Fluid Level Measurements in Shut-in Wells

Outline of Discussion

- Objectives
  - Estimate SBHP and Reservoir Pressure
  - Get better understanding of producing well performance
- Types of Wells and Measurements
  - Flowing wells
    - » Gas, Oil and Water
  - Artificial Lift Wells
    - » Pumping, Gas Lift, Plunger Lift (Rod pumping discussed in Part 1)
  - Injection Wells
- General Considerations and Procedures

Outline of Discussion

- Flowing Wells Shut-in Fluid Level
  - Oil
  - Gas
  - Water
- Gas Lift Wells Shut-in Fluid Level
  - Packed annulus
  - Open annulus
- Plunger Lift Wells
- Summary

Shut-In Fluid Levels in Today's Environment

- SBHP information is important, but often difficult to obtain during times when we attempt to maximize production
  - We want to maximize production, so we don't want to shut in wells.
- The current oilfield environment is causing many wells to be shut-in
  - Don't miss the opportunity to collect useful important data by acquiring static fluid level records.

Why Do We Need SBHP Information?

- Determine Well's Performance
  - Properly size production equipment
  - Better understanding of producing conditions
- Evaluate present production efficiency
- Determine Pump-off Rate
- Evaluate Individual Well Depletion
- Provide Data to Determine Reserves

What is Required to Shut-In Well for SBHP Test?

- Management Approval
  - Would rather have production instead of number
- Planned Well Shut In (Don’t miss an opportunity)
  - Gas Plant Turn Around
  - Storage Facilities at Capacity
  - Offshore Platform Maintenance/Safety
- Well Down for Mechanical Problems

Differences Between Producing and Static Fluid Levels

- Producing Fluid Levels have fluids flowing into and out of wellbore
  - Tend to be noisier, especially if they have gas production
  - Have to correct for gas in the fluid column
  - Oil in the Annulus above pump in a steady state condition
- Static Fluid Levels have no fluid flowing into or out of the wellbore
  - Quiet
  - No gaseous liquid column correction
  - Can have oil and water in the annulus above the pump

Preparing Well for Shut-In

- Make sure team is aware of well shut-in status
- Verify Condition of well
- Gather Baseline Production Information
- Obtain Fluid Level on Well During Production Prior to Shut-In

Preparing for Extended Shut-In

- Land and Leasehold Issues
- Long term shut-in may affect the performance of the well.
  - Wellbore Damage
    - » Corrosion
    - » Fill
  - Reservoir Damage
    - » Crossflow
    - » Incompatible fluids
- Additional Testing Prior to Shut-In
  - Dynamometer
  - Plunger Tracking
- Additional Testing During Shut-In
  - Pressure Transient

Flowing Wells Shut-in Fluid Levels

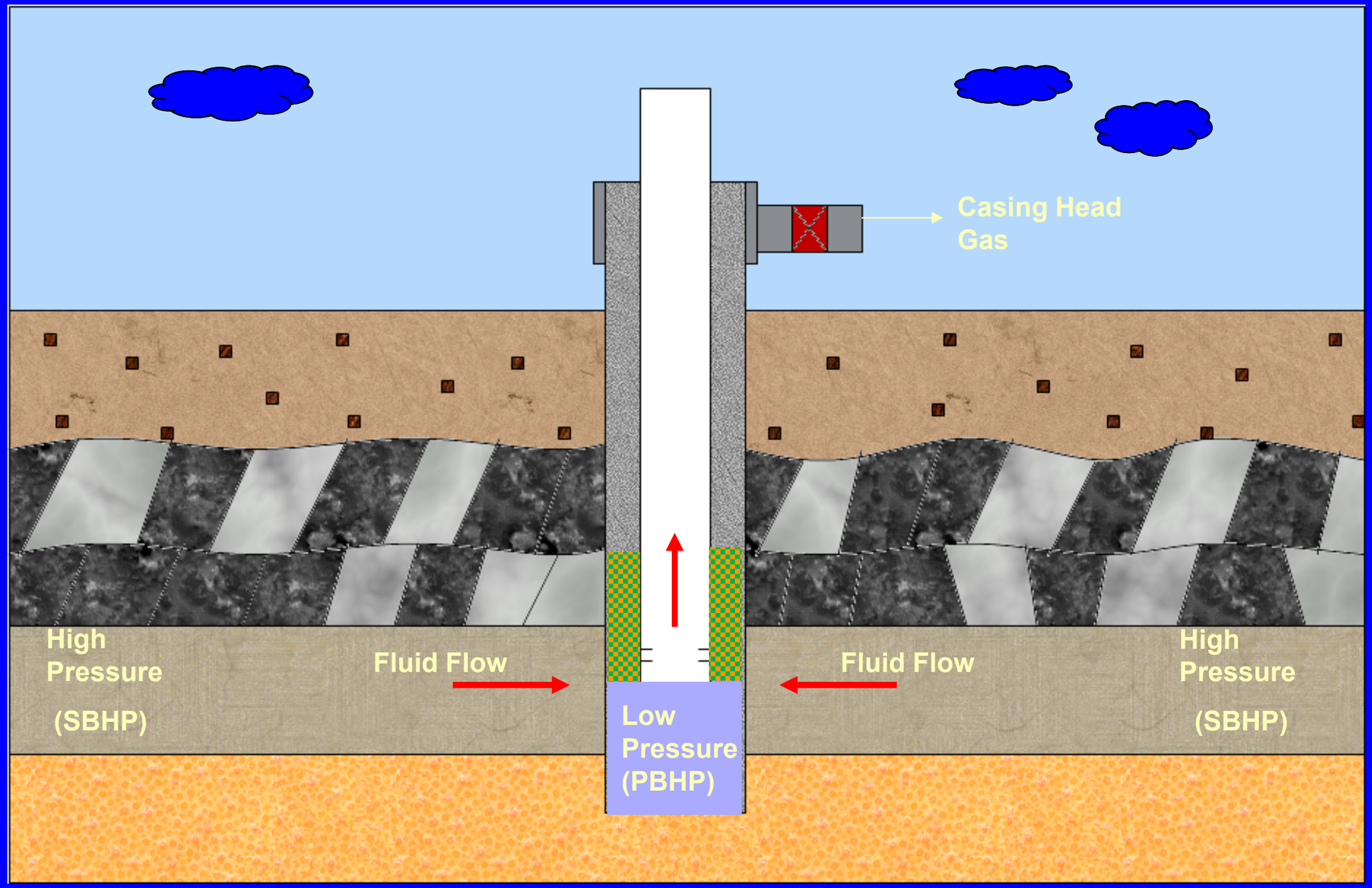
What happens in wellbore when flow is shut-in at the surface?

1. Gas and Liquid Redistribution: Liquid falls back to bottom gas percolates to wellhead. In some cases liquid is pushed back into perforations.
2. Pressures at Bottom hole and at wellhed increase
3. Flow at perforations decreases and eventually stops
4. Pressure in formation between wellbore and drainage radius increases
5. Oil and water in wellbore separate creating an oil/water interface

