suggested calling Brian

...orable ...r winter ...ndonment, ...ly ok ...appear to get ...ack on location

isolation & test zone

Kuvlum 10/1/92

RIG MODIFICATIONS NEEDED:

(1) Modify flare lines (flexible hoses) & low points allow for water & condensate to collect

(2) Curbs on Kulluk ~~[illegible]~~ 10u deck nonexistent - Predrill?

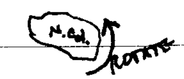
(3) Flood lights should be operable when flaring @ night - only necessary for those near flare facing outboard.

(4) Deeper glory hole for subsequent wells based on ROV survey of N. Columbia & Panama
- get copies of surveys

Kuvlum 10/2/92

0800 hrs TRIP OUT OF HOLE W/ TEST STRING CONTINUING (TOOLS ON DECK BY 1100 hrs?) - WELL STATIC

ICE: PANAMA STATIONARY
N. COLUMBIA ROTATING CCW SINCE 2200 hrs 10/1 & slightly sliding to SE



@ rig

- Supplier & Miscaroo monitoring N. Columbia; Kigoriak monitoring Panama

Panama

More manageable

(PER 10/2 415 hrs MORNING ICE ANALYSES FROM I/B GPS & Kulluk Radar.

0830 hrs Reconfirmed COCP actions w/ ARCO Engineers; plans posted
- Frank Johnson
- Dave Bumgardener (nights)
- BRUCE CAMPBELL
  company man

** - ARCO has several videos from ROV surveys of N. Columbia & Panama(?) (RUN OFF Supplier) & some reports which may be of interest to MMS

Kuvlum 10/2/92

- ROV survey shows water depths between 92' and 109' around the flows; was not picked up on side scan & subbottom profiler during site-clearance
- Gouge depths up to 15' deep based on hydrostatic measures by the ROV, converted to WD
- Deeper gouging is something we should build into our expectations/possibilities approvals after researching further

1700 hrs	finished POOH w/ Test tools, Retrieve LPR-N, OMNI & Perf guns - Recover Pressure sensors
2000 hrs	Running back into hole w/ test tools for Re-test

- Anticipate Opening up for retest by 900 or 1000 hrs 10/3

→ - analysis of LPR-N valve shows
→ Scarring on exterior of ball indicating
→ possible rust jammed up actuating mechanism - Failed open

Kuvlum 10/3/92

0800 hrs	Morning report shows N. Columbia stopped rotating but could move to SW or begin Rotating again under predicted NE winds; Panama remains stable
0930 hrs	Safety Meeting on rig floor - test procedures - ice in anchor line; may delay test (NO alert)
1030 hrs	Miscaroo frees Multiyear berg from anchor (against ship) - anchor slacked off before it could be moved - berg the size of the Miscaroo; 1 seal around vessel

[?]vik [?]ing ice off stream to keep Miscaroo loads rubble to minimum

WELL TEST #2

[?]36 hrs	OPEN on 16/64ths choke; bypass high stage & surge; into TANK #5 CP = 1500 psi; TP = 0 psi
[?]39 hrs	TP = 29 psi 28/64ths adjustable choke
[?]41 hrs	TP = 0 psi; CP = 1500 psi

Kuvlum

10/3/92

1100 hrs

T_{WH} = 38 °F

~~[illegible]~~ ; TP = 0 psi

- BridgeSol plug placed for lost circulation appears to be in tact
- switched to TANK #6
  - ~~STRAP~~ TANK #5:

PRE-TEST STRAPS

TANK #6 –

TANK #5 –

1215 hrs

~~[illegible]~~ ; TP = 0 psi

T_{WH} = 36 °F ; CP = 1500 psi

→ BridgeSol plug is a cross link polymer (very "snotty"); designed to be washed out w/ flow

1230 hrs

Switch back to TANK #5

~~STRAP =~~

wellhead temp: 35.7°F

Adjustable 28/64ths choke

— COCP —

LUM

10/3/92

0 hrs

Previously unidentified floe called into Kulluk; discovered by Kigoriak – in drift of Kulluk ≈ 4 n miles

lvik & oriak trying to manage

- ice moving earlier @ 0.4 kts (leaves ≈ 10 hrs HT)
- currently on Yellow Alert

→ CALLED BRIAN Schoof about circumstances w/ Henry Hite (MMS) & Fred Johnson (ARCO Engineer) – we discussed situation and well securing options:

→ ARCO

① Bullhead well dead; close LPR-N tester valve

② Pull subsea test tree ~~[illegible]~~ after pressure up to close ball valve in SSTT; Lay down SSTT & STT ← SURFACE TEST TREE

③ Run storm packer & choke below wellhead

Another HRS RTTS packer (would have to be made up on tubing)

* ④ Pull Stack

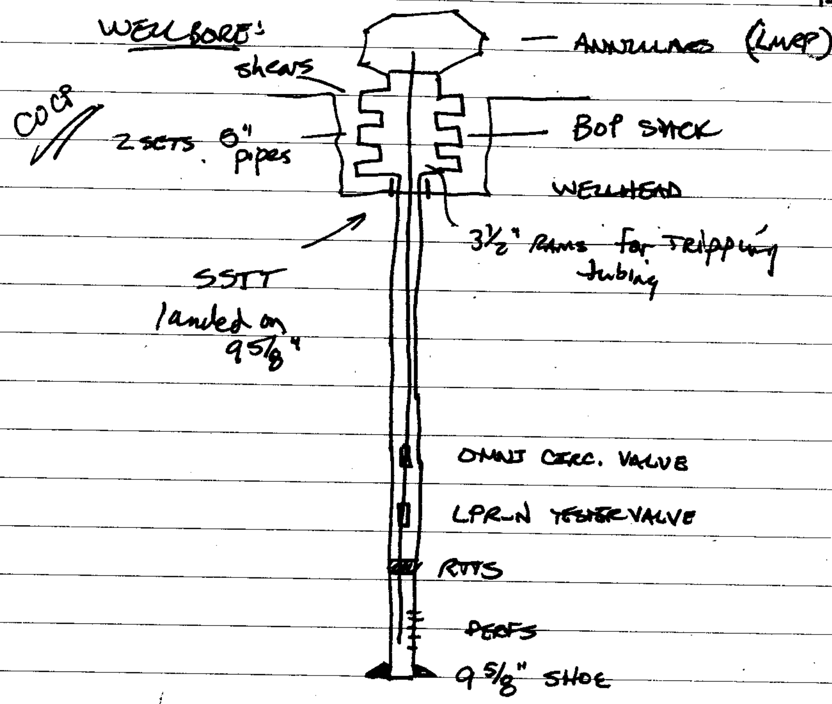
⑤ Move off location

→ Brian says to leave stack on wellhead, no matter what, per approval given to ARCO earlier

NOTE: → well is not currently flowing although it's open (BridgeSol plug still not washed out)

Kuvlum 10/3/92

WELLBORE:



1415hrs - Bruce Campbell, Fred Johnson, Henry Hite called Richard Morgan (ARCO Regional Drilling Supv.); was familiar w/ written agreement between ARCO & MMS (Brian) regarding leaving stack on well unless plugs in hole.
- Copy of Brian's approval to be faxed to rig

1430hrs Appears that ice moving in trajectory which will miss Kulluk; boats are managing ice

Kuvlum 10/3/92

TO SET STORM PACKER have to retrieve SSTT.

and valve

- to set another RTTS (storm packer) in 9 5/8" would have to release lower RTTS, POOH, retreive SSTT; place RTTS in tubing string; RIH & land out on 9 5/8"; ROTATE RTTS TO "J-IN" RTTS lower; then upper

Believe L.C. plug in tubing string

1545hrs Reverse circulate tubing w/ BRINE

1615hrs Foamy oil cut w/ diesel & water to surface; Could be part of pill w/ diesel cushion moved to 32/64ths choke

1624hrs 36/64ths choke; transition to brine/oil emulsion

1655hrs

1655hrs "clean" brine; shut in @ choke manifold
- line up to displace tubing w/ diesel

1705hrs Begin pumping diesel (44 bbls) @ 2 BPM down tubing

Kuvlum

1900hrs

Ice have moved away from Kulluk; Breakers managed ice

10/3/92

1700hrs TANK #6 - 3' 2 1/8"

CP = 1036 psi

WH = 0 psi

1822hrs Well open on 36/64ths adjust.

PLAN → Flow to clean up & ~~stabilize~~

1824hrs open to 40/64ths adjust.

1825hrs open to 44/64ths adjust.

1834hrs Back ~~off~~ to 40/64ths adjust.

1837hrs Back to 32/64ths adjust.

1842hrs Back to 28/64ths choke; trying to get the well pressured up

1845hrs ON RIG FLOOR; SAMPLE TAKEN ALL DIESEL; Choked back to 16/64ths

BOP PANEL - Lower 5" pipe rams (middle rams) Closed; hang off ~~SSTT~~ SSTT

- INTERESTING NOTE: CLOSING TIMES FOR ALL RAMS, & OTHER VALVES NOTED ON PANEL:
  - → PIPE RAMS: 20 sec
  - → Shear Rams: 20 sec
  - → Annulars: 44 sec
  - → Choke/Kill: 12 sec

NOTE: → SWITCHING TANKS ON THE HOUR

Kuvlum

10/3/92

1950 hrs Well flowrate very low; Low pressure; No WH pressure; 16/64ths Adjust choke

Brine - 9.2 ppg

PLUG - 10.2 ppg

→ Recovered fluids (samples between 1624 hrs - 1655 hrs) - 9.5 ppg (per mud engineer tests)

1955hrs Moved to 20/64ths adjust. choke to keep back pressure down; TP = 20 psi

1958hrs Moved to 24/64ths choke (adjust) TP = 30 psi, CP = 1473 psi, T = 39.4°F

2002 hrs choke backed off to 28/64ths Adjust.
- well seems to be coming on line
WH Pressure (TP) = psi

2007hrs 36/64ths adjust. choke
TP_{WH} = 70 psi

2015hrs Calculated rate = 1200 BPD

2020hrs ~~Formation fluid to surface~~
TP = 39 psi

2030hrs sample taken @ WH; 75% H_2O
25% Oil

TP = 133 psi

- formation fluid to surface; begin injection of defoamer

AMBIENT TEMP = 14.7°F

Kuvlum

10/3/92

$\boxed{2033 \text{ hrs}}$ Open Low Stage (Surge Tank)

pH = 7.5

TP = 150.5 psi ; T = 40°F

Tank #5 strap = 4'6¼"
@ 2030 hrs

Previous strap 4'3¾" →

TANK RATE =

- well slugging gas (reason for varying rate)

$\boxed{2040 \text{ hrs}}$ TP = 195 psi

T = 40°F

Choke = 36/64ths adjust.

$\boxed{2045 \text{ hrs}}$ SAMPLE: 90% water

0.3% sediment

9.7% oil

TANK #5 STRAP: 5'4"

TANK RATE ~ 1520 BPD ←

TP = 230.7 psi ; T = 40°F

$\boxed{2100 \text{ hrs}}$ TP_{WH} = 289 psi ; T = 40°F

.15% CO_2

TANK #6 STRAP = [illegible] 4'5¼"

Previous #6 STRAP 4'2¾" ←

TANK RATE = BPD

<1.375" o. plate in low stage>

$\boxed{2114 \text{ hrs}}$ Replace w/ 1.125" orifice plate in surge

$\boxed{2115 \text{ hrs}}$ – TP = 356.5 psi ; T = 40.5°F

93.9% oil

6% H_2O

0.1% sediment

~~Tank #6 Strap~~

~~Tank Rate = BPD~~

→ SWITCHED TO TANK #5 @ 2100 hrs

$\boxed{2130 \text{ hrs}}$ TP = 449 psi ; T = 40.9°F

99.7% oil

.3% water

TRACE SEDIMENT

TANK #5 STRAP = 5'4"

TANK RATE = —

Fill SURGE TANK

...um

10/3/92

...9

$\boxed{\text{...hrs}}$ Route flow through separator (high stage)

$\boxed{\text{...45 hrs}}$ OPEN TO 40/64ths choke

TP = 439 psi ; T = 41°F

- well flow: still slugging gas

Sample: 5% H_2O; TRACE Sediment

$\boxed{\text{...00 hrs}}$ SWITCH TO TANK #5

TANK #6 STRAP = 5'5¼"

TANK RATE = BPD

TP_{WH} = 479 psi ; T_{WH} = 42°F

$\boxed{2210 \text{ hrs}}$ 1.500" orifice plate for separator

$\boxed{2219 \text{ hrs}}$ TP = 498 psi ; T = 41.9°F

$\boxed{2230 \text{ hrs}}$ TP = 553.8 psi ; T = 43°F

TANK #5 STRAP = 7'1¼" (Switch to TANK #6)

TANK RATE = 1700 BPD

Meter rate oil = N/A

gas = 773.7 MSCFD

water = 0

$\boxed{2245 \text{ hrs}}$ TP = 548.8 psi ; T = 41.9°F

Metered q_o = 3047 BPD

Metered q_g = 868.5 MSCFD

q_o = 2495 BPD, q_g = 862 [illegible]

$\boxed{2250 \text{ hrs}}$ begin flow through high & low stage separation

NOTE → Surge tank problems — use meter rates; meter correction factor by averaging Tank rates over several hrs

KUVLUM 10/3/92

~~TANK STRAPS~~

~~TANK #5 TIME (BSS) TANK #6~~

TANK STRAPS

TANK #5	TIME	TANK #6
	2000hrs	
	2015	
	2030	
5'4"	2045	—
—	2100	4'5¼"
5'4"	2130	—
—	2200	5'5¼"
7'1¼"	2230	—
—	2300	6'9¼" ← 2315 hrs shut in to run prod. logs
7'2½"	2312	
—	2330	—
—	2400	—
—	0100	—
	0117 OPEN	
7'4¾"	0130	—
—	0200	11'4"
10'8¼"	0230	—
—	0300	14'7½"
13'9¼"	0330	—
—	0400	18'¼"
17'3¼"	0430	—
TANK FULL		TANK FULL

...um 10/3/92

...00 hrs TP = 569.5 psi; T = 41.9 °F

switch to Tank #5

TANK #6 STRAP = 6'9¼"; TANK RATE = 1280 BPD

[illegible] adjust

Meter q_o = 1623 BPD

Meter q_g = 886.6 MSCFD

water = 0

...308 hrs shut in @ choke manifold

- will not close LPR-N
- Run Schlumberger wireline tools for production logs

...t in @ lubricator (subsea) bleed off choke manifold

TP = 580 psi
T = 42 °F

...311 hrs Lubricator valve closed

- bleeding off manifold pressure

2315 hrs - Pressure bled down; begin running wireline for production logs

- want bottom hole pressure while logging and during stabilized rate

NOTE: GET COPY OF TEST #2 PROGRAM; INCLUDING LIST OF PRODUCTION LOGS TO BE RUN

Kurum 10/4/92

0004 hrs Begin to pressure up to equalize pressure across subsea lubricator (to run in w/ wireline)

0011 hrs Lubricator

0018 hrs Running wireline tools into hole thru SS lubricator

0115 hrs Open well on 16/64ths Adjust choke
Shutin TP = 880 psi BHP shut in = 2809 psi
Flow TP_{WH} = psi

0117 hrs OPEN WELL to 20/64ths adjust chok
TP = 779 psi

INC. DRAWDOWN FLOW TO

0118 hrs TP = 766 psi
Open to 28/64ths adjust choke

0119 hrs TP = 752 psi

0120 hrs Open to 36/64ths choke
TP = 726 psi

0123 hrs BHP = 2659 psi
TP = 620 psi ?
Open to 40/64ths choke (adjust)

um 10/4/92

0126 hrs BHP = 2543 psi ; dropping
TP_{WH} = 542 psi ; T = 38 °F

0130 hrs Open choke to 46/64ths
Switch flow into TANK #6
~~GAUGE~~ GAUGE TANK # 5 = 7'4 3/4"
TANK RATE = 180 BPD
WH = 512 psi ; T = 38.5° F

0132 hrs BHP = 2445 psi
TP = 466 psi ; T = 39.8°F

BHP

(Pres = 3000 psi)

0135 hrs TP = ~~464~~ psi ; T = 40.5°F

0136 hrs BHP = 2412 psi ; TP = 466 psi
T = 40.7°F

0138 hrs Open choke to 52/64ths adjust.
TP = 464 psi ; T = 41 °F

0140 hrs BHP = 2365 psi ; TP = 415 psi
T = 41.2°F

2" Choke installed

Kuvlum 10/4/92

[0144 hrs] open to 60/64ths adjust.
TP - 425 psi ; T = 42.2°F

[0145 hrs] TP = 364 psi ; T = 42 °F

[0147 hrs] BHP = 2289 psi ; T = 42.4°F
TP = 353 psi

[0150 hrs] WH = 347 psi ; BHP = 2273 psi
T = 43.6°F

[0155 hrs] WH = 366.5 psi ; BHP = 2269 psi
T = 43.8°F

well out of critical flow

[0158 hrs] WH = 358.8 psi ; T = 43.9°F

[0200 hrs] switch to tank #5
WHP = 352 psi ; T = 44 °F
BHP = 2259 psi TANK GAUGE = 11'4"
TANK RATE = 4381 BPD
- Begin injecting defoamer @ separator

30 min averaged rate (Rate taken every min over 30 min interval) { metered q_o meter = 7100 BPD
q_g meter = 1664 MSCFD

oil grav = 34° API

FLOW TEST - (CONT'D)

Kuvlum 10/4/92

[0205 hrs] WH = 344 psi ; T = 44.5°F

[0210 hrs] WH = 328.3 psi ; T = 44.7°F

trying outside critical

[0215 hrs] WH = 327.3 psi ; T = 45.1 °F

[0220 hrs] WH = 325.5 psi ; T = 45.3°F
~~BHP =~~ psi ?