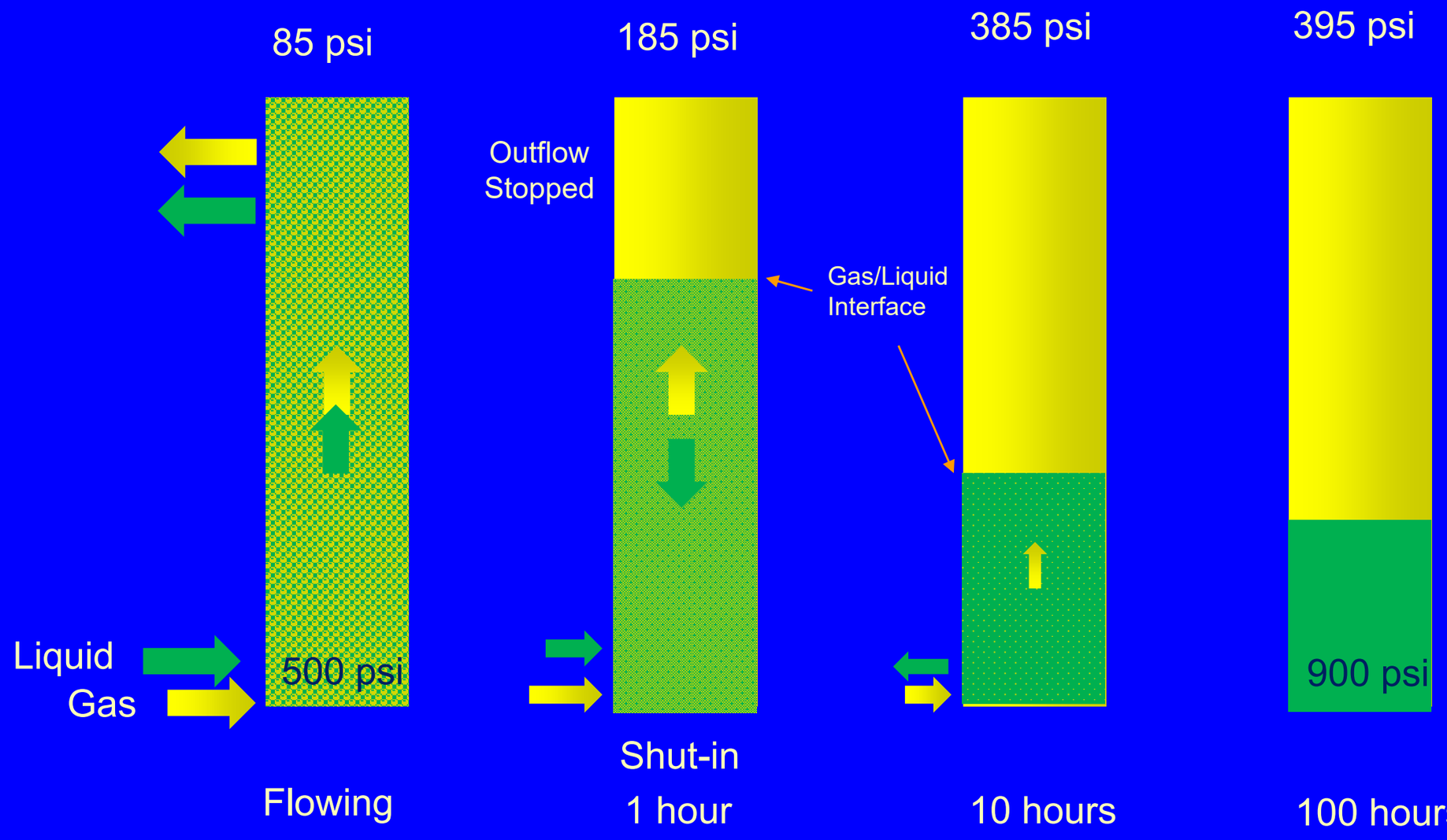
Return Well to Production

- Verify Production Facilities are Ready
- Consider Draw Down / Monitor Unloading
- Consider Needs for Additional Equipment to Bring Well Online

Fluid Removal



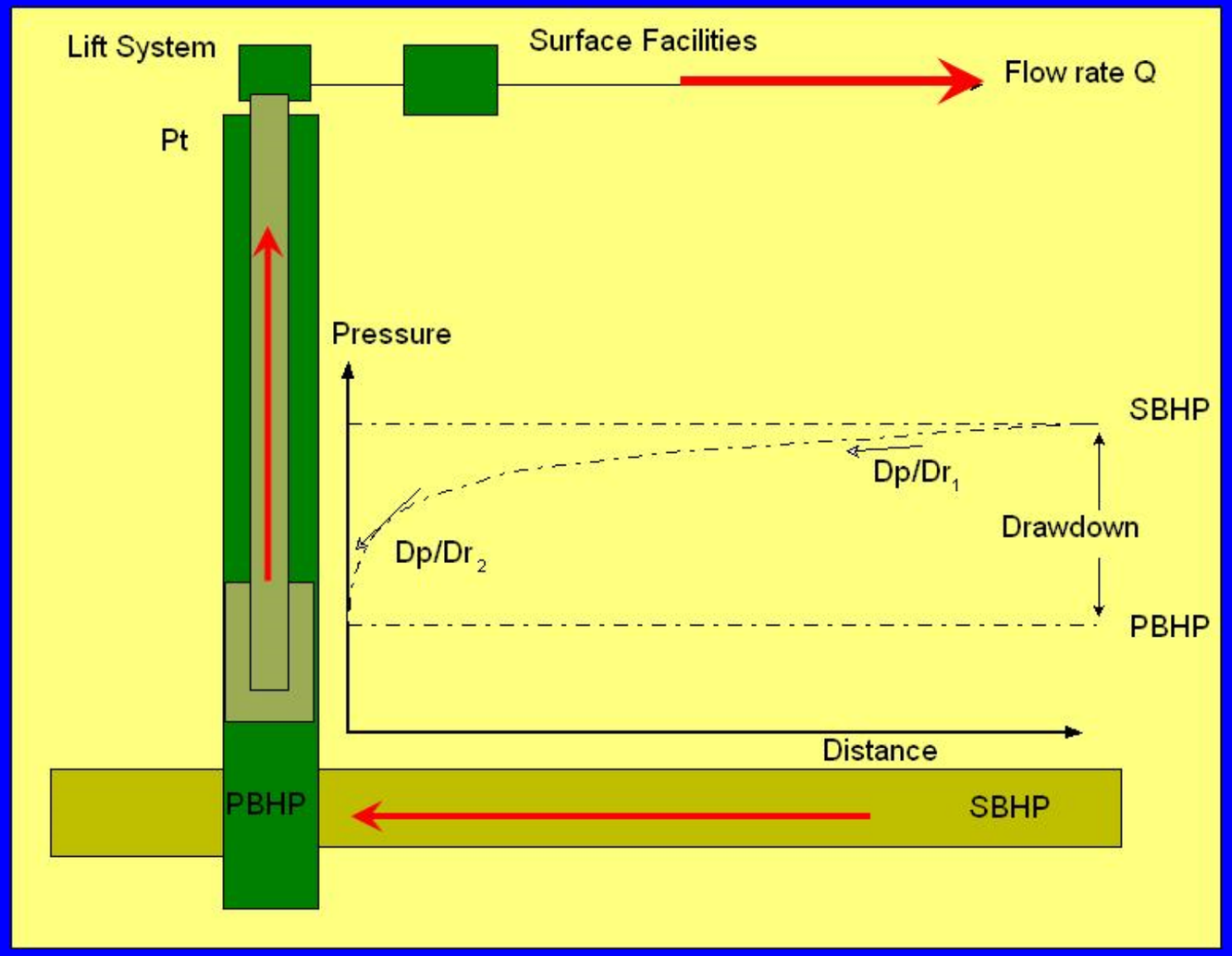
Change of Wellbore Fluid Distribution when a Flowing Well is Shut-in



- When flow is stopped at the surface fluids in the wellbore will segregate by gravity.
- **Liquid** falls back to bottom.
- **Gas** percolates to surface
- **Liquid** may flow back into perforations

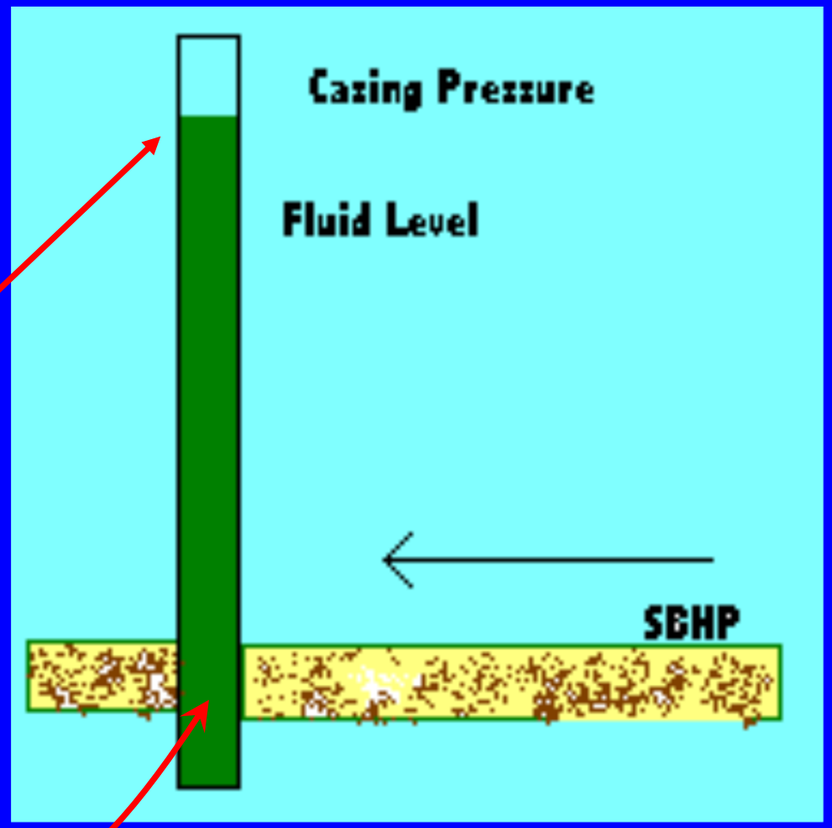
Static BHP

- SBHP: also known as the Reservoir Pressure at the drainage radius, P_{re}.
- Represents the pressure available to push the fluids to the wellbore from the formation.



Static Bottom Hole Pressure - SBHP

- Generally *GUESSED*
- Needed within +/- 15% for well potential calculation.
- Operator Should Measure *Static Fluid Level* and Casing Pressure in wells shut-down for any reason (mechanical failure).
- *Use TAM, TWM or AWP2000* to compute the SBHP

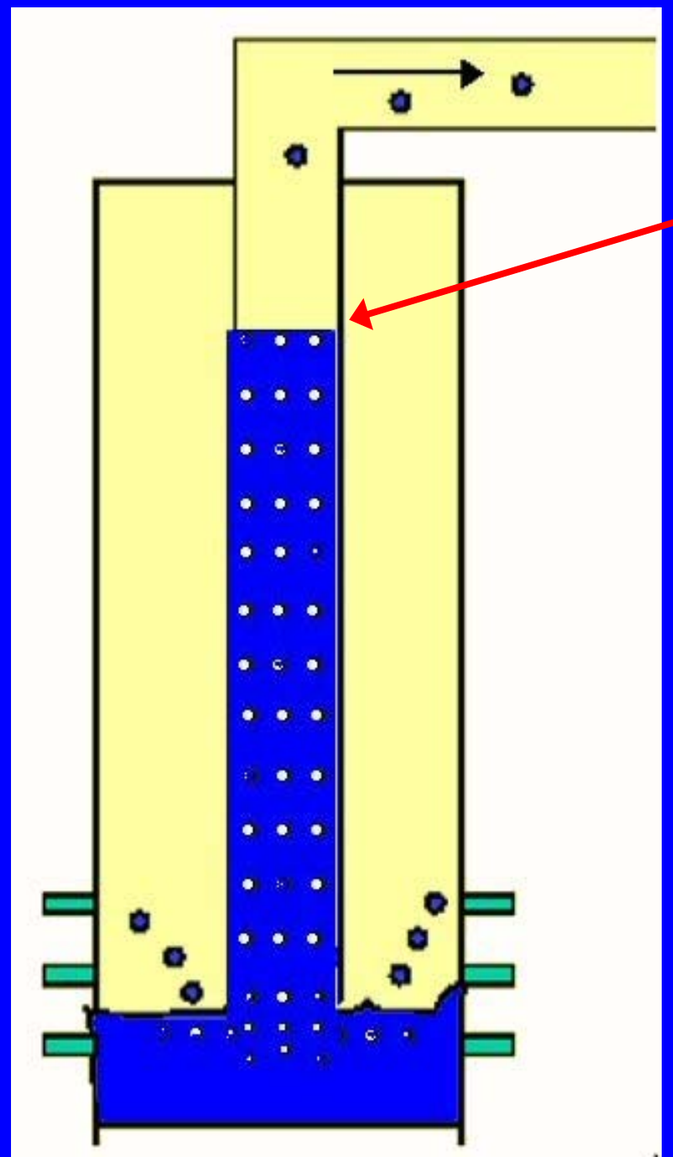


Shut-in Gas Wells Fluid Levels

- Dry gas or Gas rate above critical rate
  - Liquid droplets continuously carried out by gas flow
  - No liquid level echo detected when fluid level shot while flowing
  - Liquid level echo may be detected after some time as liquid falls back as gas flow rate decreases below critical flow rate
- Liquid Loaded Flowing Gas well
  - Mostly gas flowing at wellhead
  - Liquid level detected when first shot while flowing
  - Liquid level collapses as flow is shut-in

Gas Gun Physical set-up on Well

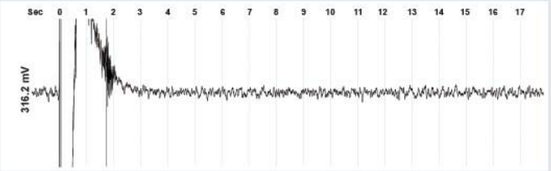
on Gas Well



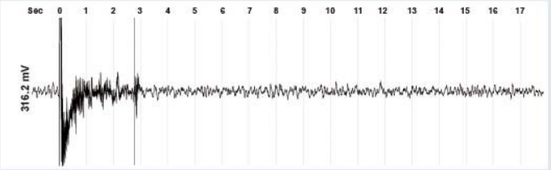
Gas Velocity Impacts Result of Acoustic Liquid Level Shot:

1. Below Critical Velocity:
   - Usually see liquid level above bottom of Tubing

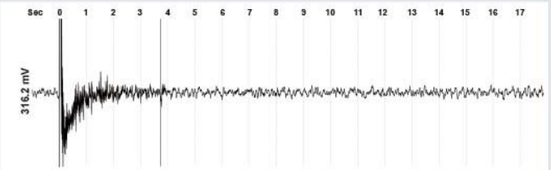
2. Above Critical Velocity:
   - May not see a liquid level because liquid droplets may fill tubing and absorb all energy from shot
   - May see bottom of tubing and/or perforations due to small amount of liquid



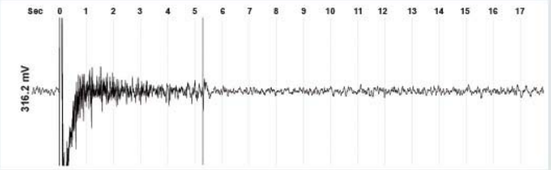
16:48:04 RTT = 1.733 Seconds
Questionable Fluid Level Echo, Explosion Shot



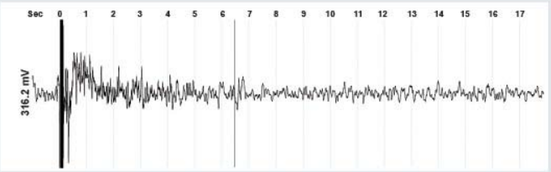
16:52:44 RTT = 2.779 Seconds, Explosion Shot
Liquid Level = 1,823 ft



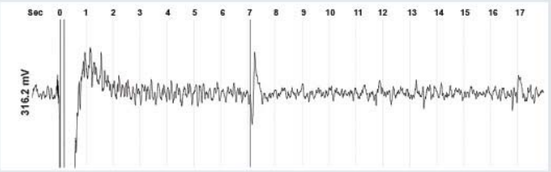
16:56:59 RTT = 3.73 Seconds, Explosion Shot
Liquid Level = 2,447 ft



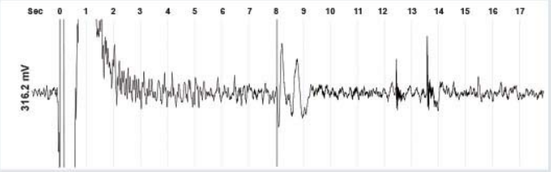
17:02:53 RTT = 5.294 Seconds, Explosion Shot
Liquid Level = 3,472 ft