[0225 hrs] open well on 60/64ths choke
WH = 322.5 psi ; T = 45.5 °F

[0228 hrs] SAMPLE: TRACE SAND ; 0.3% Sediment - wax
All oil water = ∅ ; 34° API oil

[0230 hrs] TANK #5 GAUGE = 10'8¼"
TANK RATE = 3160 BPD
WH = 309 psi ; T = 45.9°F
metered { q_o = 5133 BPD
q_G = 1532 MSCFD } GOR = 300 scf/bbl

Some sand showing in Shake out

BHP = 2220 psi ; dropping

Flowing on 60/64ths adjust. choke

Kuvuum

10/4/94

~~0235 hrs~~

FLOW ~~TEST~~ - CONT'D

0240 hrs — WH = 309.3 psi; T = 46.6 °F

meter { q_o = 4467 BPD ; q_G = 1437 MSCFD } GOR = 322

~~[illegible]~~

34° API gravity

0250 hrs — WH = 305 psi; T = 46.9 °F

60/64ths choke

meter { q_o = 4774 BPD ; q_G = 1392 MSCFD }

water = 0

0300 hrs — WH = 302.5 psi; T = 47.4 °F

60/64ths choke

meter { q_o = 5243 BPD ; q_g = 1339 MSCFD } GOR = 260

~~[illegible]~~ — Begin Running production logs

60/64ths choke

GAUGE TANK # 6 = 14' 7 1/2"

TANK RATE = 3160 BPD

0310 hrs — WH = 298 psi; T = 47.8 °F

meter { q_o = 5399 BPD ; q_G = 1276 MSCFD } GOR = 236

0318 hrs — 1.250" plate in high stage separator

flowing; 60/64ths choke (adjust)

MM

10/4/92

20 hrs — WH = 301.5 psi; T = 48.1 °F

meter { q_o = 5081 BPD ; q_G = 1729 MSCFD } GOR = 340

30 hrs — WH = 299.5 psi; T = 48.7 °F

meter { q_o = 4156 BPD ; q_G = 1310 MSCFD } GOR = 315

TANK #5 GAUGE = 13' 9 1/4" ; TANK RATE = 2961 BPD

meter { cum oil = 402 BBL ; cum. gas = 155 MSCF }

0340 hrs — WH = 297 psi; T = 49 °F

metered { q_o = 4381 BPD — 34° API ; q_G = 1254 MSCFD — 0.73 sp.gr. }

GOR = 286

0350 hrs — WH = 298 psi; T = 49.5 °F

meter { q_o = 4398 BPD — 34° API ; q_G = 1189 MSCFD — 0.73 sp.gr. }

0400 hrs — WH = 298 psi; T = 49.8 °F

meter { q_o = 4625 BPD ; q_G = ~~[illegible]~~ 1121 MSCFD } GOR = 242

TANK #6 GAUGE = 18' 1/4" ; TANK RATE = 3261 BPD

meter { cum. oil = 495 BBL ; cum. gas = 179 MSCF }

Flowing on 60/64ths choke (adj.)

Kuvlum 10/4/92

0410 hrs WH = 294 psi ; T = 50 °F

meter { q_o = 4756 BPD ; q_g = 1091 MSCFD } GOR = 229

water = 0

0420 hrs WH = 295 psi ; T = 50.5°F

went to 30 min increments { metered { q_o = — BPD - 34° API ; q_g = — MSCFD - 0.73 sp.gr

0430 hrs WH = 294.5 psi ; T = 59.7 °F

metered { q_o = 4717 BPD ; q_g = 999.6 MSCFD } GOR = 212 SCF/BBL

Tank #5 gauge = 17'3 3/4"

TANK RATE = 3361 BPD

* SWITCH TO TANK #7

METER { cum. oil = 594 BBL ; cum. gas = 201 MSCF. water = 0

0440 hrs WH = 294 psi ; T = 51.0 °F

meter { q_o = 4633 BPD ; q_g = 876 MSCFD } GOR = 189

0500 hrs WH = 292 psi ; T = 51.6°F

meter { q_o = 4757 BPD ; q_g = 771.3 MSCFD } GOR = 162

TANK #7 GAUGE = 4'9"

TANK RATE = 4561 BPD

WATER = 0

meter { cum. oil = 692 BBL ; cum. gas = 218 MSCF

Kuvlum 10/4/92

TANK GAUGES

TANK #7	TIME	TANK #8
4'9"	0500 hrs	—
—	0530	—
—	0600	—
—	0630	—
—	0700	—
—	0730	—
—	0800	—
5'10 1/4"	0830	—
—	0900	3'1/4"
	0930	—
	1000	
	1030	
	1100	
	1130	
	1200	
	1230	
	1300	

0917 hrs RED ALERT DECLARED BECAUSE OF ICE

KUVLUM 10/4

0500hrs Shut in @ choke manifold to pull wireline tools & RUN SPRO (surface pressure-read-out)

0512hrs Close LPR-N by bleeding pressure on annulus

0513 hrs LPR-N Closed

- will open well again gradually to a rate at least equal to the previous flow test!

- intent is to get another pressure transient into the reservoir, shut in at the bottom & build up.

~~MAXIMUM RATE~~ FLOW TEST (PRIOR TO BUILD UP)

0820hrs ? Open choke manifold; up to 26/64ths choke

BHP = psi

WHP = psi

T = °F

KUVLUM 10/4/92

25hrs BHP = ~~[illegible]~~ psi; WHP = 296 psi

open on 76/64ths choke BHT = 118 °F

WHT = 47.4 °F

0827hrs open on 88/64ths choke; well back-pressure controlled by separator

BHP = psi; WHP = psi

0830hrs 5' 10 1/4" TANK #2 GAUGE TANK RATE = 2651 BPD

0833hrs full open on choke - 2"

BHP = psi; WHP = psi

T = °F

0835hrs Plate in service in high stage separator (1.375")

WHP = psi; BHP = psi

0840hrs BHP = psi; WHP = psi

T = °F

0845hrs PANAMA ICE FLOE ROTATING; MAY HAVE TO MOVE FROM LOCATION

- IF RECON BY BOATS

Kuvlum   T = °F   10/4/92

0845 hrs   BHP = psi
            WHP = psi

0850 hrs
BHP = psi ; WHP = psi
T = °F

0855 hrs
BHP = psi ; WHP = psi
T = °F

0900 hrs   TANK GAUGE =
            TANK RATE = BPD

BHP = psi ; WHP = psi
T = °F

- SPRO tool leaking ; pressure data ok for flow but would be invalid for Build up

WELL TEST SUSPENDED - RED ALERT DUE TO ICE

COCP

Kuvlum   10/4/92

0916 hrs   RED ALERT DECLARED
- WELL SHUT-IN NOTICE GIVEN TO SCHLUMBERGER (WIRE LINE TOOL - SPRO)

0917 hrs   LPRN CLOSED

Panama flow has begun to move (rotate) toward the location

PLAN: ① Bull head after Schlumberger ~~tools~~ out of hole
② Close LPR-N
③ Cycle OMNI to blank

NOTE: Subsea Test tree hung off in wellhead, not on pipe rams

1000 hrs   Schlumberger tools out of hole

1016 HRS   BLOW DOWN COFLEX HOSE w/ AIR - CIRC. OUT OIL INTO TEST SEPARATOR

1017 HRS   ICE PLOTS INDICATE PANAMA WILL LIKELY MISS US; CONTINUE w/ SECURE PER RED ALERT

COCP

Kuvlum 10/4/92

- DECISION TO BULLHEAD TO BE MADE AFTER FURTHER ICE ANALYSIS

[1020 HRS] DOWNGRADE ALERT TO "YELLOW"
- FLOE TO MISS KULLUK
- STANDBY UNTIL FLOE SEPARATES AT A DISTANCE FROM KULLUK
- CONTINUING TO BLOW DOWN COFLEX

STANDBY ON ICE ALERT STATUS

[1030 hrs] DEBRIEF ON RIG FLOOR
- STATUS OF OPS
- OVERVIEW OF WORK COMPLETED
- DAVE BUMGARDNER (ARCO)

[1100 hrs] Debrief in Control Room w/ Captain (Guy Kendell) and OIM (Grant Stafford)
- discussed safety margins in Alert times (Secure times)
- discussed time savings

- discussed operations to follow per ARCO (In Anchorage) - continue to do build up; time will be determined later

COCP

lum 10/4/92

- YELLOW ALERT CONTINUES; RECALC. SECURE TIME BASED ON WORK COMPLETED THUS FAR IN SECURE

- ICE FLOE (PANAMA) gouging as it moves; moving much slower than rest of 1st YEAR ICE; BRIDGE MONITORING AND ICE BREAKERS KALVIK, KIGORIAK and Supplier on Panama; Miscaroo managing 1st year sheet in drift of Kulluk

- WEATHER: POOR VISIBILITY; STRONG WINDS (APPROACHING 30 KTS); VERY COLD

[..0 hrs] Well Test called off officially as of 1130 hrs, 10/4/92.
- plan is to ~~~~ ~~up~~ pull tubing out of hole, lay down test tools, RIH w/ EZSV, ~~squeeze~~ bullhead fluids; & squeeze perfs, set plugs - P&A

- Build up data (from downhole gauges) until open well again (2ND B.U.)

T NOTES 10/6/92

FOLLOW UP NOTES

1) Well perforated @ 0845 hrs 9/30

2) 10 Minute cleanup flow 0845 -0855 hrs

3) Could not seat (latch) SRO probe
∴ all P & T readings from
flowing well head

4) flow #1 initiated @ 1145 hrs 9/30
- opened gradually to 28/64ths choke

5) Surge Tank (Low stage separation)
problems from improperly working dump
valve - caused fluctuating Tank
flow rate readings (based on gauging)

6) Foaming persistent ; began using
defoamer @ 1745 hrs 9/30

7) Gas rates through orifice plate,
calculated on differential pressure

8) Oil rates measured through tubine
meter & calculated based on volume
flowed into stock tank over Δt.

KUVLUM – NOTES 10/6/92

(9) Oil Gravity = 34° API
Gas Gravity = 0.722 - 0.73
- both measured on site

(10) Metered oil rates and GOR's are questionable – measured by unproved meter

(11) LPR-N Tester Valve failed in partial open position when attempted to cycle close for Build up Test
- closed OMNI Circulating Valve up hole of LPR-N @ 1045 hrs on 10/1/92

(12) Begin Build Up #1 @ 1045 hrs, 10/1
- no surface read out since SRO tool could not be latched into place downhole prior to Flow Test.

(13) BU #1 Test suspended @ 1800 hrs 10/1/92
- RETRIEVE TOOLS, REPLACE LPR-N & OMNI; RECOVER GUNS; RECOVER PRESSURE RECORDERS; RETEST

KUVLUM – NOTES 10/6/92

Flow Test #2 initiated 1036 hrs 10/3/92
- problems getting well to flow initially because loss circulation pill was used after suspending Build up (well was losing fluids)
- well came back on line 1822 hrs w/ very low Tubing (well head) Pressure and flow rate
- 2030 hrs: formation fluid to surface

RAN INTO WELL WITH SUITE OF PRODUCTION LOGS
OPEN GRADUALLY TO 40/64THS choke

RUNNING PRODUCTION LOGS BOTTOM TO TOP BEGINNING @ 115 hrs 10/4/92
- OPEN GRADUALLY TO 60/64 THS choke

Shut in Flow Test #2 to pull wireline logs (production logs) from wellbore @ 0500 hrs 10/4/92

MAXIMUM FLOW RATE TEST (FLOW #3) prior to Build up begins @ 0820 hrs 10/4/92

Shut in @ 0917 hrs – RED ALERT DECLARED – ICE

Kuvlum NOTES 10/6/92

(19) Build up #2 Data should be available from downhole gauges beginning 0917 hrs through ?

PROPRIETARY

UNITED STATES GOVERNMENT
MEMORANDUM

To: File

Through: Supervisor, Operations Review and Approval
Supervisor, Operations Unit

From: Geologist

Subject: Log Analysis in Support of Reserve Estimate

I have completed log analysis of the first three Kuvlum wells. The results of the last two Kuvlum wells, Y-0865 #1 and Y-0866 #2, indicated that ARCO Alaska, Inc. (ARCO), has substantially overestimated the extent and productivity of the field. This is indicated by the drastic decrease in reservoir quality reported in the second well, Y-0865 #1, and by the lack of reservoir in Y-0865 #2 where presumably it has been removed by erosion. However, in drilling Y-0865 #1, ARCO discovered a second reservoir overlying the first. This result strongly supported the interpretation of Kuvlum reservoir presented by Chevron U.S.A. during the creation of the Kuvlum Unit. While this second reservoir is not as thick as the first encountered in the Kuvlum #1 well, Y-0866 #1, it could also add to the reserve estimate of the Kuvlum Unit. Since the log analysis indicates that the Kuvlum sands vary laterally, additional drilling is necessary to accurately define the reservoir and estimate reserves. If ARCO is asked to provide an estimate of the size of the Kuvlum accumulation, they should be advised to include in their estimate the size and geographic extent of the new reservoir and also predict where both reservoirs will be removed by erosion. This could result in either or both expansion and contraction of the Kuvlum Unit.

bcc: File OCS Y-0866 Well No. 1, 5A

FMiller:pmw:2/22/94
F:\users\warnerp\kuvres.pri

PROPRIETARY

MEMO

TO:
ENGINEER'S FILE, 5A, OCS Y-0866 WELL NO. 1

THRU:
SUPERVISOR, OPERATIONS UNIT
SUPERVISOR, ORA

FROM: GEOLOGIST

SUBJECT:
LOG ANALYSIS IN SUPPORT OF RESERVE ESTIMATE

I have completed log analysis of the first three Kuvlum wells. The results of the last two Kuvlum wells, Y-0865#1 and Y-0866#2 indicate that Arco has substantially overestimated the extent and productivity of the field. This is indicated by the drastic decrease in reservoir quality reported in the second well, Y-0865#1, and by the lack of reservoir in Y-0865#2 where presumably it has been removed by erosion. However, in drilling Y-0865#1 Arco discovered a second reservoir overlying the first. This result strongly supported the interpretation of Kuvlum reservoir presented by Chevron during the creation of the Kuvlum Unit. While this second reservoir is not as thick as the first encountered in the Kuvlum #1 well, Y-0866#1, it could also add to the reserve estimate of Kuvlum Unit. Since the log analysis indicates that the Kuvlum sands vary laterally, additional drilling is necessary to accurately define the reservoir and estimate reserves. If Arco is asked to provide an estimate of the size of the Kuvlum accumulation, they should be advised to include in their estimate the size and geographic extent of the new reservoir and also predict where both reservoirs will be removed be erosion. This could result in either or both expansion and contraction of the Kuvlum Unit.

Details forthcoming? If not, what is this?

OPRIETARY

MEMO

August 5, 1994

TO: KUVLUM UNIT FILE

THROUGH: REGIONAL SUPERVISOR, FIELD OPERATIONS
SUPERVISOR, ORA
SUPERVISOR, OPERATIONS UNIT

FROM: GEOLOGIST

SUBJECT: PETROPHYSICAL ANALYSIS OF KUVLUM PROSPECT, Y-0866 No.1

This memo will present a preliminary petrophysical analysis of the Kuvlum Prospect. The discovery well, OCS-Y 0866 No.1 (Kuvlum No.1), was drilled by ARCO during the 1992 open water drilling season. The well was logged and tested productive over a 155 foot interval.(see attachment No.1) Subsequently, during the 1993 open-water drilling season, two additional wells, OCS-Y 0865 No.1 (Kuvlum No.2) and OCS-Y 0866 No.2 (Kuvlum No.3) tested the limits of the field. Discouraging results from those wells were reported by ARCO. Currently, no additional drilling is planned for Kuvlum Prospect.