17:08:27 RTT = 6.483 Seconds, Implosion Shot
Liquid Level = 4,252 ft

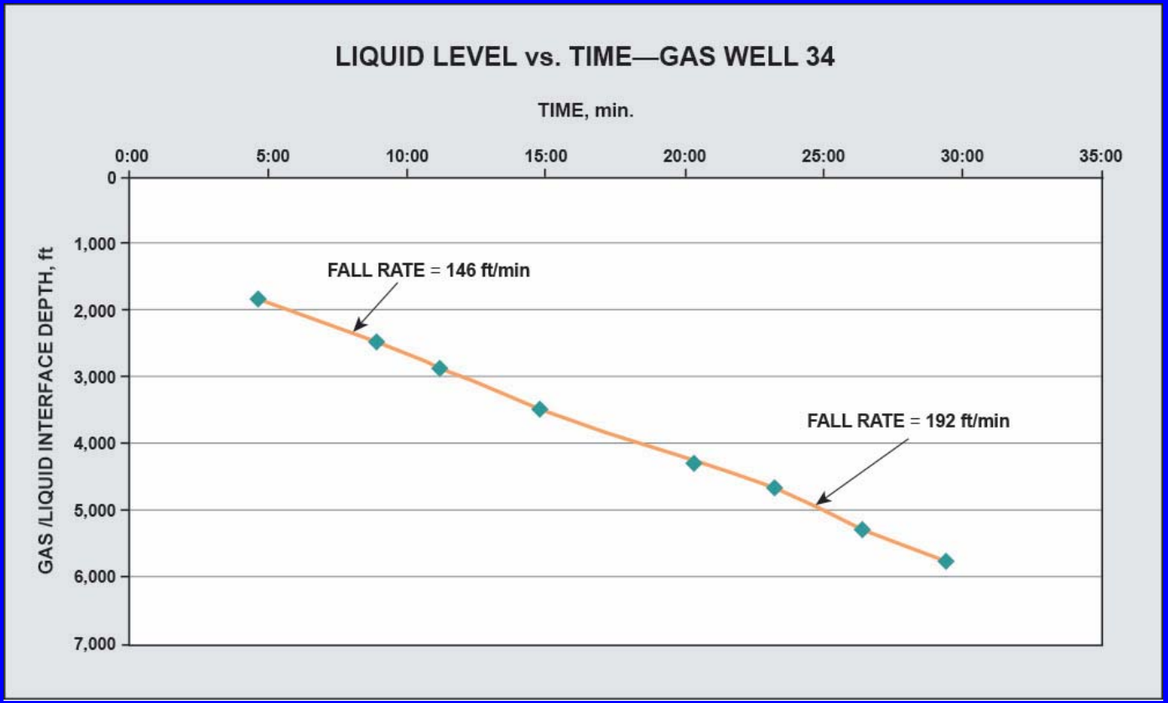


17:11:17 RTT = 7.1 Seconds, Implosion Shot
Liquid Level Echo Clearly Detectable
Liquid Level = 4,657 ft



17:14:27 RTT = 8.027 Seconds, Implosion Shot
Fluid Level Below End of Tubing at 5,256 ft

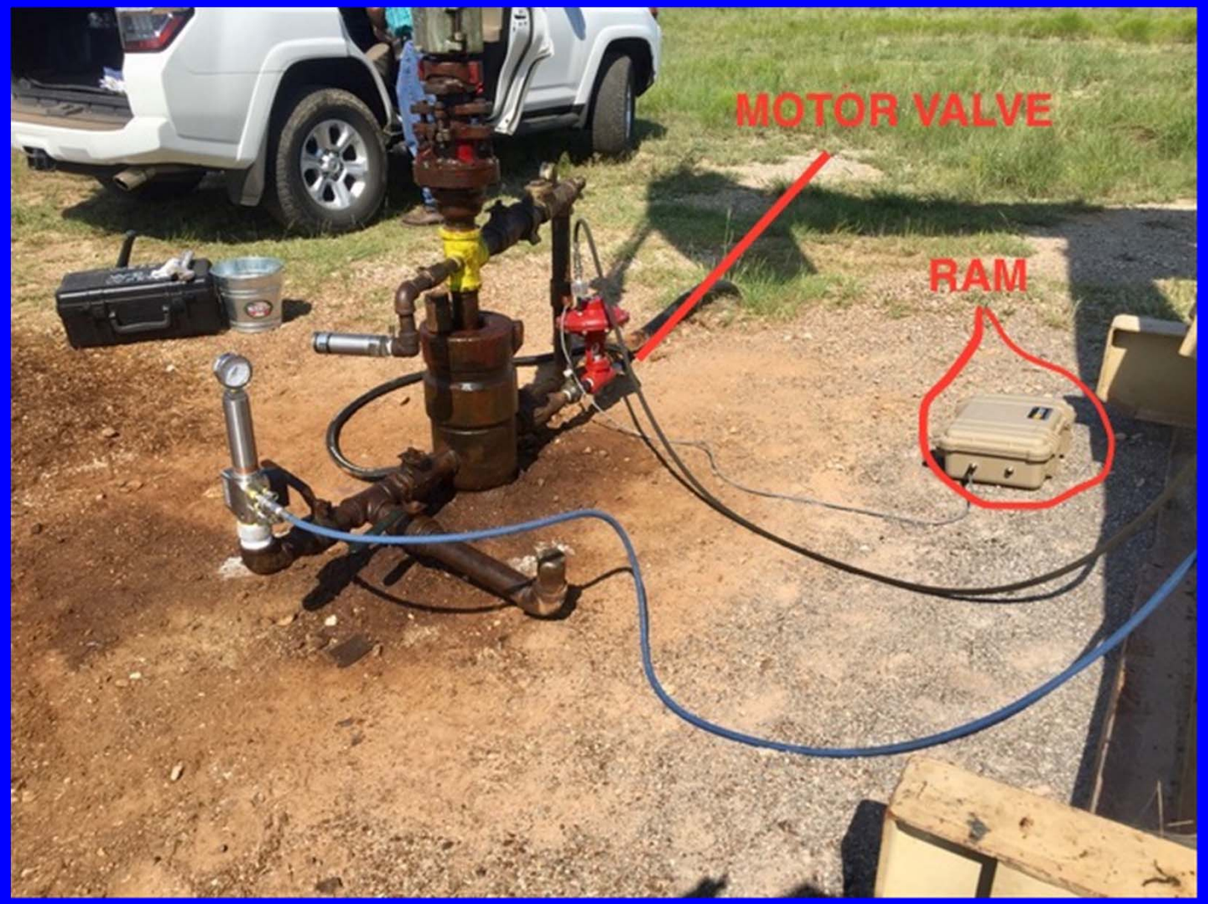
Example Liquid Loaded gas well fluid level in tubing as a function of time