Stratigraphy:

The Kuvlum reservoir consists of Oligo-Miocene shelfal sands and underlying channel sands of the advancing delta front. These sediments were deposited into the Kaktovik sedimentary basin and resemble the sands encountered in the Hammerhead No.1 well which occurs along depositional strike to the northwest. The reservoir sands overly the silts and coal-rich muds of the advancing delta front. The top of the reservoir is sealed by a well consolidated, dark grey, silty, micaceous mudstone with local pyrite and sparse coal. To the northeast in the Kuvlum No.3 well, erosion was observed to have removed the entire interval of Kuvlum reservoir sands. While to the southwest in well Kuvlum No.2 the shelfal sands grade to silts and muds.

Lithology:

The sandstones of the Kuvlum reservoir are described as moderately consolidated, structureless to mottled to crudely laminated with internal grading, light grey, moderate- to well-sorted, subangular, very fine-grained, cherty, quartz sand to silty sand. Where the sandstones occur with mudstones they are described as well- to poorly sorted and contain wood/coal fragments some of which are pyritized.

The sandstones were encountered between 6507' and 6662' for a total thickness of 155'. Sidewall cores collected within this interval were described as consisting of sands and mud. From the results of the coring no internal subdivisions of the reservoir were evident.

Logging Tools:

The suite of logs utilized for the petrophysical analysis included: the Array Induction Log in place of the standard resistivity suite; the Dipole Sonic Log; and the Lithodensity/Neutron Log. The Array Induction Tool is a recent addition which permits the identification of zones of deep invasion and directly reads both R_{XO} and R_T. Additionally, a Formation Microimager log was obtained to permit an estimation of the sand count.

Log Editing:

The gamma ray traces of each logging tool were compared and no depth adjustment was performed. The neutron logs were compensated with the procedure of Elphick (Elphick,1987). Gamma ray traces were compensated for mud weight and hole volume.

Shale Analysis:

The gamma ray index of the formation was calculated assuming a maximum response, in shales, of 88.7 API units and a minimum response, in sands, of 30.0 API units. The clay volume was calculated from the gamma ray index using the Clavier formula.

$$V_{CL} = (1.7-(3.38-(GR+0.7))^2)^{1/2}$$

where V_{CL} = volume of clay
and GR = gamma ray index

Porosity:

Total and effective porosities were determined from the density-neutron crossplot. (see attachment No. 2) Total porosities were calculated as the numerical average (except in the presence of gas) of the density and neutron log readings.

The total porosity was calculated as the numerical average of the uncorrected log readings.

where $\Phi_{Density}$ = the density log response
and $\Phi_{Neutron}$ = the neutron log response
then Φ_{Total} = the total porosity

$$\Phi_{Total} = (\Phi_{Density} + \Phi_{Neutron}) / 2$$

Effective porosities were determined by first removing the effects of shale and then averaging the shale-corrected porosities. The density log had a response of 13.5% porosity in shale; while the neutron log (corrected) had a response of 35.8% in shale. Both log readings were corrected for shale using the clay volume.

where Φ_{Shale} is the porosity observed in shales
and V_{CL} is the shale volume
and $\Phi_{Uncorrected}$ is the uncorrected porosity
then $\Phi_{Shale\ Corrected}$ is the shale corrected porosity

$$\Phi_{Shale\ Corrected} = \Phi_{Uncorrected} - (V_{CL} * \Phi_{Shale})$$

The effective porosity was taken as the numerical average of the shale corrected density and shale corrected neutron log readings.

where $\Phi_{DensitySC}$ = the density log response corrected for shales
and $\Phi_{NeutronSC}$ = the neutron log response corrected for shales
then $\Phi_{Effective}$ = the effective porosity

$$\Phi_{Effective} = (\Phi_{DensitySC} + \Phi_{NeutronSC}) / 2$$

Where the presence of gas was inferred from $\Phi_{Density} > \Phi_{Neutron}$ (the crossover effect), Φ_{Total} and $\Phi_{Effective}$ were calculated from a the root mean square formula.

$$\Phi_{Total} = ((\Phi_{Density}^2 + \Phi_{Neutron}^2)/2)^{1/2}$$

$$\Phi_{Effective} = ((\Phi_{DensitySC}^2 + \Phi_{NeutronSC}^2)/2)^{1/2}$$

Formation Water Resistivity:

The formation water resistivity was determined by analysis of well Y-0866#1 which penetrated the formation beneath the oil/water contact. The resistivity of the formation water at the formation temperature was 0.153 ohms. This value was determined from the chemical analysis of formation water in Kuvlum #2 and agrees well with the value of 0.155 ohms derived from the spontaneous potential log using the modified method of Bates & Konen (1977)(see Asquith).

Dispersed Clay Analysis:

Oil saturations within the formation were determined by both a dual water and a dispersed clay analyses. Dispersed clay within the sandstones was reported by the sidewall core analysis. However, the high water resistivity, in excess of 0.1 ohms, indicated that these values be treated with caution and compared with results obtained via the dual water method. The amount of dispersed clay within the formation was calculated from the "Q" factor (the ration of dispersed to total clay). The equation chosen to calculate Q did not require the sonic log.

$$Q = (\Phi_{Total} - \Phi_{Effective})/\Phi_{Total}$$

The volume of dispersed clay (V_{Disp}) may then be determined.

$$V_{Disp} = Q * V_{Clay}$$

and the volume of shale (V_{Sh}) is taken as the remainder of the clay.

$$V_{Sh} = (1-Q) * V_{Clay}$$

Water Saturations with Dispersed Clay Method:

When Q is known, the water saturation of the reservoir is calculated from the dispersed clay equation.

$$S_{we} = ((((0.8/\Phi^2)*(R_W/R_T))+(Q/2)^2)^{1/2})/(1-Q)$$

Water Saturations with Dual Water Analysis:

A Dual Water Analysis may be necessary when dispersed clay is associated with high formation water resistivities (> 0.10 ohm-m). In the current petrophysical analysis a dual water analysis was also performed. The total porosity of the adjacent shale was first calculated.

$$\Phi_{TSH} = \delta\Phi_{DSH} + (1-\delta)\Phi_{NSH} = 0.202 \ (20.2\%)$$

Where Φ_{TSH} is the total porosity of the adjacent shale,
Φ_{DSH} is the density log porosity of that shale,
Φ_{NSH} is the neutron log porosity of that shale,
and δ is a proportional constant generally equal to 0.7.

The total porosity of the formation is then calculated from the effective porosity and the volume of shale.

$$\Phi_T = \Phi_e + (V_{SH} * \Phi_{TSH})$$

where Φ_T is the total porosity of the formation,
Φ_e is the effective porosity of the formation,
V_{SH} is the volume of shale,
and Φ_{TSH} is the total porosity of shale previously calculated.

Next, the clay-bound water saturation (S_b) is derived.

$$S_b = V_{CL} * (\Phi_{TSH}/\Phi_T)$$

The value of the bound water resistivity (R_b) is subsequently determined for the formation.

$$R_b = R_{SH} * \Phi_{TSH}^2 = 3.92*(0.202)^2 = 0.160 \text{ ohm-m.}$$

where R_{SH} is the resistivity of the dispersed shale phase determined from a crossplot of V_{CL} vs R_T.(see attachment No.3)

The apparent water resistivity in the shaly sand (R_{WA}) is found from the equation:

$$R_{WA} = R_T*\Phi_T^2$$

The total water saturation corrected for clay is then

$$S_{WT} = b + (b^2+(R_W/R_{WA}))^{1/2}$$

where $b = (S_b(1-(R_W/R_b))$.

The effective water saturation of the shaly sand (S_{we}) may now be determined from the equation:

$$S_{WE} = (S_{WT} - S_b)/(1-S_b)$$

PERMEABLE SANDS (sand count):

The agreement between the dispersed clay and dual water methods suggests that the dispersed clay model is valid for the Kuvlum reservoir. Producible sands may be determined for dispersed clay reservoirs from a crossplot of Q versus $\Phi_{Effective}$. From such a crossplot producible sands were distinguished. The actual equation used:

IF $2*\Phi_{Effective} - Q > 0.1$ THEN the sands are producible;
IF $2*\Phi_{Effective} - Q > 0.0$ THEN the sands are producible with stimulation;
IF $2*\Phi_{Effective} - Q < 0.0$ THEN the sands are non-producible.

This equation is only valid for sands with the field and represents an extrapolation from the crossplot of Dresser. (1979)

The calculated value of producible sands was 96.5 feet of producible sands in the interval between 6,507 to 6,662 ft. TVD. This value is also in close agreement with the 96 feet (corrected to 93 feet) obtained from the formation microscanner. This also appears to confirm the validity of the dispersed clay model.

Pay Determination:

Pay intervals within the formation were identified by the following criteria:

(1) Effective porosity (Φ) greater than 10%
(2) Water saturation (S_{we}) less than 50%
(3) $2*\Phi_{Effective} - Q > 0.1$

These criteria served to define three major potential zones of production. Additionally, two intervals appear capable of production only under stimulation. The intervals are numbered from the bottom to the top:

Zone 1 (6662-6608) 54 feet Major Zone of Production
Zone 2 (6608-6557) 51 feet producible under stimulation
Zone 3 (6557-6530) 27 feet Major Zone of Production
Zone 4 (6530-6519) 11 feet producible under stimulation
Zone 5 (6519-6507) 12 feet Major Zone of Production

Zone 1 is the largest producing interval within the well and additionally contains the highest porosity and lowest shale contents. The interval appears subdivided into two subintervals from 6662-6624 and 6624-6607 which may well act as distinct flow units. Minor producible intervals occur in Zone 2 which, however may not be laterally continuous in the vicinity of the well. The second and third major producible intervals, Zones 3 and 5, are probably continuous in the vicinity of the well due to their increased thickness. Zone 4 which separates these reservoirs may be non-productive due to reduced permeability and serve as a barrier to vertical fluid flow. Hence, the value of the gas/oil contact at 6518 feet TVD should only be considered an upper limit and gas may occur to 6530 feet TVD in other locations.

The calculated values for the total field as well as the respective zones are presented in Table 1.

Zone	Gross Ft.	Net Pay	$\Phi_{Effective}$	Swe	fluid
1	54.0 feet	51.5 feet	22.5%	34.9%	oil
2	51.0 feet	11.5 feet	18.2%	46.2%	oil
3	27.0 feet	23.5 feet	18.9%	43.6%	oil
4	11.0 feet	00.5 feet	17.3%	45.1%	oil ?
5	12.0 feet	09.5 feet	18.6%	39.9%	gas

MMS U.S. Department of the Interior
Minerals Management Service

OMB APPROVAL NO. 1010-0045
EXPIRES OCTOBER 31, 1991
SUBMIT. Original, two copies, and one public information copy.

SUNDRY NOTICES AND REPORTS ON WELLS

1. FIELD NAME Wildcat	2. MMS LEASE, UNIT OR COMM. NO. (6) Y 0866 0	3. MMS OPERATOR NUMBER (5) 0635

4. OPERATOR WELL NUMBER (6) 1	5. API NUMBER (10) or (12) STATE (2) COUNTY (3) WELL CODE (5) SIDE TRACK(2) 55 171 00008	COMPLETION CODE (3) NA	6. TYPE WELL (1) E	7. CORRECTED ELEVATION (5) -169' (ML-RKB)

8. OPERATOR NAME AND ADDRESS (SUBMITTING OFFICE) ARCO Alaska, Inc. PO Box 100360 Anchorage, AK 99510-0360	9. CURRENT WELL DEPTH (5) MD 8500' TVD 8500' LEAVE BLANK	10. CORRECTED WATER DEPTH (5) 103'

11. CORRECTED LOCATION OF WELL (12) Surface: 5884' FWL and 5598' FSL of Block 673 Production zone: NA Total depth: NA	12. OPERATING AREA CODE (2) FI	13. BLOCK NUMBER (6) 0673
	14. MAP OR OFFICIAL PROTRACTION DIAGRAM NUMBER (7) NR 6-4, Flaxman Island	

15. OPERATOR LEASE, UNIT OR COMMUNITIZATION NAME Kuvlum	16. RIG/PLATFORM NAME BeauDril - Kulluk	17. RIG TYPE (2) SS

18. WELL STATUS, e.g., shut-in, drilling, etc. Testing BOP Equipment	19. LAST CASING STRING: size, lb/ft, grade, and setting depth (MD) 9-5/8", 53.5#, L-80, BTC @ 8459' MD	20. APPROXIMATE START DATE (6) YYMMDD 92 09 18

21. PRESENT PRODUCTION ZONE, IF ANY, AND PRODUCTIVE CAPABILITY

NA

22. CHECK APPROPRIATE ACTIVITY:

Data correction	☐	Fracture/acidize	☐	Artificial Lift	☐	Other	☒
Change plans	☐	Pull or alter casing	☐	Repair well	☐	Perforate	☒
Request approval	☒	Sidetrack	☐	Deepen	☐	Plug back	☐
Subsequent report	☐	Reenter to complete	☐*	Multiple complete	☐*	Recomplete	☐*

Note: Submit a separate Well (Re) Completion Report and a subsequent report of operations on this form for each completion. *Alternatively*, submit a Well (Re) Completion Report for each completion with a narrative as in item 23 of this form.

23. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (Clearly state all pertinent details in this space and on the reverse, and/or on an attachment, and give pertinent dates, including estimated date for starting any proposed work. If well is directionally drilled, give subsurface locations and measured and true vertical depths for all markers and zones pertinent to this work.

1. Attached with this Sundry request for approval to complete / test the subject well is a general testing procedure and test string schematic. It should be noted that sand procuction problems are no longer anticipated due to data obtained during logging operations.
2. Pressure data indicates that the reservoir to be tested has a pressure equivalent to an 8.8 ppg EMW. Anticipated brine weight for the test is 9.5 ppg, (+/-240 psi overbalanced.)
3. The perforated interval outlined in Attachment 5 may be compressed upon futher evaluation of the open hole logs.

Attachments:
1 General Procedure
2 Tool Operation Pressures
3 Test String Schematic
4 Test String Description
5 Perforation Interval

Form MMS-331 (November 1991)
(Supersedes Form MMS-331 (July 1988) which will not be used)

CONTINUED ON REVERSE
COMPLETE REVERSE SIDE, SIGN, AND DATE

FORM MMS-331 SUNDRY NOTICES AND REPORTS ON WELLS Page 2

23. DESCRIBE PROPOSED OR COMPLETED OPERATIONS (continued from page 1)

SUBSURFACE SAFETY VALVE: SUBSURFACE CONTROLLED ☐ SURFACE CONTROLLED ☐ SET AT DEPTH OF ______

MANUFACTURER: ______________________ MODEL NO. __________ SERIAL NO. __________

WARNING: PUBLIC LAW 97-451 provides civil and criminal penalties for false or inaccurate reporting. Failure to report as required under the terms of the lease, permit, or contract may result in suspension of operations or other enforcement actions.

CONTACT NAME (First, MI, Last) Lowell R. Crane	PHONE NUMBER (10) EXTENSION NUMBER (4) (907) 265-1544
AUTHORIZING NAME (First, MI, Last) Mike B. Wintree	TITLE New Ventures Area Drilling Engineer
AUTHORIZING SIGNATURE	DATE YYMMDD (6) 92 09 15

(THIS SPACE IS FOR FEDERAL OFFICE USE)

CONDITIONS OF APPROVAL FOR SPECIAL CIRCUMSTANCES: ARE ATTACHED ☐ NONE ☐

☐ APPROVED BY: DATE (6) YYMMDD

☐ ACCEPTED BY: ______________________ TITLE ______________

PAPERWORK REDUCTION ACT STATEMENT

The Paperwork Reduction Act of 1980 (44 U.S.C. 3501 et seq.) requires us to inform you that: This information is being collected to obtain knowledge of the equipment and procedures to be used during well-completion, workover, and production operations. This information will be used by the District Supervisor to evaluate and approve or disapprove the adequacy of the equipment and procedures to safely perform the proposed operations. Response to this request is mandatory (43 U.S.C. 1334).

Public reporting burden for this form is estimated to average 1/2 hour per response, including the time for reviewing instructions, gathering and maintaining data, and completing and reviewing the form. Direct comments regarding the burden estimate or any other aspect of this form to the Information Collection Clearance Officer, Mail Stop 631, Minerals Management Service, 12203 Sunrise Valley Drive, Reston, VA 22091; and Office of Information and Regulatory Affairs, Office of Management and Budget, Washington, DC 20503.

ATTACHMENT 1

KUVLUM TEST PROCEDURE

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PRIOR TO TEST:

i) Measure initial formation pressure using formation tester.

ii) Obtain rotary sidewall cores for rock strength analysis and brine compatability test.

iii) Develop Sand Strength Analysis Log using data from Sonic Dipole and LDT. Correlate to sidewall core rock strength data.

iv) If 9-5/8" casing has been drilled thru, run corrosion log to ensure casing strength (RD circ valve set at 5000 psi).

SET TEST STRING/PERFORATE: Tubing Conveyed Perforating

1) Replace mud with clear brine.

2) RIH with test string/TCP guns. Tie in to perf interval, set packer.