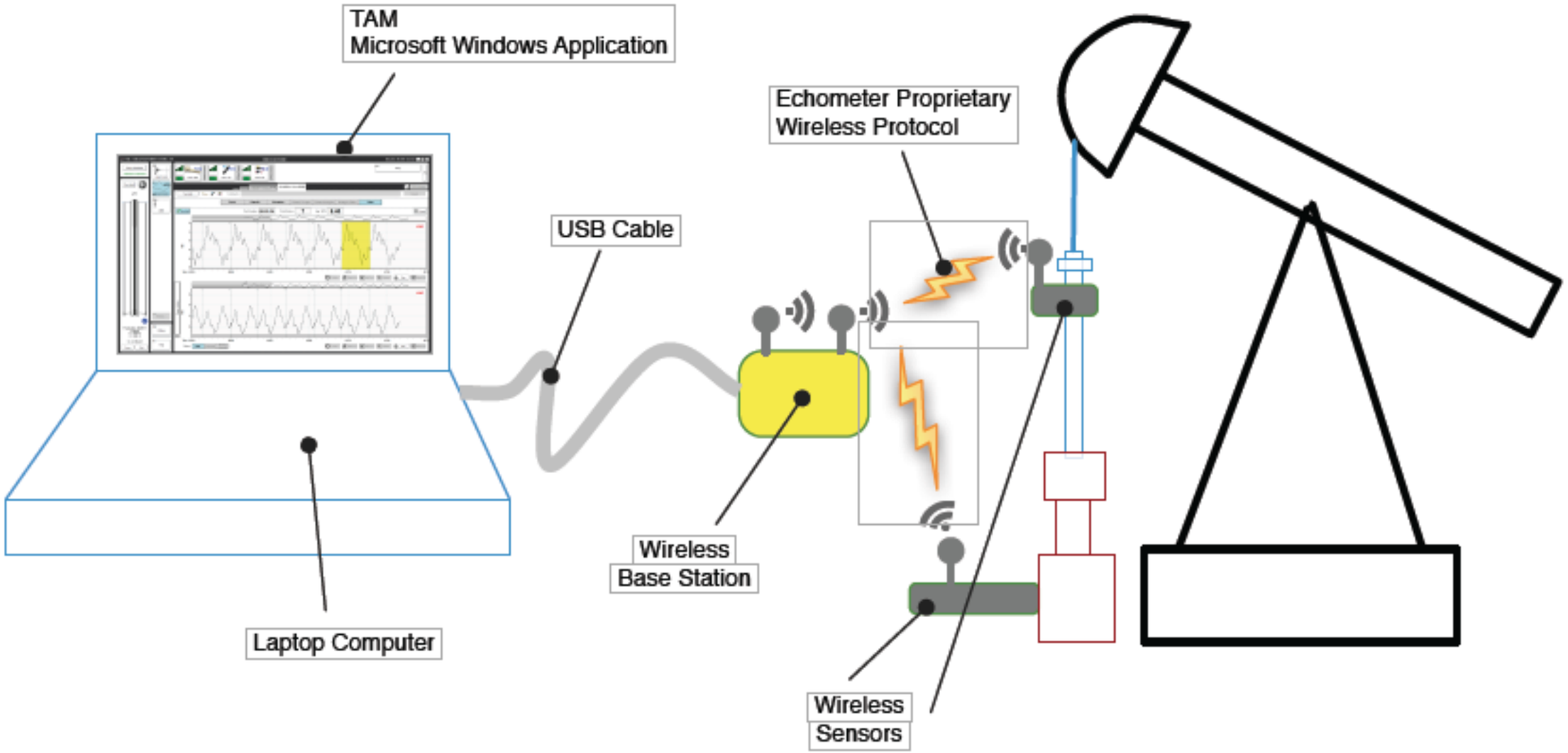
Break for Answering Questions

Examples

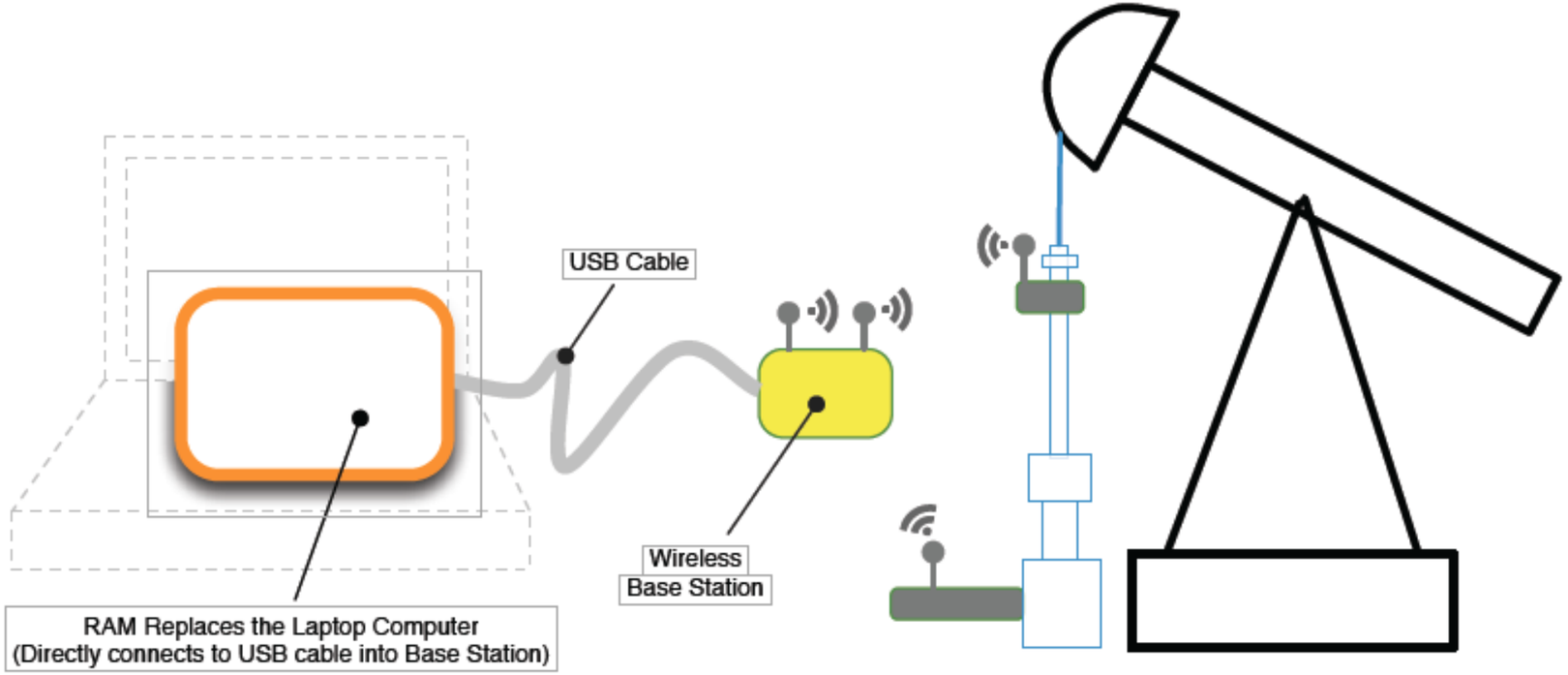
RAM



Total Asset Management [TAM] and Wireless Data Acquisition System
(Echometer's Current System)

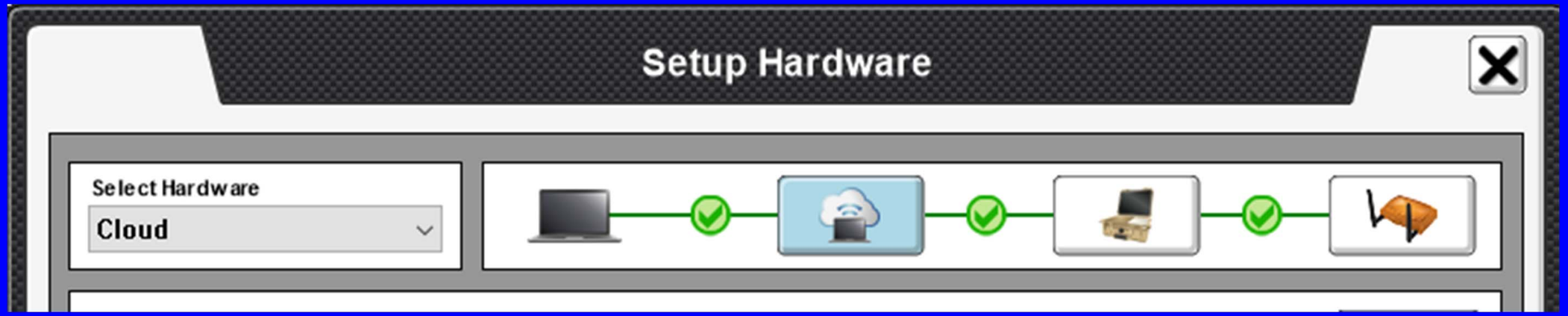


NEW Communication Acquisition & Control System [RAM]
Interfaced With Existing Wireless Data Acquisition System