3) Open OMNI circ valve and inject diesel down tubing to create an underbalance (volume to be determined by onsite New Ventures Engineer). Shut OMNI circ valve.

4) Fire TCP guns with well shut in at surface.

5) RIH with SRO probe assembly and latch in place to monitor bottomhole pressure.

ϕ = 20% ± ?
Pi = ?
°API = ?
ΔP = ?
T = ?
BS&W = ?

BEGIN TEST:

6) Open well to flow. Limit drawdown per sand strength analysis to minimize sand production. Stabilize rate (target = 1000 - 2000 BOPD). Flow at stabilized rate for 24 hours. 12 hrs 9/29/92

7) Shut in for pressure buildup. Shut in time to be determined by onsite New Ventures Engineer (estimated 12 - 96 hours).

8) Open well at low rate to condition for bottomhole sample. Shut in well. RIH with MSST/HUM/Gradio/Pres/Temp, obtain sample in oil column, POOH.

9) Gradually open well to high rate for maximum flowrate test. Flow time to be based on rate and available tank capacity. Shut in well. (4000 bbls) TOTAL

10) Reinject all produced liquids into formation using mud pumps.

See notes for revised procedure

IF WELL WON'T FLOW/LOADS UP:

11) POOH with SRO probe assembly.

12) Hold open tester valve with annulus pressure. RIH with wireline and remove jet pump isolation dummy (below tester valve).

KUVLUM TEST PROCEDURE (CONT.)

13) RIH with jet pump on wireline (below tester valve) and latch in place. POOH with WL.

14) Increase annulus pressure to open jet pump valve and begin injecting power fluid down annulus.

15) After hydrocarbon appears at surface, drop annulus pressure to shut pump. Monitor flowrate. When rate stabilizes, RIH with WL and pull jet pump. RIH with SRO probe assembly and latch in place.

16) Continue test as in steps 6 through 10.

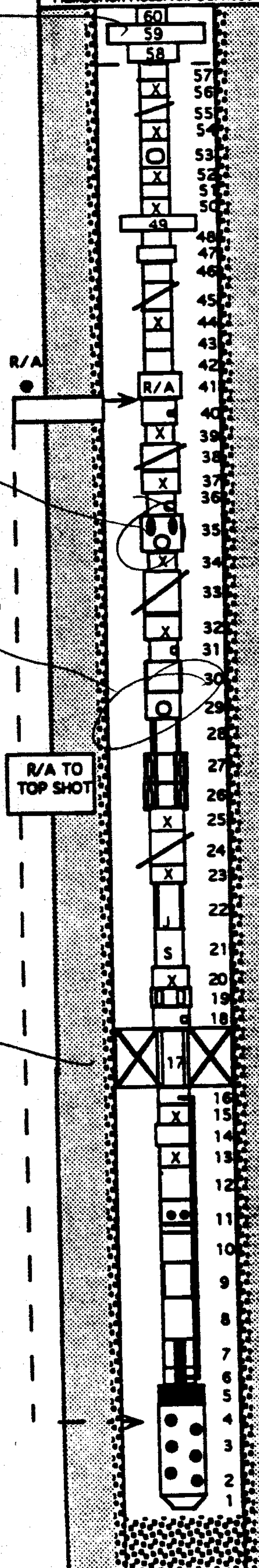
KUVLUM DOWNHOLE TEST EQUIPMENT
Operating Requirements

Tool	Preparation	To Open	To Close
LPR-N Tester Valve	OMNI ball open	Apply 1500 psi to annulus	Drop annulus pres below 1500 psi
OMNI Circ. Valve	None	Cycle annulus pres @ 1500 psi	Cycle annulus pres @ 1500 psi
Jet Pump Assembly	Set pump w/WL	Pull isolation dummy, apply > 2200 psi to annulus	Drop annulus pres below 2000 psi
RD Safety Circ Valve	None	Apply 5000 psi to annulus	Can't reclose once open

Tool	Preparation	To Set/Fire
Champ III Packer	Reach test depth	Raise to set position, rotate 1/2 turn right, apply tubing weight
Differential Firing Head	Set packer	Apply 2000 psi to tubing

ATTACHMENT 2

ATTACHMENT 3



HRS
Halliburton Reservoir Services

HRS - INSTALLATION

COMPANY: ARCO ALASKA		COMPANY REP:	MR. B. BERG	DATE: 8-25-92
WELL NAME KUVLUM #1		FIELD W/C	COUNTY: NORTH SLOPE	STATE: ALASKA
CASING	SIZE 9-5/8"	WEIGHT 53.5#	GRADE L-80	TOP
LINER	SIZE	WEIGHT	GRADE	TOP
TUBING	SIZE 3-1/2"	WEIGHT 12.9#	THREAD PH-6	GRADE
VANN GUN	SIZE 6"	JSPF 12	CHARGE 32 GM DP	EXPLO. RDX
PERFORATION INTERVAL			MAX. DEV. DEG.	BH TEMP DEG. F

ITEM	DESCRIPTION	I.D."	O.D."	LENGTH FT.	DEPTH
60	X-OVER TO LUBRICATOR				
59	HRS TEST TREE	3.06			
58	SWIVEL	2.68			
57	STIFF JOINT	2.50	7.87	9.45	
56	3-1/2" PH-6 P X 5-3/4 4STB ACME B				
55	3-1/2 PH-6 & SPACER SUBS AS NEEDED	2.75	3.50		
54	X-OVER, 4-1/2" 4STB P X 3-1/2 PH-6 B				
53	WIRELINE LUBRICATOR VALVE	3.00	10.75	5.95	
52	X-OVER, 3-1/2" PH-6 X 4-1/2" 4 STB B				
51	1 - JOINT 3-1/2" PH-6	2.75	3.50		
50	X-OVER, 4-1/2" 4 STB X 3-1/2" PH-6				
49	SUB SEA TEST TREE	3.00	13.00	5.62	
48	SLICK JOINT	3.00	5.00	3.00	
47	ADJUSTABLE FLUTED HANGER	3.00			
46	3-1/2" PH-6 P X 4-1/2 4 STB ACME B	2.50	4.50	1.46	
45	3-1/2" PH-6 TUBING	2.75	3.50		
44	XO 3-1/2" IF PIN X 3-1/2" PH-6 BOX	2.75	4.75	0.85	
43	SLIP JOINT	2.25	5.03	13.15	
42	SLIP JOINT	2.25	5.03	13.15	
41	RADIOACTIVE MARKER	2.68	4.75	2.01	
40	RD SAFETY CIRCULATING VALVE	2.25	5.03	7.53	
39	X-OVER 4-1/2" IFPIN X 3-1/2" IF BOX				
38	2 - JOINTS OF 6 1/2" DC'S	2.25	6.50	62.09	
37	X-OVER, 3-1/2" IF PIN X 4-1/2" IF BOX				
36	DRAIN VALVE	2.25	5.03	.97	
35	APR OMNI VALVE	2.25	5.03	21.15	
34	X-OVER, 4-1/2" IF PIN X 3-1/2" IF BOX				
33	2 - JOINTS OF 6 1/2" DC'S	2.25	6.50	61.97	
32	X-OVER, 3-1/2" IF PIN X 4-1/2" IF BOX				
31	DRAIN VALVE	2.25	5.03	.97	
30	MODEL "E" VALVE	1.87	5.00	13.53	
29	LPR-N TESTER VALVE	2.25	5.03	15.61	
28	JET PUMP RECEPTICLE	1.75	5.53	7.00	
27	INSTREAM BUNDLE CARRIER	2.25	5.50	7.77	
26	FUL FLO BUNDLE CARRIER	2.25	5.38	7.77	
25	X-OVER, 4-1/2" IF PIN X 3-1/2" IF BOX				
24	2-STANDS OF 6-1/2" DC'S	2.25	6.50	180.00	
23	X-OVER, 3-1/2" IF PIN X 4-1/2" IF BOX				
22	BIG JOHN JARS	2.37	5.03	5.14	
21	VR SAFETY JOINT	2.25	4.62	4.09	
20	X-OVER, 4 1/2" IF PIN X 3 1/2" IF BOX				
19	RTTS BYPASS	3.00	6.12	4.20	
18	ANNULAR PSI TRANSFER RESERVOIR				
17	9 5/8" RTTS PACKER	4.00	8.25	6.48	
16	ANNULAR PRESSURE TRANSFER SUB	2.37	6.12	1.50	
15	X-OVER, 3 1/2" IF P X 3 1/2" 8RD B				
14	BELOW PACKER SAFETY JOINT				
13	X-OVER, 2 7/8" 8RD P X 3-1/2" IF B	1.87	3.38	1.80	
12	2 7/8" X 10' TUBING SUB	2.44	3.06	10.00	
11	2-7/8" BALANCED ISOLATION TOOL	2.45	3.75	2.24	
10	2 7/8" X 10' TUBING SUB	2.44	3.06	10.00	
9	2 7/8" APF MECH. TUBING RELEASE	1.88	3.38	1.89	
8	2 - 2 7/8" TUBING JOINTS	2.44	3.06	60.00	
7	TIME DELAY FIRING HEAD	N/A	3.38	2.00	
6	ANNULAR PRESSURE FIRING HEAD	N/A	3.38	3.70	
5	BLANK SECTION OF GUN	N/A	6.00	5.00	
4	VANNGUN TOP SHOT	N/A	N/A	0.00	
3	6" X 12 SPF 32GM DP VANNGUN	N/A	6.00	0.00	
2	VANNGUN BOTTOM SHOT	N/A	N/A	0.00	
1	BULL PLUG	N/A	6.00	.75	

PBTD =
TVD - PKR =
TVD - TOP SHOT =

BY K. CODER | 3000 "C" ST., SUITE 200 ANCHORAGE, ALASKA 99503 | PHONE: 907-261-7750 | FAX: 907-562-1612

CONFIDENTIAL

KUVLUM #. OL STRING

ITEM	TOOL	ID (IN.)	OD (IN.)	LENGTH (FT.)	CONNECTION
1	BULL PLUG	N/A	3.380	0.75	
2	6" 12 SPF TUBING CONVEYED GUNS	N/A	6.000	?	
3	ANNULAR PRESSURE FIRING HEAD	N/A	3.750	3.70	
4	TIME DELAY FIRER	N/A	3.375	2.00	2 7/8" PIN UP
5	2 - 2 7/8" TUBING JOINTS	2.440	2.870	60.00	2 7/8" P X B
6	2 7/8" APF MECHANICAL TUBING RELEASE	1.880	3.375	1.89	2 7/8" P X B
7	2 7/8" X 10' TUBING SUB	2.440	2.870	10.00	2 7/8" P X B
8	2 7/8" BALANCED ISOLATION TOOL	2.440	3.750	2.24	2 7/8" 8RD P X B
9	2 7/8" X 10' TUBING SUB	2.440	2.870	10.00	2 7/8" P X B
10	2 7/8" PIN X 3 1/2" IF BOX CROSSOVER				
11	BELOW PACKER SAFETY JOINT	1.990	6.000	7.50	3 1/2" IF P X B
12	3 1/2" IF PIN X 3 1/2" 8 RD BOX CROSSOVER				
13	ANNULAR PRESSURE TRANSFER SUB	2.370	6.120	1.50	3 1/2" 8RD PIN X 4 1/4" IF BOX
14	9 5/8" RTTS PACKER	4.000	8.250	6.48	4 1/2" IF P X B
15	ANNULAR PRESSURE TRANSFER RESERVOIR	2.370	6.125	4.34	4 1/2" IF P X B
16	RTTS BYPASS	3.000	6.120	4.20	4 1/2" IF P X B
17	4 1/2" IF PIN X 3 1/2" IF BOX CROSSOVER				
18	VR SAFETY JOINT	2.250	4.680	4.68	3 1/2" IF P X B
19	BIG JOHN JARS	2.250	4.625	5.15	3 1/2" IF P X B
20	3 1/2" IF PIN X 4 1/2" IF BOX CROSSOVER				
21	2 - STANDS 6 1/2" DRILL COLLARS	2.250	6.500	180.00	4 1/2" IF P X B
22	4 1/2" IF PIN X 3 1/2" IF BOX CROSSOVER				
23	FUL FLO BUNDLE CARRIER	2.280	5.380	8.00	3 1/2" IF P X B
24	IN STREAM BUNDLE CARRIER	2.250	5.500	8.00	3 1/2" IF P X B
25	JET PUMP RECEPTICLE	1.750	5.532	7.00	3 1/2" IF P X B
26	LPR-N TESTER VALVE	2.280	5.030	15.94	3 1/2" IF P X B
27	MODEL E VALVE	1.875	13.530	13.53	3 1/2" IF P X B
28	DRAIN VALVE	2.280	5.030	2.75	3 1/2" IF P X B
29	3 1/2" IF PIN X 4 1/2" IF BOX CROSSOVER				
30	2 - JOINTS 6 1/2" DRILL COLLARS	2.250	4.750	60.00	4 1/2" IF P X B

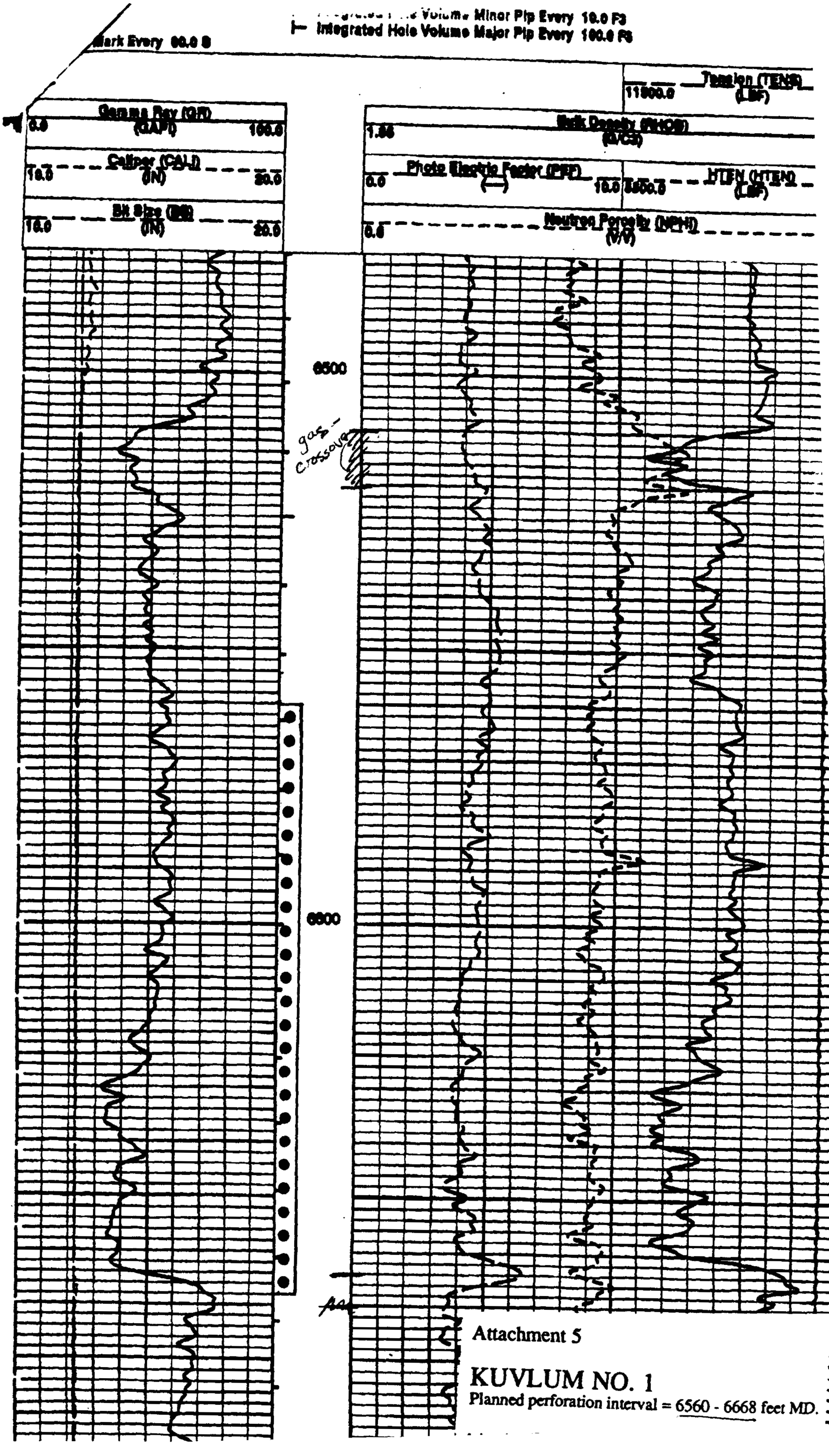
ATTACHMENT 4

CONFI[illegible]

KUVLUM # . ...OL STRING

31	4 1/2" IF PIN X 3 1/2" IF BOX CROSSOVER				
32	OMNI VALVE	2.280	5.030	21.15	3 1/2" IF P X B
33	DRAIN VALVE	2.280	5.030	2.75	3 1/2" IF P X B
34	3 1/2" IF PIN X 4 1/2" IF BOX CROSSOVER				
35	2 - JOINTS 6 1/2" DRILL COLLARS	2.250	4.750	60.00	4 1/2" IF P X B
36	4 1/2" IF PIN X 3 1/2" IF BOX CROSSOVER				
37	RD SAFETY CIRCULATING VALVE	2.280	5.030	7.52	3 1/2" IF P X B
38	RA SUB	2.680	4.500	2.00	3 1/2" IF P X B
39	SLIP JOINT	2.250	5.030	13.16	3 1/2" IF P X B
40	SLIP JOINT	2.250	5.030	13.16	3 1/2" IF P X B
41	3 1/2" IF PIN X 3 1/2" PH-6 BOX CROSSOVER				
42	3 1/2" PH-6 TUBING	2.750	3.500		3 1/2" PH-6 P X B
43	3 1/2" PH-6 PIN X 4 1/2" 4 STUB BOX XO				
44	ADJUSTABLE FLUTED HANGER	3.000	14.000	3.00	4 1/2" 4 STUB ACME B X P
45	SLICK JOINT	3.000	5.000	6.00	4 1/2" 4 STUB ACME B X P
46	SUB SEA TEST TREE	3.000	13.000	5.62	4 1/2" 4 STUB ACME B X P
47	4 1/2" 4 STUB X 3 1/2" PH-6 CROSSOVER				
48	1 JOINT 3 1/2" PH-6 TUBING	2.750	3.500	30.00	
49	3 1/2" PH-6 PIN X 4 1/2" 4 STUB BOX XO				
50	WIRELINE LUBRICATOR VALVE	3.000	10.750	5.95	4 1/2" 4 STUB ACME B X P
51	4 1/2" 4 STB PIN X 3 1/2" PH-6 BOX XO				
52	3 1/2" PH-6 TUBING AND SUBS AS NEEDED	2.750	3.500		
53	3 1/2" PH-6 PIN X 5 3/4" 4 STUB ACME BOX				
54	STIFF JOINTS	2.500	7.870	9.45	
55	SWIVEL	2.680			
56	TEST HEAD	2.650			3 1/2" IF
57	XO TO LUBRICATOR				

ATTACHMENT 4



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Attachment 5

KUVLUM NO. 1

Planned perforation interval = 6560 - 6668 feet MD.