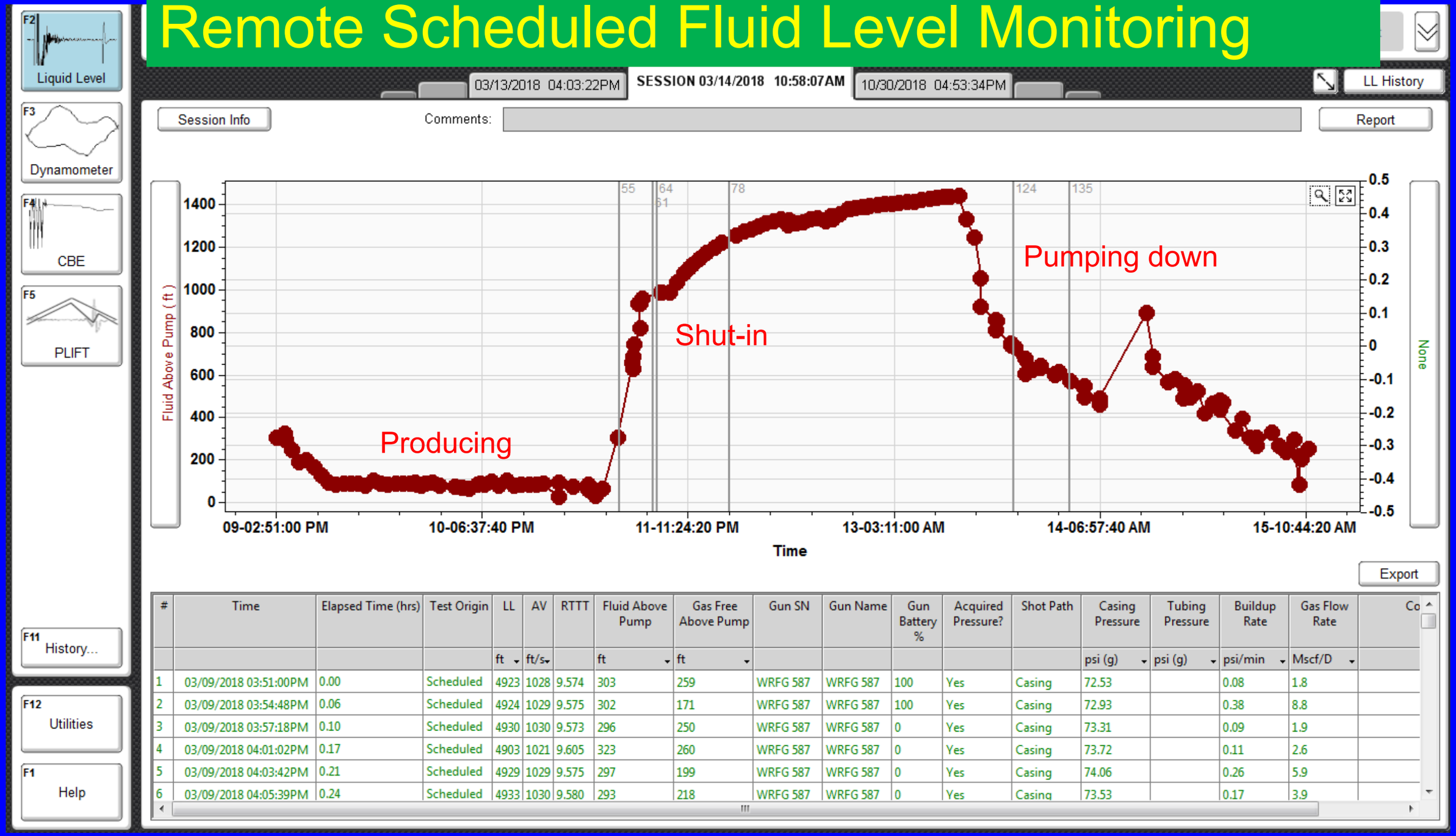


RAM: (light weight, portable system)
- Small container
- Battery operated
- Directly compatible with Echometer Wireless System
- Design for unattended data acquisition
- WiFi from Laptop to setup and control system
- WiFi to harvest collected data
- Cellular Interface
- Ability to log into remote server via 3/4G Cellular

RAM COMMUNICATION ARCHITECTURE



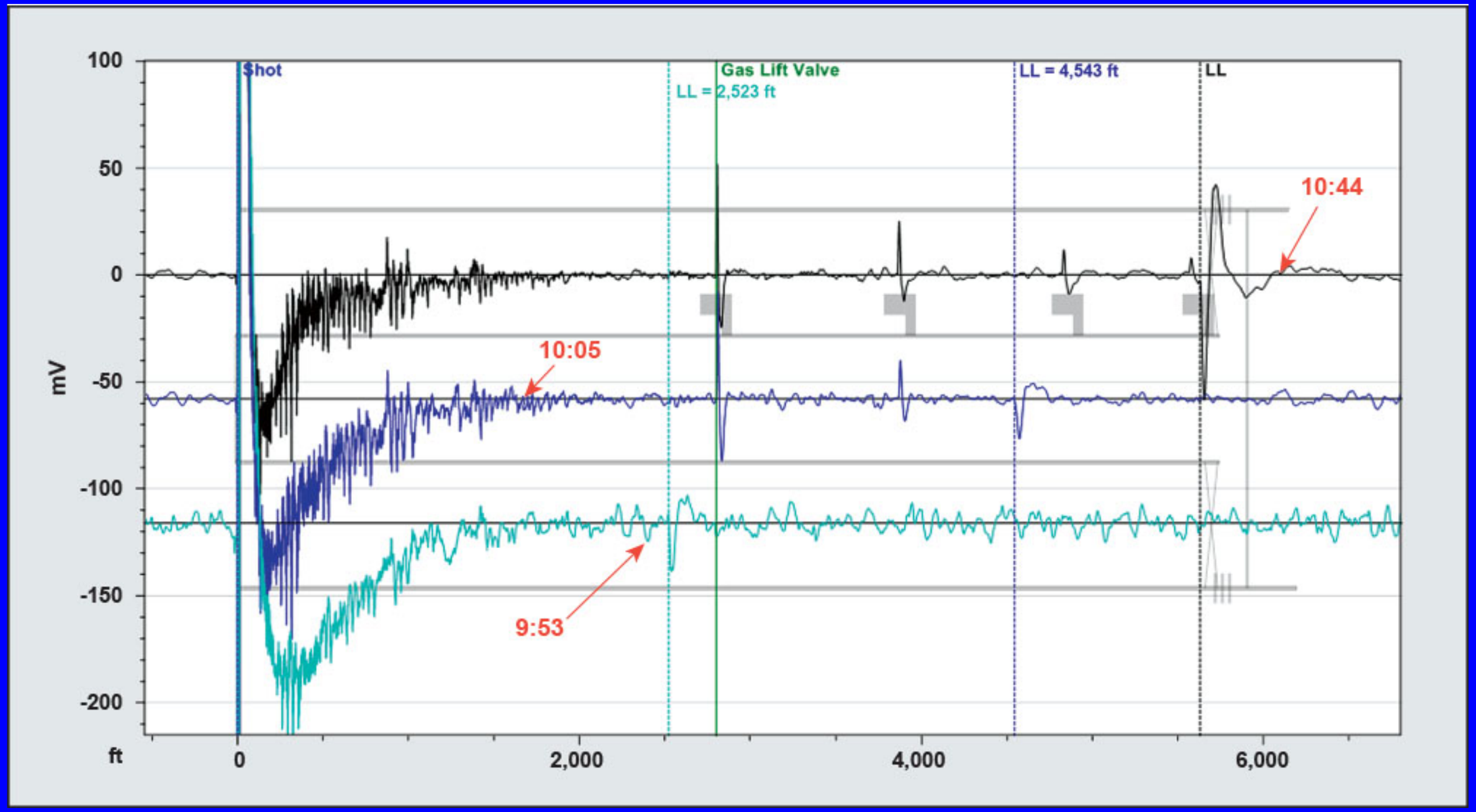
Remote Scheduled Fluid Level Monitoring



#	Time	Elapsed Time (hrs)	Test Origin	LL	AV	RTTT	Fluid Above Pump	Gas Free Above Pump	Gun SN	Gun Name	Gun Battery %	Acquired Pressure?	Shot Path	Casing Pressure	Tubing Pressure	Buildup Rate	Gas Flow Rate	Co
				ft	ft/s		ft	ft						psi (g)	psi (g)	psi/min	Mscf/D	
1	03/09/2018 03:51:00PM	0.00	Scheduled	4923	1028	9.574	303	259	WRFG 587	WRFG 587	100	Yes	Casing	72.53		0.08	1.8	
2	03/09/2018 03:54:48PM	0.06	Scheduled	4924	1029	9.575	302	171	WRFG 587	WRFG 587	100	Yes	Casing	72.93		0.38	8.8	
3	03/09/2018 03:57:18PM	0.10	Scheduled	4930	1030	9.573	296	250	WRFG 587	WRFG 587	0	Yes	Casing	73.31		0.09	1.9	
4	03/09/2018 04:01:02PM	0.17	Scheduled	4903	1021	9.605	323	260	WRFG 587	WRFG 587	0	Yes	Casing	73.72		0.11	2.6	
5	03/09/2018 04:03:42PM	0.21	Scheduled	4929	1029	9.575	297	199	WRFG 587	WRFG 587	0	Yes	Casing	74.06		0.26	5.9	
6	03/09/2018 04:05:39PM	0.24	Scheduled	4933	1030	9.580	293	218	WRFG 587	WRFG 587	0	Yes	Casing	73.53		0.17	3.9	

Shut-in Gas Lift Wells FL Measurements

- Continuous Gas Lift Injection with ***Packed*** Annulus
- While injecting
  - » One fluid level in annulus to check operating valve
  - » One flowing fluid level in tubing to check for liquid loading
- Shut-in casing injection and shut-in tubing
  - » Periodic fluid levels in tubing until dp/dt decreases and FL stabilizes
  - » One fluid level in annulus at end of test to monitor for leaks
- Open Injection to Casing and Tubing to flowline
- Monitor unloading by shooting periodically down tubing until liquid reaches surface



Acoustic records acquired down tubing of Gas Lift Well after shut-in

Shut-in Gaslift Wells FL Measurements

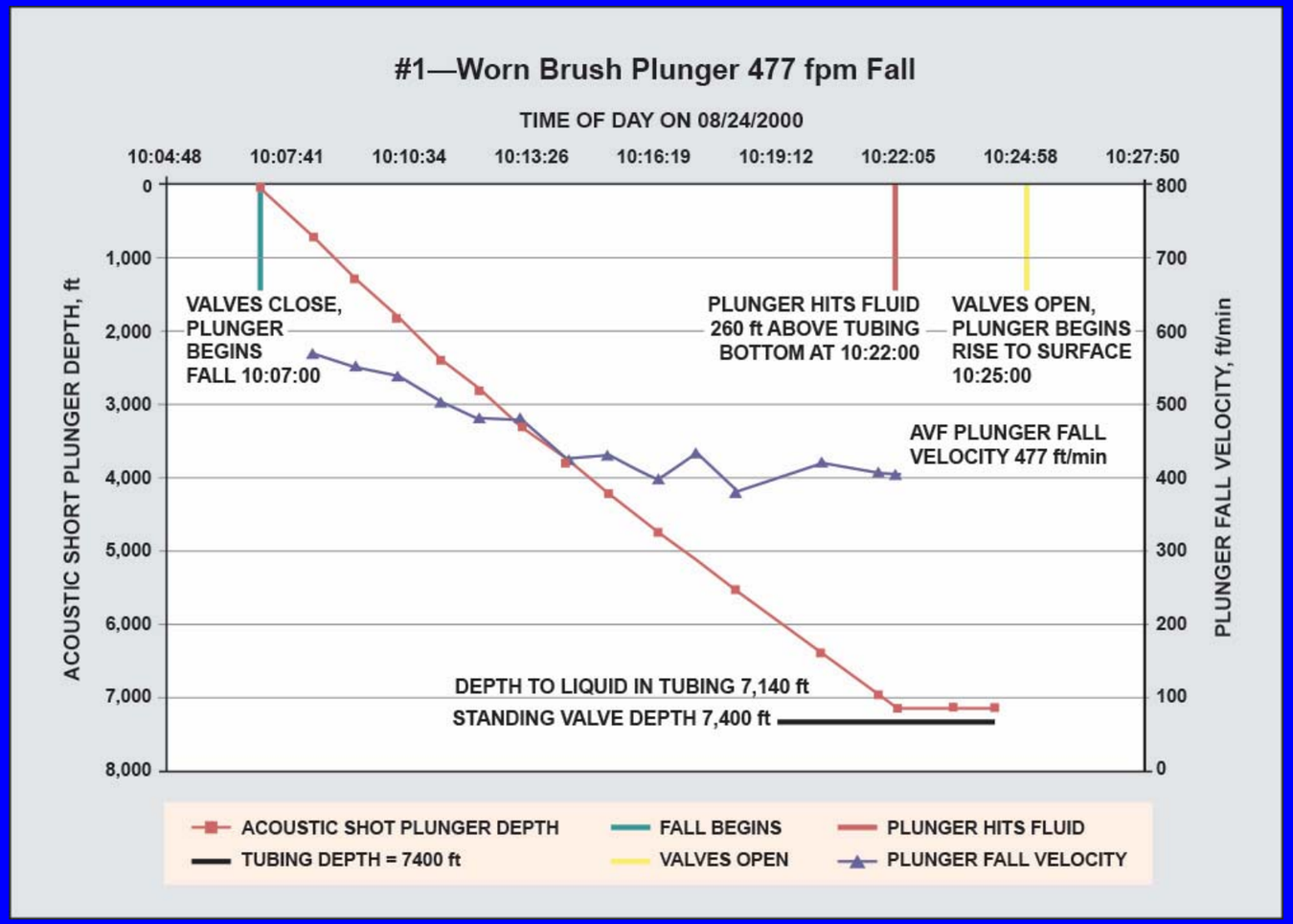
- Continuous Gaslift Injection with ***Open*** Annulus

- While injecting
  - » One fluid level in annulus to check operating valve
  - » One flowing fluid level in tubing to check for liquid loading
- Shut-in casing injection and shut-in tubing
  - » Periodic fluid levels in tubing as liquid collapses until dp/dt decreases and FL stabilizes
  - » One fluid level in annulus at end of test to monitor operating valve
- Monitor unloading by shooting periodically down casing

Shut-in Plunger lift Wells FL Measurements

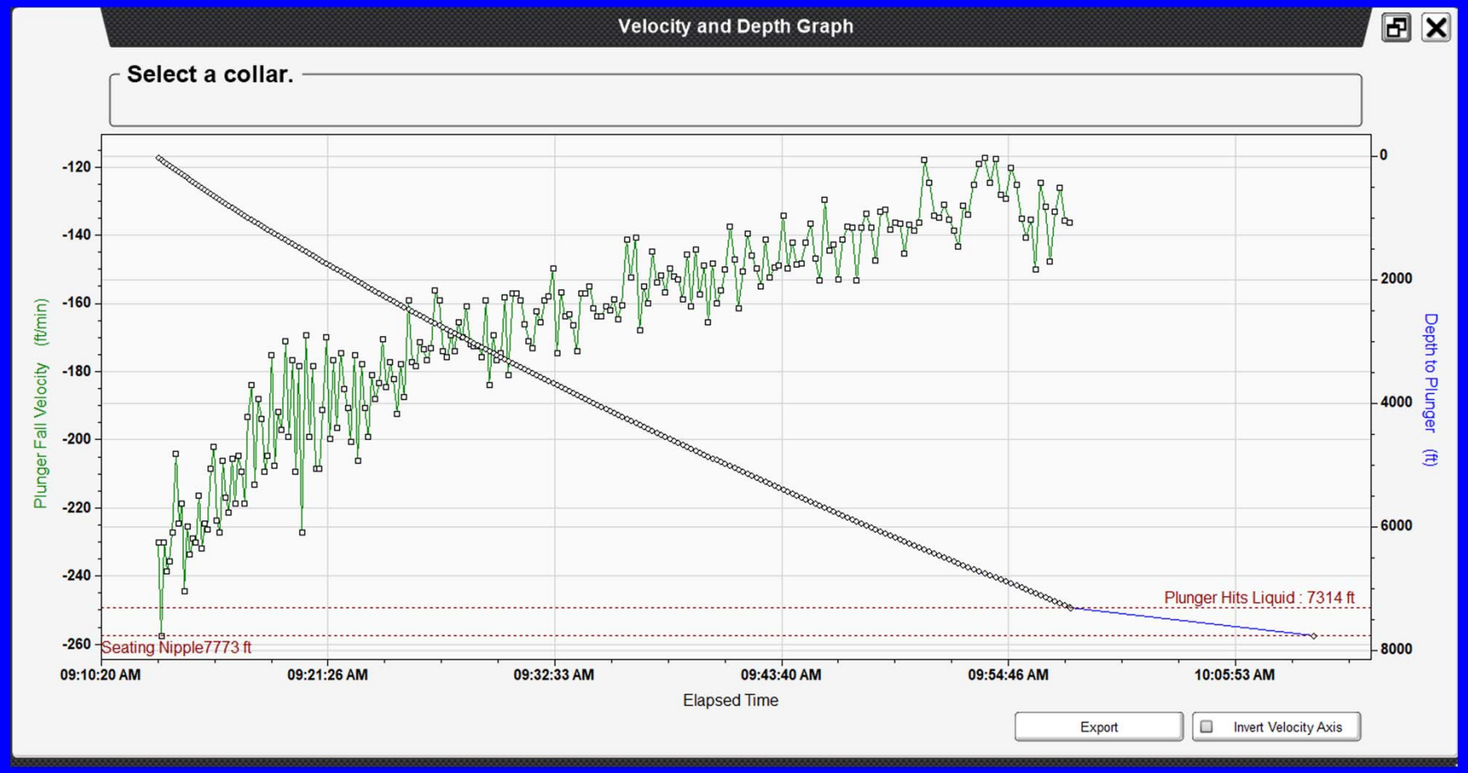
- Block Plunger in Lubricator at surface
- Shut-in casing injection if present and shut-in tubing
  - » Periodic fluid levels in tubing as liquid accumulates at bottom of tubing until dp/dt decreases and FL stabilizes
  - » Periodic fluid level in annulus to monitor pressure and fluid level
- At end of test, drop plunger and monitor plunger fall to bottom
- Open tubing to flowline and monitor one complete plunger cycle.