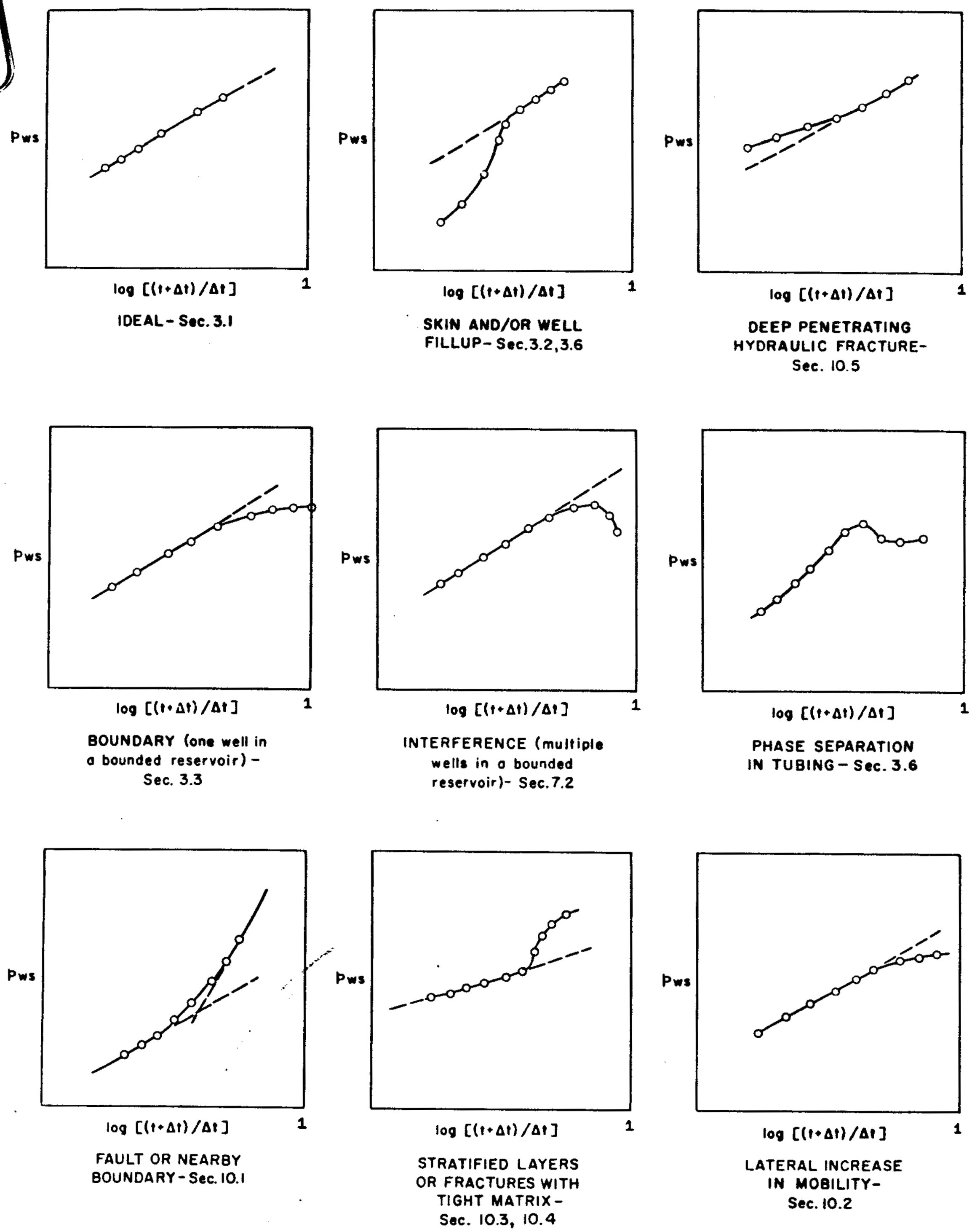


Fig. 11.6 Example buildup curves.

sure from Bottom Hole Pressure Build-up Characteristics", *Trans.*, AIME (1950) **189**, 91-104.

5. Russell, D. G. and Truitt, N. E.: "Transient Pressure Behavior in Vertically Fractured Reservoirs", *J. Pet. Tech.* (Oct., 1964) 1159-1170.
6. Odeh, A. S. and Nabor, G. W.: "The Effect of Production History on Determination of Formation Characteristics From Flow Tests", *J. Pet. Tech.* (Oct., 1966) 1343-1350.
7. Nisle, R. G.: "The Effect of a Short Term Shut-In on a Subsequent Pressure Build-up Test on an Oil Well", *Trans.*, AIME (1956) **207**, 320-321.
8. Lozano, G. and Harthorn, W. A.: "Field Test Confirms Accuracy of New Bottom-Hole Pressure Gauge", *J. Pet. Tech.* (Feb., 1959) 26-29.
9. Jones, L. G.: "Reservoir Reserve Tests", *J. Pet. Tech.* (March, 1963) 333-337.
10. van Poollen, H. K.: "Radius of Drainage and Stabilization Time Equations", *Oil and Gas J.* (Sept. 14, 1964) 133.

NOTES

10/15/82

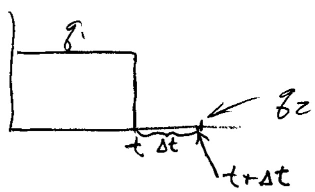
$$t_D = \frac{\lambda K t}{\phi \mu c r_w^2} \rightarrow t_D = \frac{\lambda K (\Delta t)_M}{\phi \mu c r_w^2}$$

- solve for ϕ

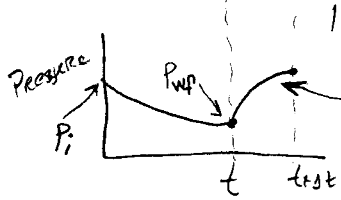
10/18/82

CHAPTER 4 - OIL WELL TESTING TECHNIQUES

Pressure Buildup Testing - most familiar T.T.T. ← TRANSIENT TESTING TECHNIQUE

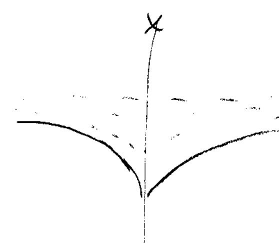


lower a pressure bomb into shut-in well



P_{ws} ← shut-in pressure, any point on curve

- pressure dist. near wellbore
  - will stabilize due to flow from outside while well is shut in



- Need knowledge of surface & subsurface data

- before starting the test, determine:
  1. Tubing size
  2. Casing size
  3. well depth
  4. Packer locations
  5. Perforation locations

- Typical Plots - all yield straight lines

  * ① Horner Plot (1951) -
  - plot P_{ws} vs $\log\left(\frac{t+\Delta t}{\Delta t}\right)$

  Most important

  ② Miller, Dice, & Hutchinson (1950)
  - plot P_{ws} vs. $\log(\Delta t)$

③ Muskat's Plot (1930)

$\log(\bar{P}_R - \bar{P}_{ws})$ vs. Δt

Fundamental Relationships (development for infinite reservoir)

Conceptually, a buildup is treated as the result of 2 superimposed effects.

any value on curve

$$P_i - P_{ws} = P_i q_D P_t((t+\Delta t)_D) + P_i(-q_1)_D P_t(\Delta t)_D$$

P_t evaluated @ $(t+\Delta t)_D$ (a function of)

P_t evaluated @ $(\Delta t)_D$

$$(t+\Delta t)_D = \frac{\lambda k t}{\phi \mu c r_w^2} = \frac{(2.637\times10^{-4})(k)(t+\Delta t)}{\phi \mu c r_w^2}$$

$$\Delta t_D = \frac{(2.637\times10^{-4})(k)(\Delta t)}{\phi \mu c r_w^2}$$

$$q_D = \frac{\gamma B q_{sc} \mu}{kh P_i} = \frac{141.2 B q_{sc} \mu}{kh P_i}$$

$P_t = -\frac{1}{2} E_i\left(-\frac{1}{4t_D}\right)$; P_t evaluated @ wellbore

$$P_i - P_{ws} = \frac{141.2 B q_{sc} \mu}{kh}\left[-\frac{1}{2} E_i\left(-\frac{\phi \mu c r_w^2}{(4)(2.637\times10^{-4})(k)(t+\Delta t)}\right)\right]$$

$q_2 - q = 0 - q_1$

$$-\frac{141.2 B q_{sc} \mu}{kh}\left[-\frac{1}{2} E_i\left(-\frac{\phi \mu c r_w^2}{4(2.637\times10^{-4})(k)(\Delta t)}\right)\right]$$

usually (9 times out of 10) $\to E_i(-x) < 0.01$,

∴ use logarithmic approximation

– with the logarithmic approximation;

$E_i(-x) \cong \frac{1}{2}\ln\left(\frac{1.781}{4t_D}\right)$

$E_i(-x) = \frac{1}{2}\ln(1.781x)$ for $x \le 0.01$

$E_i\left(-\frac{1}{4t_D}\right) \cong \frac{1}{2}\ln\left(\frac{4}{1.781} t_D\right)$; $\frac{1}{2}\ln\left(\frac{4}{1.781}\right) = \frac{1}{2}(.809)$

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$$P_i - P_{ws} = \frac{141.2\, B\, q_{sc}\, \mu}{kh} \left\{ \frac{1}{2}\left[\ln\left(\frac{(2.637\times10^{-4})(k)(t+\Delta t)}{\phi \mu c r_w^2} \right) + .809 \right] - \frac{1}{2}\left[\ln\left(\frac{(2.637\times10^{-4})(k)(\Delta t)}{\phi \mu c r_w^2} \right) + .809 \right] \right\}$$

$$P_i - P_{ws} = \frac{141.2\, B q_{sc} \mu}{kh} \left[\frac{1}{2} \ln(t+\Delta t) - \frac{1}{2} \ln(\Delta t) \right]$$

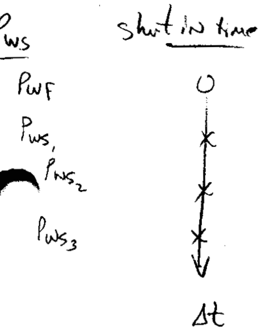
$$P_i - P_{ws} = \frac{141.2\, B q_{sc} \mu}{kh} \left[\frac{1}{2} \ln\left(\frac{t+\Delta t}{\Delta t} \right) \right]$$

$$\boxed{\ln x = 2.3026 (\log x)}$$

$$P_i - P_{ws} = \frac{141.2\, B q_{sc} \mu}{kh} \underbrace{\left(\frac{1}{2}\right)(2.3026)}_{1.1513} \left(\log\left(\frac{t+\Delta t}{\Delta t} \right) \right)$$

$$P_i - P_{ws} = \frac{162.6\, B q_{sc} \mu}{kh} \left[\log\left(\frac{t+\Delta t}{\Delta t} \right) \right]$$

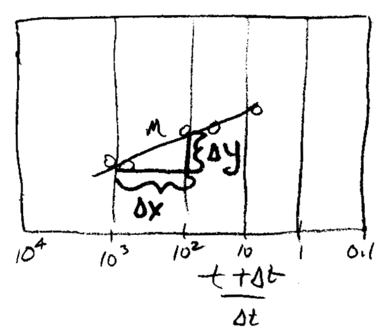
(Practical field UNITS)



$$P_{ws} = P_i - \frac{162.6\, B q_{sc} \mu}{kh} \left[\log\left(\frac{t+\Delta t}{\Delta t} \right) \right]$$

– equation of straight line on semi-log coordinates

P_{ws}



← decreasing function

$y = A + B \log x$

$\Delta x = \log 10^3 - \log 10^2$

$\Delta x = 3 - 2 = 1$

Early times, this should be fractions of a minute to account for wellbore storage/unloading

- increase Δt with later times.

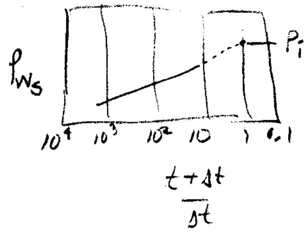
P_{ws}	Δt	$\frac{t+\Delta t}{\Delta t}$
P_{wf}	0	
P_{ws_1}	Δt_1	
P_{ws_2}	Δt_2	

$$\boxed{m = -\frac{162.6\, B q_{sc} \mu}{kh}}$$

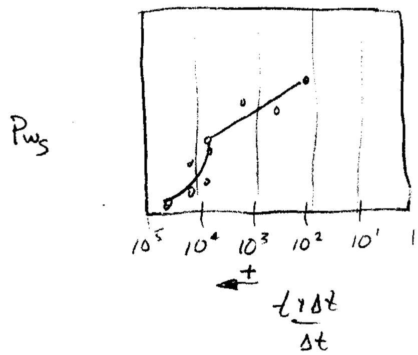
$$kh = -\frac{162.6\, B q_{sc} \mu}{m}$$

when $B \log x$ goes to zero, we obtain an intercept & thus the ultimate shutin pressure ; extrapolate straight line to obtain P_i

when $\frac{t+\Delta t}{\Delta t} \to 1$, extrapolate the straight line & Read P_i



- skin factor will affect this plot



Let P_δ @ $\Delta t = \delta$

P_{wf} @ $\Delta t = 0$

$$P_\delta - P_{wf} = \underbrace{(P_i - P_{wf})}_{\Delta t = 0} - \underbrace{(P_i - P_{\delta f})}_{\Delta t = \delta}$$

No skin; $P_\delta - P_{wf} = P_t$

skin; $P_\delta - P_{wf} = P_t + S$

$$\Delta P_D\big|_{well} = P_t + S = \frac{P_i - P_{wf}}{P_i q_D}$$

$$P_\delta - P_{wf} = P_i q_D (P_t + S) - \frac{141.2\, B q_{sc} \mu}{kh}\left[\frac{1}{2}\ln\left(\frac{t+\delta}{\delta}\right)\right]$$

$$P_\delta - P_{wf} = \frac{141.2\, B q_{sc} \mu}{kh}\left[\frac{1}{2}\ln\left(\frac{2.637\times10^{-4}\, k t}{\phi \mu c r_w^2} + .809\right) + S\right] - \frac{141.2\, B q_{sc} \mu}{kh}\left[\frac{1}{2}\ln\left(\frac{t+\delta}{\delta}\right)\right]$$

APPROXIMATION $\Rightarrow$ Letting $\frac{t+\delta}{\delta} \cong \frac{t}{\delta}$ when $t \gg \delta$

$\frac{.809}{2.3}$

$$P_\delta - P_{wf} = \frac{162.6\, B q_{sc} \mu}{kh}\left[\log 2.637\times10^{-4} + \log\frac{k}{\phi \mu c r_w^2} + \log t + 0.351 + \frac{2S}{2.3026} - \log t + \log \delta\right]$$

$$P_\delta - P_{wf} = \frac{162.6\, B q_{sc} \mu}{kh}\left[\log\frac{k\delta}{\phi \mu c r_w^2} + 0.8685\, S - 3.2275\right]$$

only unknown is S

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- if no deviations from ideal behavior;

$$P_{ws} = P_i - \frac{162.6\, B\, g_{sc}\, \mu}{kh} \log\left(\frac{t + \Delta t}{\Delta t}\right)$$

can determine P_i & K from this relationship

Horner Plot →

define $\boxed{M = -\frac{162.6\, B\, g_{sc}\, \mu}{Kh}}$; slope of straight line

$$P_\delta - P_{wf} = -m\left[\log \frac{K\delta}{\phi \mu c r_w^2} + .8685\, S - 3.2275\right]$$

flowing sandface pressure just before shutting well in ($\Delta t = 0$)

S is only unknown

→ solving for S;

$$\boxed{S = 1.1513\left[\frac{(P_\delta - P_{wf})}{-m} - \log\left(\frac{K\delta}{\phi \mu c r_w^2}\right) + 3.2275\right]}$$

- pts located on straight line (smoothed data line) are the points used for P_δ

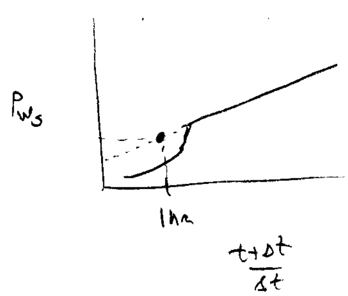
very important →

- note: P_δ should be read from the straight line

set $\delta = 1$ hr

$$\therefore \quad \boxed{S = 1.1513\left[\frac{P_{1hr} - P_{wf}^{(\Delta t = 0)}}{-m} - \log \frac{K}{\phi \mu c r_w^2} + 3.2275\right]}$$

if using $\delta = 1$ hr :



- Read value of P_{1hr} from extrapolated straight line

Composite skin factor - includes all effects causing pressure drop
- APPARENT SKIN

From our equation -

q_{sc} → may be variable
- well could be shut in for mechanical problems, etc.

$$t = \frac{24(V_p)}{q}$$; V_p ≡ cumulative volume produced (STB)
q ≡ last flow rate before you shut the well in (STB/day)

t ≡ hours synthetic time
hypothetical time

- gives production time to use in the equation.

Flow efficiency - definitions

$$J_{IDEAL} = \frac{q}{\bar{P} - P_{wf}}$$

Productivity Index

$$J_{ACTUAL} = \frac{q}{\bar{P} - P_{wf} - \Delta P_{SKIN}}$$

$\bar{P} \approx P_i$

→ Flow efficiency (F.E.) $= \frac{J_{actual}}{J_{ideal}}$

→ Damage ratio $= \frac{1}{F.E.} = \frac{J_{ideal}}{J_{Actual}}$

→ DAMAGE FACTOR $= (1 - F.E)$

From monograph #5.

$$F.E = \frac{J_{actual}}{J_{ideal}} = \frac{\bar{P} - P_{WF} - \Delta P_{SKIN}}{\bar{P} - P_{WF}}$$

DAMAGE RATIO $= \frac{1}{F.E.}$

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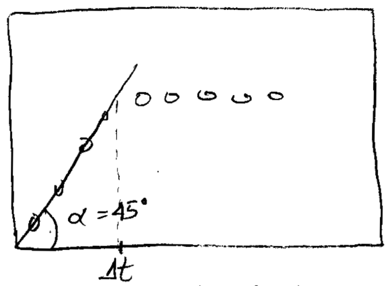
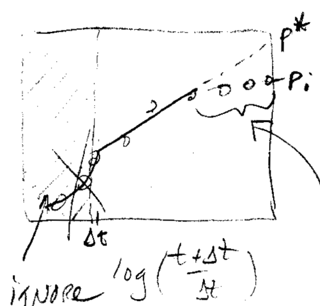
Determination of wellbore storage time:

$\alpha = 45$
$m = 1$



No wellbore storage after this time



∴ data points before Δt on our other graph will be ignored in determining the regression (straight line)

Pressure affects are being felt @ boundaries i.e. - system is finite

p^* - false pressure

PRESSURE BUILD-UP ANALYSIS IN FINITE RESERVOIRS

Relate P_i & P^* as follows:

$$P_{ws} = P^* - m \log\left(\frac{t+\Delta t}{\Delta t}\right)$$

Knowing that (infinite acting system)

$$P_i - P_{ws} = P_i g_D P_t((t+\Delta t)_D) - P_i g_D P_t((\Delta t)_D)$$

$$P_{ws} = P_i - P_i g_D \left\{ P_t((t+\Delta t)_D) - P_t((\Delta t)_D) \right\}$$

$$P_{ws} = P_i - \frac{141.2\, B q_{sc} \mu}{Kh} \left[P_t((t+\Delta t)_D) - P_t((\Delta t)_D) \right]$$

$$(P_i - P_{ws}) \frac{Kh}{141.2\, B q_{sc} \mu} = \frac{1}{2} \ln\left[((t+\Delta t)_D)\right] - \frac{1}{2} \ln\left[(t+\Delta t)_D\right] + P_t \left\{((t+\Delta t)_D\right\} - P_t \left\{\Delta t_D\right\}$$

$$P_t\{(\Delta t_D)\} \approx \frac{1}{2}\left(\ln(\Delta t_D) + .80907\right)$$

$$\frac{Kh}{141.2\, B_g q_{sc}\, \mu}(P_i - P_{ws}) = P_t\{(t+\Delta t)_D\} - \frac{1}{2}\left(\ln(\Delta t_D) + .80907\right) + \frac{1}{2}\ln\left((t+\Delta t)_D\right)$$

$$\frac{Kh}{141.2\, B_g q_{sc}\, \mu}(P_i - P_{ws}) = \frac{1}{2}\ln\left(\frac{t+\Delta t}{\Delta t}\right) + P_t\left((t+\Delta t)_D\right) - \frac{1}{2}\left[\ln\left(t+\Delta t\right)_D + .80907\right]$$

SINCE $P_{ws} = P^* - m\log\left(\frac{t+\Delta t}{\Delta t}\right)$

OR $P_{ws} = P^* - \frac{141.2\, B_g q_{sc}\, \mu}{Kh}\left(\frac{1}{2}\right)\ln\left(\frac{t+\Delta t}{\Delta t}\right)$

$$\frac{Kh}{141.2\, B_g q_{sc}\, \mu}P_i - \frac{Kh}{141.2\, B_g q_{sc}\, \mu}P^* + \frac{1}{2}\ln\left(\frac{t+\Delta t}{\Delta t}\right) = \frac{1}{2}\ln\left(\frac{t+\Delta t}{\Delta t}\right) + P_t\left((t+\Delta t)_D\right) - \frac{1}{2}\left[\ln(t+\Delta t)_D + .80907\right]$$

$$P^* = P_i - \frac{141.2\, B_g q_{sc}\, \mu}{Kh}\left[P_t\left((t+\Delta t)_D\right) - \frac{1}{2}\left\{\ln(t+\Delta t)_D + .80907\right\}\right]$$

IF $\Delta t \ll t$; $(t+\Delta t)_D \cong t_D$

$$\therefore P^* = P_i - \frac{141.2\, B_g q_{sc}\, \mu}{Kh}\left[P_t\{t_D\} - \frac{1}{2}\ln t_D + .80907\right]$$

P_t as a function of t_D

MILLER, DYES & HUTCHINSON ANALYSIS -

- simplified form of HORNER Plot.

HORNER Plot -

$$P_{ws} = P_i + m \log\left(\frac{t+\Delta t}{\Delta t}\right)$$

— if m is taken as positive, then:

$$P_{ws} = P_i - m \log\left(\frac{t+\Delta t}{\Delta t}\right)$$

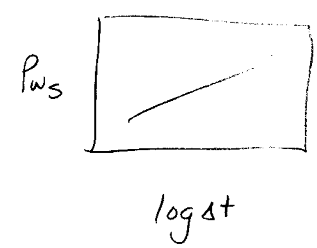
if $t \gg \Delta t$ $\qquad \frac{t+\Delta t}{\Delta t} \approx \frac{t}{\Delta t}$

t = total production time

Δt = shut in time

substituting into our equation:

$$P_{ws} = P_i - m \log\left(\frac{t}{\Delta t}\right) \Rightarrow P_{ws} = P_i - m \log t + m \log \Delta t$$



if $\Delta t = 1\,hr$;

$$P_{ws} = \underbrace{P_i - m \log t}_{P_{1hr}} \quad ; \text{ intercept}$$

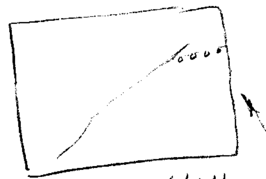
P_{1hr} (from the straight line)

$$\boxed{P_{ws} = P_{1hr} + m \log(\Delta t)}$$

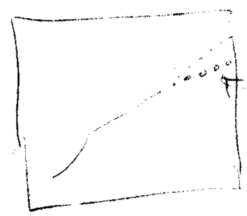
- equation for Miller, Dyes, & Hutchinson Plot

(MDH Plot)

Horner Plot -



MDH Plot -



If these points do not form another straight line, then the system is feeling the pressure drop @ the boundaries.

Monograph Volume 5

compressibility (total)

$$\Delta t = \frac{\phi \mu C_t A}{0.0002637\, k} \left(\Delta t_{DA}\right)_{esl}$$

end of the semilog straight line

dimensionless shut in time @ the end of the semilog straight line } depends on reservoir shape & well location

Pg. 50 - Fig. 5.6 - 5.7

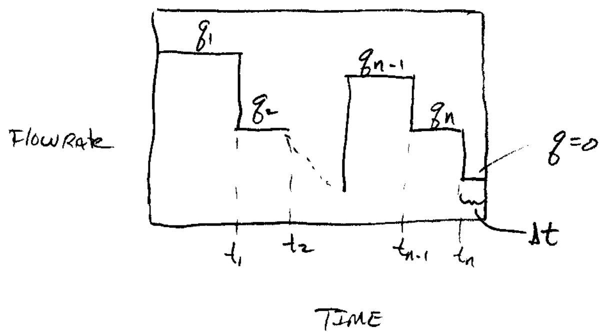
Table 5.2

- useful when know Δt_{DA} & shape of reservoir

$$t_{DA} = t_D \frac{r_w^2}{A}$$

Build up TEST ANALYSIS when RATE VARIES

Before TESTING

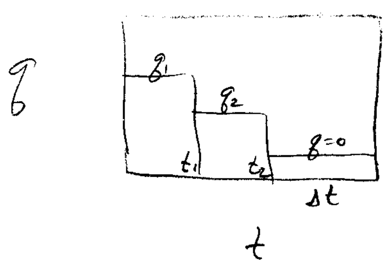


$$P_{ws} = P_i - m \sum_{j=1}^{n} \frac{q_j}{q_n} \log\left(\frac{t_n - t_{j-1} + \Delta t}{t_n - t_j + \Delta t}\right)$$

- Above equation indicates that plot of P_{ws} vs $\Sigma(\ )$ on RHS should yield a straight line with slope m & intercept P_i.

example - 2 different flow rates before shut well in

$n=2$



$$P_i - P_{ws} = P_i\, q_{D_1} P_t\left\{(t_2+\Delta t)_D\right\} + P_i(q_2 - q_1)_D P_t\left\{((t_2+\Delta t)-t_1)_D\right\}$$

P_t evaluated @ this

$$+\ P_i\,(0-q_2)\,P_t\left\{(\Delta t)_D\right\}$$

$$P_i - P_{ws} = P_i \frac{\gamma B q_1 \mu}{kh P_i}\left[\frac{1}{2}\left\{\ln(t_2+\Delta t)_D + .809\right\}\right]$$

$$+ P_i \frac{\gamma B (q_2 - q_1)\mu}{kh P_i}\left[\frac{1}{2}\left\{\ln((t_2+\Delta t)-t_1)_D + .809\right\}\right]$$

$$- P_i \frac{\gamma q_2 B \mu}{kh P_i}\left[\frac{1}{2}\left\{\ln(\Delta t_D) + .809\right\}\right]$$

$$P_i - P_{ws} = \frac{\gamma B q_1 \mu}{kh}\left[\frac{1}{2}\ln(t_2+\Delta t)_D\right] + \frac{\gamma B q_2 \mu}{kh}\left[\frac{1}{2}\ln(t_2+\Delta t - t_1)_D\right]$$

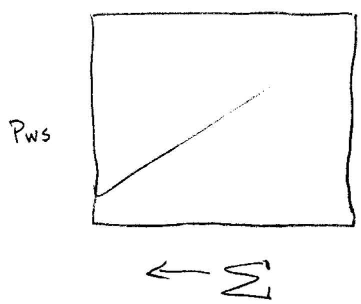
$$- \frac{\gamma B q_1 \mu}{kh}\left[\frac{1}{2}\ln(t_2+\Delta t - t_1)_D\right]$$

$$- \frac{\gamma B q_2 \mu}{kh}\left[\frac{1}{2}\ln(\Delta t)_D\right]$$

$$m = \frac{162.6\, B \mu q_2}{kh}$$

$$P_i - P_{ws} = \underbrace{\frac{162.6\, B \mu q_2}{kh}}_{m} \left[\frac{q_1}{q_2} \log (t_2 + \Delta t)_D + \frac{q_2}{q_2} \log (t_2 - t_1 + \Delta t)_D - \frac{q_1}{q_2} \log (t_2 - t_1 + \Delta t)_D - \frac{q_2}{q_2} \log (\Delta t)_D \right]$$

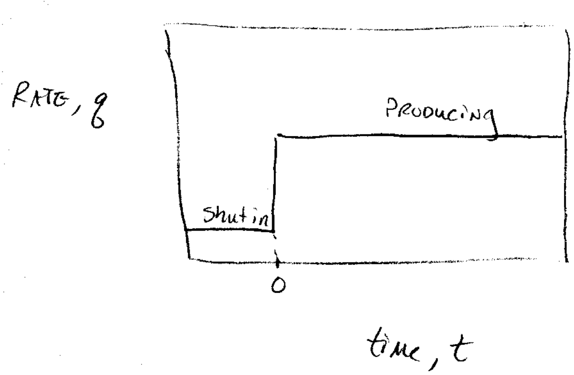
$$P_i - P_{ws} = m \left[\frac{q_1}{q_2} \log \left(\frac{t_2 + \Delta t}{t_2 - t_1 + \Delta t} \right) + \log \left(\frac{t_2 - t_1 + \Delta t}{\Delta t} \right) \right]$$

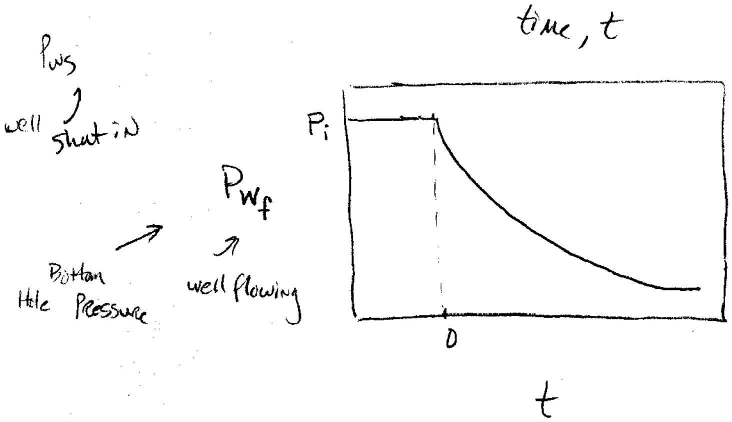


Example 5.5
Monograph V5
Fig. 5.16

PRESSURE DRAWDOWN TESTING –

– Recently discovered well is good candidate for this





– don't have to shut well in before this but constant producing rate is hard to maintain (Radio off)

– test implementation may be hard since constant q is hard to maintain.