Acoustic Shots during Plunger Fall



Compact gas gun fired at about 1 minute intervals to track plunger fall.

Plunger Tracking / Plunger Fall



Break for answering Questions

Calculation of SBHP from Fluid Level

Static BHP =

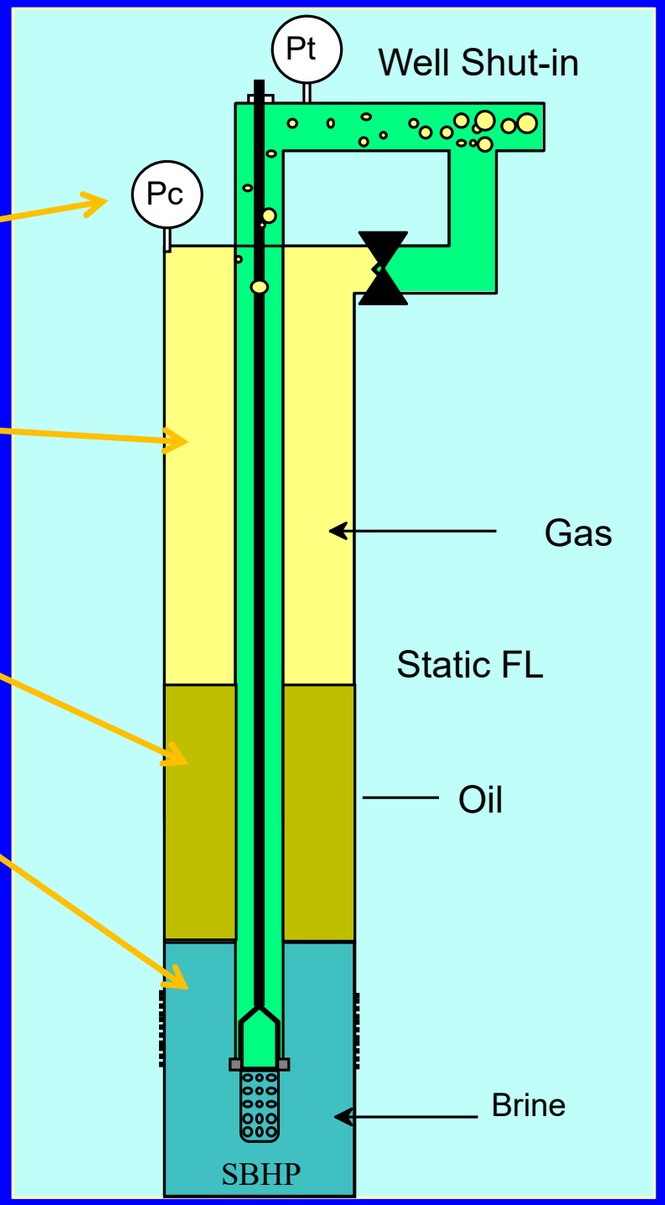
Casing Pressure +

Gas Column Pressure +

Oil Column Pressure +

Brine Column Pressure.

Note:
All flow from perforations has stopped
Fluids Segregated by Gravity
Depth of Oil/Brine interface above pump intake must be computed.

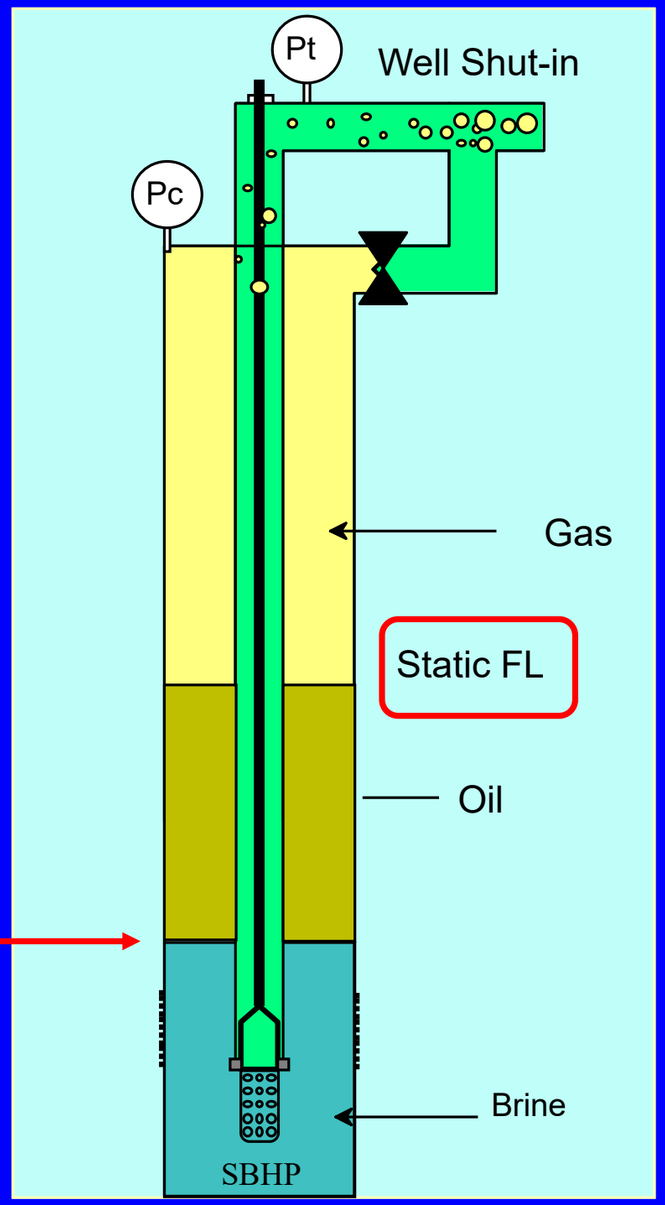


Oil/Water Interface at end of shut-in

- Cannot Accurately Predict WOR during after-flow.

Assume that during after-flow the WOR remains same as that measured by well test.

Program computes location of water/oil interface from the Static Fluid Level, the <u>last measured Producing Fluid Level</u> and the wellbore dimensions.



Summary

- Fluid levels acquired in shut-in wells combined with producing fluid levels yield much information about production efficiency of flowing and artificial lift wells.
- The longer the well is shut-in the computed bottom hole pressure (SBHP) will be a better estimate of the reservoir pressure.
- Periodic fluid level measurements acquired after shutting in the flow are used to analyze in detail well performance.
- Programmable stand alone fluid level instruments facilitate data acquisition and analysis

Break for answering Questions

End of presentation