- usually a pressure build-up is followed by a drawdown test

Recording P_{wf} as a function of time

P_{wf}	t
P_i	0
⋮	⋮

FUNDAMENTAL RELATIONSHIP

- well acting in an infinite system
- using superposition principle

$$P_i - P_{wf} = P_i q_{D_1} P_t\{(t+\Delta t)_D\} + P_i q_{D_2} P_t(t_D)$$

since $q_{D_1} = 0$ & let $q_{D_2} = q_D$

$$P_i - P_{wf} = P_i q_D P_t\{t_D\}$$

$$t_D = \frac{\lambda k t}{\phi \mu c r_w^2} = \frac{2.637 \times 10^{-4}\, k t}{\phi \mu c r_w^2}$$ ← hours

$$q_D = \frac{\gamma B q_{sc} \mu}{k h P_i} = \frac{141.2\, B q_{sc} \mu}{k h P_i}$$

@ the well bore:

$$P_t(t_D) = -\frac{1}{2} E_i\left(-\frac{1}{4t_D}\right)$$

$$P_i - P_{wf} = \frac{141.2\, B q_{sc} \mu}{kh}\left\{-\frac{1}{2} E_i\left(-\frac{\phi \mu c r_w^2}{(4)(2.637 \times 10^{-4}) k t}\right)\right\}$$

with Logarithmic Approximation -

$$P_i - P_{wf} = \frac{141.2\, B q_{sc} \mu}{kh}\left\{\frac{1}{2}\left(\ln \frac{(2.637 \times 10^{-4}) k t}{\phi \mu c r_w^2} + .809\right)\right\}$$

$$\ln x = 2.3026 \log x$$

$$P_i - P_{wf} = \frac{141.2\, B q_{sc} \mu}{kh}\left[\frac{1}{2}\left(2.3026 \log t + 2.3026 \log 2.637\times10^{-4} + 2.3026 \log\left(\frac{k}{\phi \mu c r_w^2}\right) + .809\right]$$

$$P_i - P_{wf} = \left[\frac{162.6\, B q_{sc} \mu}{kh}\right]\left[\log t + \log \frac{k}{\phi \mu c r_w^2} - 3.2275\right]$$

Practical field units

skin is a dimensionless pressure drop
$S = \frac{(\Delta P)_{skin}}{P_i q_D}$

$q_D = \frac{\gamma B q_{sc} \mu}{kh}$

If consider skin effects:

$$P_i - P_{wf} = \frac{162.6\, B q_{sc} \mu}{kh}\left[\log t + \log \frac{k}{\phi \mu c r_w^2} - 3.2275\right] + \left[\quad\right]$$

ΔP_{skin}

$$P_i - P_{wf} = \frac{162.6\, B q_{sc} \mu}{kh}\left[\log t + \log \frac{k}{\phi \mu c r_w^2} - 3.2275\right] + \left(\frac{141.2\, B q_{sc} \mu}{kh}\right) S$$

$$P_i - P_{wf} = \frac{162.6\, B q_{sc} \mu}{kh}\left[\log t + \log \frac{k}{\phi \mu c r_w^2} - 3.2775 + 0.86859\, S\right]$$

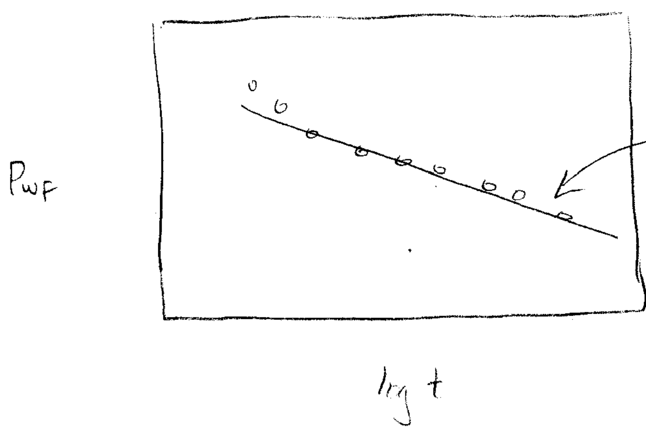
– the above equation describes a straight line relationship between P_{wf} and $\log t$, such that:

$$P_{wf} = P_{1hr} + m(\log t)$$

where $P_{1hr} = P_i - \frac{162.6\, B q_{sc} \mu}{kh}\left[\log \frac{k}{\phi \mu c r_w^2} - 3.227 + .86859\right.$

$$m = -\frac{162.6\, B q_{sc} \mu}{kh}$$

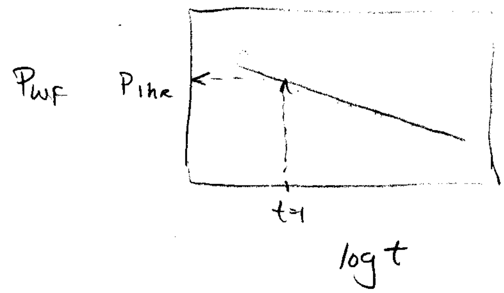
P_{wf} vs. $\log t$



$m = -\frac{162.6\, B q_{sc} \mu}{kh}$ psia/cycle

10/25/82

when $t = 1$ hour:



Rearranging & solving for S:

$$S = 1.1513 \left[\frac{P_{1hr} - P_i}{m} - \log \frac{k}{\phi \mu c r_w^2} + 3.2275 \right]$$

use slope with its proper sign

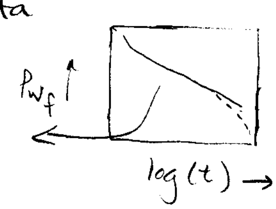
- if drawdown period is fairly long, can determine the volume of the reservoir.
  - called Reservoir Limit testing
  - must record P_{wf} vs t for long time

RESERVOIR LIMIT TESTING -

① plot short time data

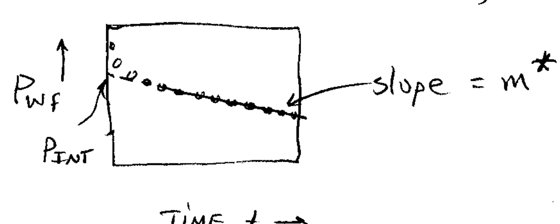
from the standard drawdown analysis →

Read m &
Read P_{1hr}



- extended drawdown analysis

② Plot Long time data (Cartesian coordinates)



$$P_{wf} = P_{INT} + m^* t$$

intercept

- for Large t_{DA}, when all the boundaries are felt,
@ pseudo-steady state:

$$P_t = \frac{1}{2}\ln\left(\frac{4A}{1.781\, r_w^2 C_A}\right) + 2\pi t_{DA}$$

composite

$$\Delta P_D = 2\pi t_{DA} + \frac{1}{2}\ln\left(\frac{A}{r_w^2}\right) + \frac{1}{2}\ln\left(\frac{2.2458}{C_A}\right) + S$$

$$P_i - P_{wf} = P_1 q_0 \left[2\pi \frac{(2.637\times10^{-4})kt}{\phi \mu c A} + \frac{1}{2}\ln\left(\frac{A}{r_w^2}\right) + \frac{1}{2}\ln\frac{2.2458}{C_A} + S\right]$$

$$P_{wf} = P_i - \frac{141.2\, Bq\mu}{kh}\left[2\pi \frac{2.637\times10^{-4} kt}{\phi\mu c A} + \frac{1}{2}\ln\left(\frac{A}{r_w^2}\right) + \frac{1}{2}\ln\left(\frac{2.2458}{C_A}\right) + S\right]$$

$$P_{wf} = P_i - \frac{0.23395\, qB}{\phi c h A}t - \frac{70.60\, qB\mu}{kh}\left[\ln\left(\frac{A}{r_w^2}\right) + \ln\frac{2.2458}{C_A} + 2S\right]$$

$$m^* = -\frac{0.23395\, qB}{\phi c\, hA} \rightarrow \text{res. vol.}$$

- solve for (hA) to get reservoir volume

$P_{INT} \Rightarrow$ @ $t=0$

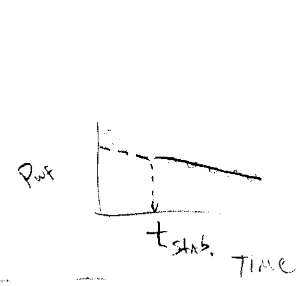
$$P_{INT} = P_i - \frac{70.6\, q\mu B}{kh}\left[\ln\frac{A}{r_w^2} + \ln\frac{2.2458}{C_A} + 2S\right]$$

Solve for C_A & find an approximate configuration

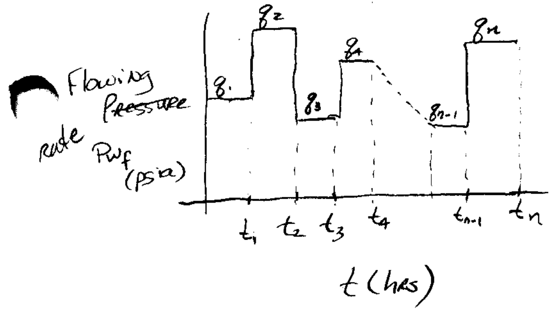
- solve for A in m^*

- need t_{DA} value to accompany C_A

- find time that stabilized conditions take over (when straight line starts) (on the Long time Plot)



MULTIPLE RATE TESTING



- For a constant flow rate, we have obtained the following expression

$$P_i - P_{wf} = \frac{162.6\, B q_{sc}\, \mu}{kh}\left[\log t + \left\{\log\frac{k}{\phi\mu c r_w^2} - 3.2275 + .86859\, S\right\}\right]$$

Now;

$$\bar{S} = \left[\log\frac{k}{\phi\mu c r_w^2} - 3.2275 + .86859\, S\right]$$

the rate-Time schedule

① $q = q_1$ $\qquad 0 \le t < t_1$

② $q = q_2$ $\qquad t_1 \le t < t_2$

③ $q = q_3$ $\qquad t_2 \le t < t_3$

⋮ $\qquad$ ⋮

④ $q = q_n$ $\qquad t_{n-1} \le t < t$

- After applying superposition, we find the pressure drop during the second period to be as follows:

$$P_i - P_{wf} = \frac{162.6\, B q_1 \mu}{kh}\left[\log t + \bar{S}\right] + \frac{162.6\, B(q_2 - q_1)\mu}{kh}\left[\log(t - t_1) + \bar{S}\right]$$

- For the third period;

$$P_i - P_{wf} = \left\{\frac{162.6\, q_1 \mu}{kh}\left[\log t + \bar{S}\right]\right\} + \left\{\frac{162.6\, B(q_2 - q_1)\mu}{kh}\left[\log(t - t_1) + \bar{S}\right]\right\}$$
$$+ \left\{\frac{162.6\,(q_3 - q_2) B\mu}{kh}\left[\log(t - t_2) + \bar{S}\right]\right\}$$

– thus during the n^{th} time period, the pressure drop is given by:

$$P_i - P_{wf} = \frac{162.6\, B\mu\, q_1}{kh}\left[\log t + \bar{S}\right] + \frac{162.6\, B\mu (q_2 - q_1)}{kh}\left[\log(t - t_1) + \bar{S}\right] + \frac{162.6\, B\mu (q_3 - q_2)}{kh}\left[\log(t - t_2) + \bar{S}\right]$$
$$+ \ldots + \frac{162.6\, B\mu (q_n - q_{n-1})}{kh}\left[\log(t - t_{n-1}) + \bar{S}\right]$$

The above equation can also be written as follows:

$$P_i - P_{wf} = \frac{162.6\,\mu B}{kh}\left[q_1 \log t + (q_2 - q_1)\log(t - t_1) + (q_3 - q_2)\log(t - t_2) + \ldots + (q_n - q_{n-1})\log(t - t_{n-1})\right] + \frac{162.6\,\mu B}{kh} q_n \bar{S}$$

OR

$$\frac{P_i - P_{wf}}{q_n} = \frac{162.6\,\mu B}{kh}\sum_{j=1}^{N}\left[\left(\frac{q_j - q_{j-1}}{q_N}\right)\log(t - t_{j-1})\right] + \frac{162.6\,\mu B}{kh}\bar{S}$$

$$t_0 = 0 \; ; \; q_0 = 0$$

Letting the following:

$$m' = \frac{162.6\,\mu B}{kh} \; ; \; b' = \frac{162.6\,\mu B}{kh}\bar{S}$$

$$\therefore \; \frac{P_i - P_{wf}}{q_n} = m' \sum_{j=1}^{N}\left[\left(\frac{q_j - q_{j-1}}{q_N}\right)\log(t - t_{j-1})\right] + b'$$

Multiple rate transient data should appear as a straight line when plotted as

$$\frac{P_i - P_{wf}}{q_N} \quad \text{vs.} \quad \sum_{j=1}^{N}\left[\left(\frac{q_j - q_{j-1}}{q_N}\right)\log(t - t_{j-1})\right]$$

NOTES 10/27/82

Once this data is plotted, the straight line slope & intercept data measured, permeability & skin factor are estimated from the slope & intercept data

$$K = \frac{162.6\, B\mu}{m' h} \quad \& \quad S = 1.1513\left[\frac{b'}{m'} - \log\left(\frac{k}{\phi\mu c r_w^2}\right) + 3.2275\right]$$

Disadvantages of this method -

① initial reservoir pressure, P_i, must be known

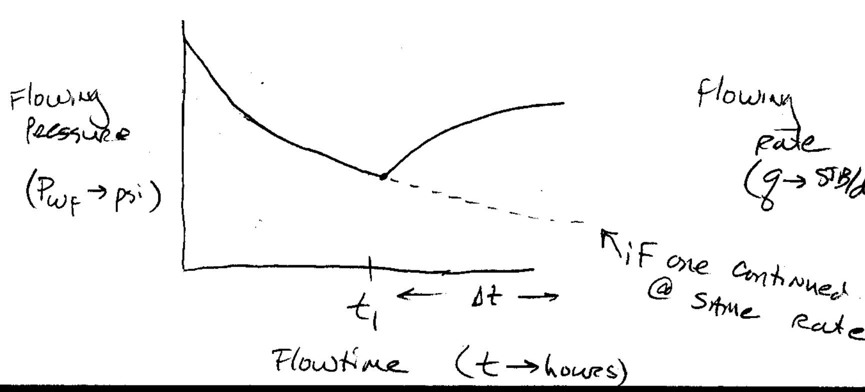
if P_i is not known → ② An exceedingly long shut in period is necessary to obtain a reasonable estimate of P_i
∴ would be good for brand new reservoir

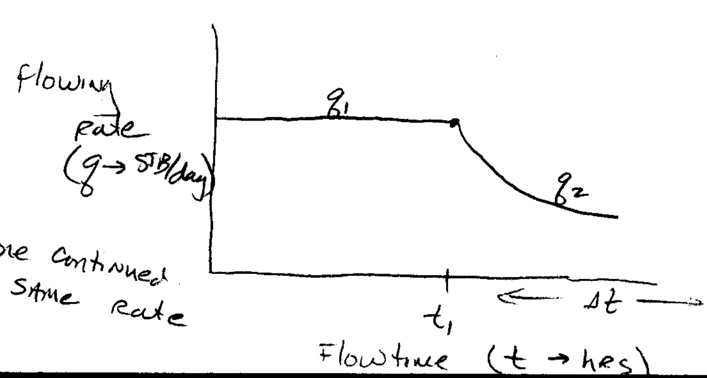
$\boxed{\text{example in text}}$

Two Rate Testing -

- when a multiple rate test consists of only two flow rates both testing & analysis are simplified

- a Two Rate Test provides information about k & S while production continues. Furthermore, wellbore storage effects are often "thought" to be minimized or eliminated by the Two Rate Test.





$$P_{wf} = P_i - \frac{162.6\, B\mu q_1}{kh}\left[\log(t_1+\Delta t) + \log\frac{k}{\phi\mu c r_w^2} - 3.2275 + .86859\, S\right]$$

$$- \frac{162.6\, B\mu (q_2 - q_1)}{kh}\left[\log \Delta t + \log\frac{k}{\phi\mu c r_w^2} - 3.2275 + .86859\, S\right]$$

$$P_{wf} = P_i - \frac{162.6\, q_2 B\mu}{kh}\left[\log\frac{k}{\phi\mu c r_w^2} - 3.2275 + .86859\, S\right] - \frac{162.6\, q_1 B\mu}{kh}\left[\log\left(\frac{t+\Delta t}{\Delta t}\right) + \frac{q_2}{q_1}\log \Delta t\right]$$

- this may be modified into the following form:

$$P_{wf} = M_1' \log\left(\frac{t_1+\Delta t}{\Delta t}\right) + \frac{q_2}{q_1}\log(\Delta t) + P_{INTERCEPT}$$

- this assumes a constant q_1

(if not a constant q_1, a stabilized q_1)

- if have to use a stabilized q_1, we must estimate t_1 as follows:

$$t_1 = \frac{24\, V_p}{q_1}$$; V_p = cumulative volume produced since the last rate stabilization

- if you plot P_{wf} vs. $\left[\log\left(\frac{t+\Delta t}{\Delta t}\right) + \frac{q_2}{q_1}\log \Delta t\right]$ you obtain a straight line, where

$$M_1' = -162.6\frac{q_1 \mu B}{kh}$$

$$P_{intercept} = P_i + M_1' \frac{q_2}{q_1}\left[\log\left(\frac{k}{\phi\mu c r_w^2}\right) - 3.2275 + .86859\, S\right]$$

- once the plot of P_{wf} vs $\left[\log\left(\frac{t+\Delta t}{\Delta t}\right) + \frac{q_2}{q_1}\log \Delta t\right]$ is obtained, the reservoir permeability may be obtained from:

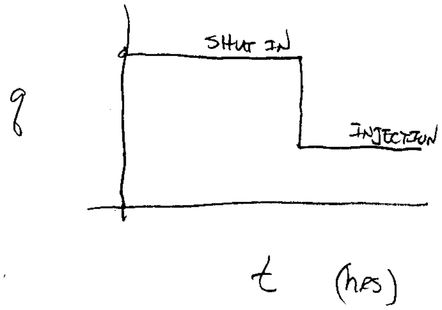
$$K = \frac{-162.6\, q_1 B\mu}{M_1' h}$$

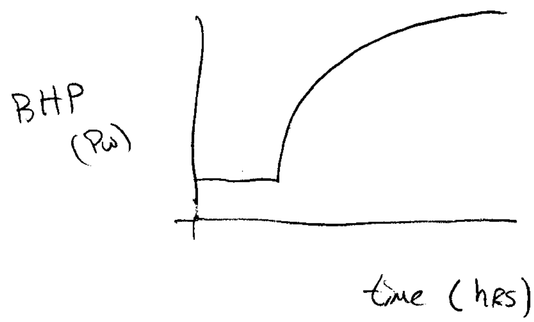
- the skin factor S may be estimated from

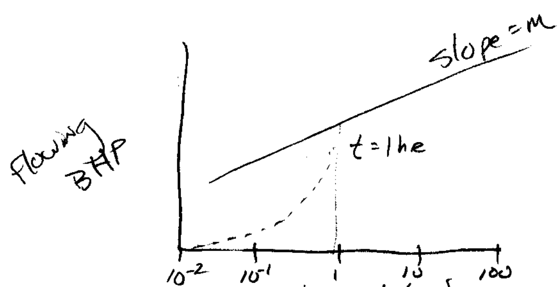
$$S = 1.153\left[\frac{q_1}{q_2 - q_1}\left(\frac{P_{wf}^{\Delta t=0} - P_{1hr}}{M_1'}\right) - \log\frac{k}{\phi\mu c r_w^2} + 3.2275\right]$$

Injection Well Testing

Plot Rate q vs t







semilog plot of typical injectivity data

For the constant rate injection test, the BHP is given by:

$$P_{wf} = P_i - \frac{162.6\, \mu B q}{kh}\left[\log t + \log\left(\frac{k}{\phi \mu c r_w^2}\right) - 3.2275 + .86859\, S\right]$$

OR $\quad P_{wf} = P_{1hr} + m \log t$

- The intercept, $P_{1hr} = P_i + m\left[\log\left(\frac{k}{\phi \mu c r_w^2}\right) - 3.2275 + .86859 S\right]$

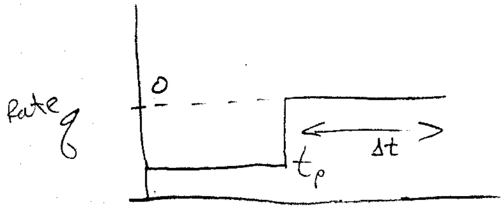
slope;

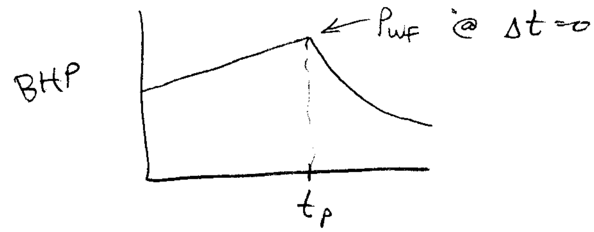
$$m = -\frac{162.6\, q B \mu}{kh}$$

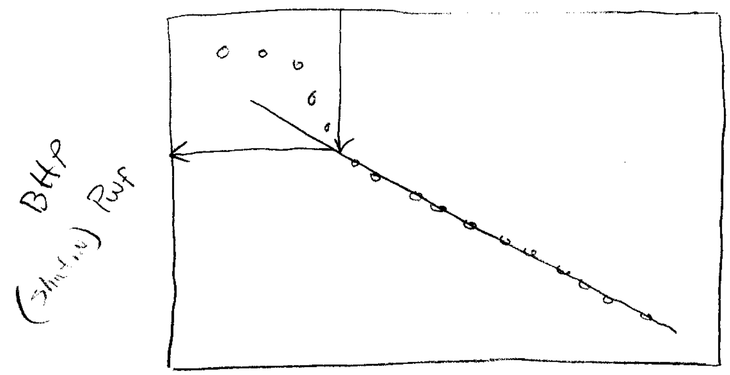
& then skin factor

$$S = 1.1513\left[\frac{P_{1hr} - P_i}{m} - \log\left(\frac{k}{\phi \mu c r_w^2}\right) + 3.2275\right]$$

Fall off Test Analysis for Liquid filled Unit-Mobility-Ratio Reservoirs







Pressure data taken immediately before & during shut-in period are analyzed as pressure build up data are analyzed

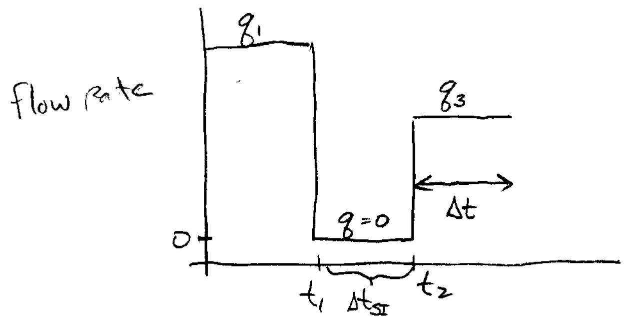
$$P_{ws} = P^* - m \log\left(\frac{t_p + \Delta t}{\Delta t}\right) \qquad P^* = P_i$$

$$m = \frac{162.6\, q B \mu}{kh}$$

$$S = 1.1513 \left[\left(\frac{P_{1hr} - P_{wf\,(\Delta t = 0)}}{m} \right) - \log\left(\frac{k}{\phi \mu c r_w^2}\right) + 3.2275 \right]$$

DRAWDOWN TESTING AFTER A SHORT SHUTIN -

It is a common practice to run a drawdown test after a short shutin period (pressure buildup test)



$\Delta t \equiv$ time of test

$$\frac{p_i - p_{wf}}{q_N} = \frac{162.6\,\mu B}{kh} \sum_{j=1}^{N} \left[\left(\frac{q_j - q_{j-1}}{q_N} \right) \log(t - t_j) \right] + \frac{162.6\,\mu B}{kh}\,\bar{s}$$

$$\frac{P_i - P_{wf}}{q_3} = \frac{162.6\,\mu B}{kh} \left[\frac{q_1 - \overset{=0}{q_0}}{q_3} \log(t - \overset{=0}{t_0}) + \frac{\overset{=0}{q_2} - q_1}{q_3} \log(t - t_1) + \frac{q_3 - \overset{=0}{q_2}}{q_3} \log(t - t_2) \right]$$
$$+ \frac{162.6\,\mu B}{kh} \left[\log\left(\frac{k}{\phi \mu c r_w^2} \right) - 3.2275 + .86859\, S \right]$$

$$\frac{P_i - P_{wf}}{q_3} = \frac{162.6\,\mu B}{kh} \left[\frac{q_1}{q_3} \log(t) - \frac{q_1}{q_3} \log(t - t_1) + \log(t - t_2) \right]$$
$$+ \frac{162.6\,\mu B}{kh} \left[\log\left(\frac{k}{\phi \mu c r_w^2} \right) - 3.2275 + .86859\, S \right]$$

if we let $t = t_1 + \Delta t_{SI} + \Delta t$

& if we let $t_2 = t_1 + \Delta t_{SI}$

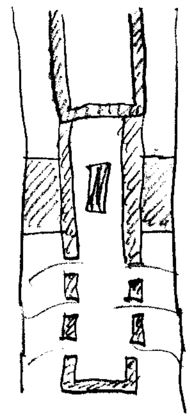
$$\therefore \quad P_{wf} = P_i - \frac{162.6\,\mu B}{kh} q_3 \left[\frac{q_1}{q_3} \log(t_1 + \Delta t_{SI} + \Delta t) - \frac{q_1}{q_3} \log(\Delta t_{SI} + \Delta t) + \log \Delta t \right]$$
$$+ \frac{162.6\,\mu B}{kh} q_3 \left[\log\left(\frac{k}{\phi \mu c r_w^2} \right) - 3.2275 + .86859\, S \right]$$

Let $M_3' = -\dfrac{162.6\,\mu B}{kh} q_3$

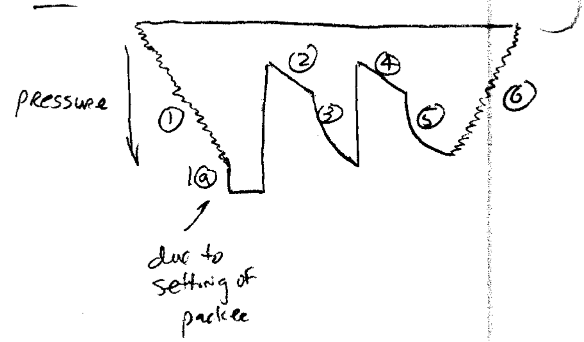
$$P_{int} = P_i + M_3' \left[\log\left(\frac{k}{\phi \mu c r_w^2} \right) - 3.2275 + .86859\, S \right]$$

then finally:

Formation closed in



Classical DST Chart:



① increase in hydrostatic mud pressure

①(a) setting of packer causes compression in the annulus. (mud)

② Inflow from the formation

③ Pressure build up

④ Same as ②

⑤ same as ③

⑥ decrease in hydrostatic mud pressure

Data obtained from a DST includes

① physical description of fluids

② volume of recovery

③ Flow times

④ Shut in times and a bottom hole pressure time chart

Reservoir characteristics may be calculated from formation test data are

① permeability

② wellbore damage

③ reservoir pressure

④ Depletion

⑤ Radius of investigation

⑥ Barrier indications

TES

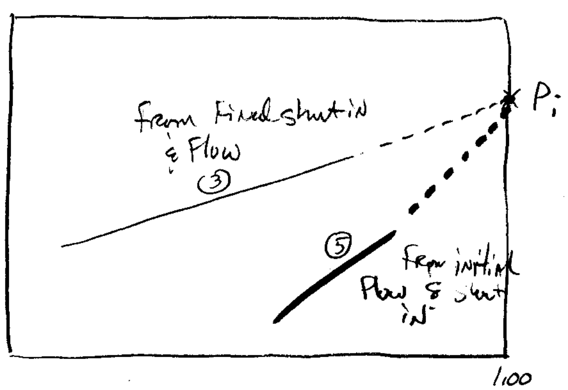
11/1/82

Analyzing DST Pressure Data

- Pressure Buildup data must be analyzed with the Horner Plot (Because Δt & t_p are comparable)

- we need to plot P_{ws} vs $\log\left(\frac{t_p + \Delta t}{\Delta t}\right)$
- The value of t_p is usually the length of the preceeding flow period. However, if the initial flow period is very long, it is more accurate to use the sum of the flow period lengths for t_p for the final buildup

P_{ws}



$\leftarrow \log \frac{t + \Delta t}{\Delta t}$

← ideally, the straight lines should approach the value of P_i

if P_i's do not agree, use the final data

$$m = -\frac{162.6 q \mu B}{kh} \quad \text{psia/cycle}$$

In conventional build up analysis in skin factor calculation we assumed that $\frac{t_p + \Delta t}{\Delta t} \approx \frac{t_p}{\Delta t}$

- Not valid for DST since t_p & Δt are fairly close.

Skin factor Analysis for DST Pressure Data -

$$P_\delta - P_{wf} = 141.2 \frac{B q_{sc} \mu}{kh}\left[\frac{1}{2}\left(\ln \frac{2.637\times10^{-4}\,kt}{\phi \mu c r_w^2} + .80907\right) + S\right] - \frac{141.2}{kh}\left[\frac{1}{2}\ln\left(\frac{t+\delta}{\delta}\right)\right]$$

since $\frac{t+\delta}{\delta} \not\approx \frac{t}{\delta}$, we have:

$$P_\delta - P_{wf} = 141.2 \frac{B q \mu}{kh}\left[\frac{1}{2}(2.3026)\left(\log \frac{2.637\times10^{-4}\,kt}{\phi \mu c r_w^2} + \frac{0.809}{2.3026}\right) + S\right] + \left[-\frac{1}{2}(2.3026)\left(\log(t+\delta) - \log \delta\right)\right]$$

$$P_\delta - P_{wf} = \underbrace{\frac{162.6\, B q \mu}{kh}}_{-m}\left[\log 2.637\times10^{-4} + \log \frac{k}{\phi \mu c r_w^2} + \log t + .3513 + \frac{2S}{2.3026} - \log(t+\delta) + \log \delta\right]$$

Let $\delta = 1 \longrightarrow P_{1hr}$ is need (from straight line on Horner plot)

$$P_{1hr} - P_{wf} = -m\left[\log\left(\frac{k}{\phi \mu c r_w^2}\right) + \log\left(\frac{t}{t+1}\right) + \frac{2S}{2.3026} + \log 2.637\times10^{-4} + 0.3513\right]$$

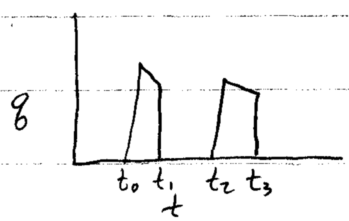
$$* \Rightarrow S = 1.1513\left[\frac{P_{1hr} - P_{wf(\Delta t=0)}}{-m} + \log\left(\frac{t+1}{t}\right) - \log\left(\frac{k}{\phi \mu c r_w^2}\right) + 3.23\right]$$

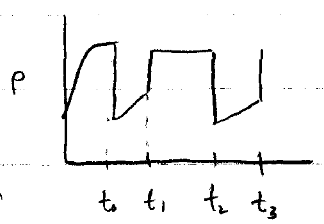
Drillstem Test - DST

- normally run in a zone of unknown potential in a well being drilled
- provides a temporary completion with the drillstring serving as flowstring.
- * a good DST yields
  1. a sample of reservoir fluid
  2. an indication of flow rates
  3. BHP, both static & flowing
  4. short term pressure transient test

- a DST helps determine
  1. possibility of commercial production
  2. estimate of formation properties & wellbore damage.

- Most DST's include:
  1. short production period (initial flow)
  2. short shutin (initial buildup)
  3. longer production period (final flow)
  4. longer shut in (final build up)





In a standard DST, (1) the initial flow period is usually short (5-10 MIN); the idea is simply to release the high hydrostatic mud pressure
(2) initial shut-in should be long enough to approach stabilized flow.
(experience shows ≈ 1 hour)

DST pressure build up data must be analyzed with the Horner plot (since $t_p \cong \Delta t$)

→ p_{ws} vs. $\log\left(\frac{t_p+\Delta t}{\Delta t}\right)$

→ the value used for t_p is usually the length of the preceding flow period.

- if the initial flow period is very long, it is more accurate to use the sum of the flow-period lengths for t_p for the final buildup

for liquid-producing wells, the flow rate during a drillstem test decreases with time since the backpressure exerted on the formation face increases as the produced fluid moves up the drillstring

* Normally, the decreasing flow rate over the flow period is neglected in analyzing DST pressure buildup data and the average flow rate over the flow period is used.

The controlling factor for flow rate from a porous medium to a wellbore is critical flow thru the perfs in the anchor pipe.

- in this instance, p_{wf} from the flowstring recorder are useless, although shut-in data are analyzable
- all data from the blanked-off recorder can be analyzed in a normal fashion.

wellbore storage is not often significant in the buildup portion of a DST since the well is closed in near the formation face.

- if analysis results are suspicious, the log-log plot ($\log(P_{ws}-P_{wf})$ vs $\log \Delta t$) should be made to determine what part of the data should be analyzed.

(wellbore storage can be significant if thick sections in low permeability reservoirs are being tested)

If the shut-in period is long enough, and if wellbore storage is not dominant, a Horner plot of the buildup data should have a straight line section & slope $= -m$

$$K = \frac{162.6\, q \mu B}{|m| h}$$

TOTAL SKIN

$$S' = 1.1513 \left[\frac{P_{1hr} - P_{wf}(\Delta t=0)}{m} + \log\left\{\frac{t_p+1}{t_p}\right\} - \log\left(\frac{k}{\phi \mu c_t r_w^2}\right) + 3.2275 \right]$$

Damage Ratio: $\frac{J_{IDEAL}}{J_{ACTUAL}} = \frac{\bar{P} - P_{wF}}{\bar{P} - P_{wF} - \Delta P_s}$; $\Delta P_s = \frac{141.2\, q \mu B}{kh} S'$

Initially, the drillpipe will be empty for the DST

- before opening, the pressure existing for the first flow is atmospheric