Gas Lifting on TLP's

2/7/08

Nora Ghobrial

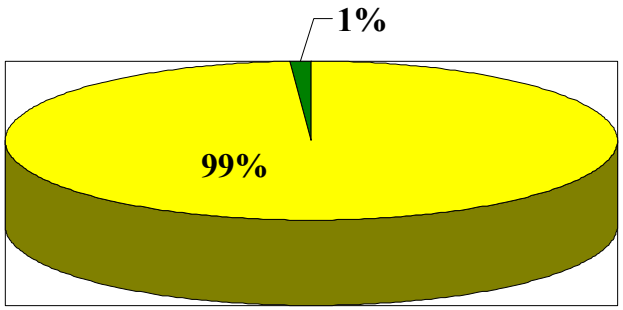
Shell is pursuing gas lift projects on most of it's TLP's in the GOM
(Ram/Powell 1st TLP to Gas Lift – Dec 2005)

- **State of the Portfolio**
- **Deepwater Gas Lift: What's different vs. the Shelf?**
- **Safety Issues**
- **Project Design & Execution Considerations**
  - **Well Design**
  - **Facility Design**
  - **Operational Readiness**

Gas Lift/Artificial Lift - Deepwater GOM

Our New Frontier

Current GOM TLP/SS AL Portfolio

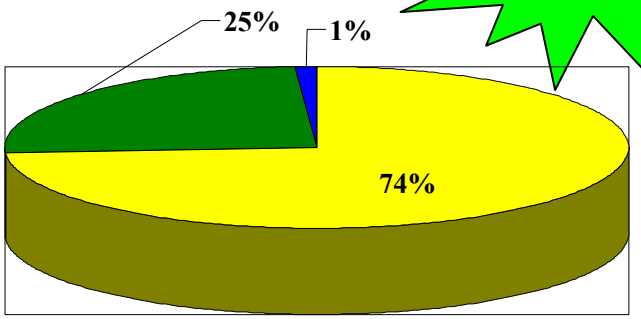


Natural Lift | Gas Lift | ESP's | Beam | Other

Deepwater Portfolio
△ Time

- Decreasing Res. Pressures
- Increasing Watercuts
- Implementing Waterfloods

GOM TLP/SS AL Portfolio within 5 yrs

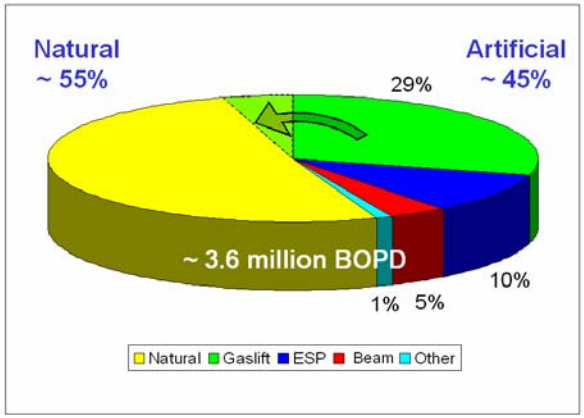


Natural Lift | Gas Lift | ESP's | Beam | Other

Aligning w/global portfolio

Global AL Portfolio

BUSINESS DIMENSIONS OF ARTIFICIAL LIFT



	TLP/Subsea	Type AL	Start AL	AL Now	AL w/in 5yrs
			Year	# Wells	# Wells
Ursa	TLP	GL	2008	0	8
Mars	TLP	GL	2008	0	12
Princess	Subsea	GL	2009	0	1
Ursa North	Subsea	GL	2009	0	1
	Subsea	Caison ESP	2010/11	0	1
Brutus	TLP	GL	2008	0	1
Ram/Powell	TLP	GL	2005	1	2
Total TLP/SS AL			99	1	26
% GOM TLP/SS			100%	1%	26%

Lots of Deepwater Reserves tied to AL

Are we identifying all of the artificial lift candidates?

Significant Achievements/Upcoming Challenges

Achievements

Ursa, Mars, and Brutus

- GL Teams established/working/staffed
- Holistic Artificial Lift Designs Complete (hub-level cross-discipline tech design effort leveraging Global AL team)
- Topside Design Basis, Well Design Basis, Compressor Selection Approved on all assets
- New Technology being leveraged on all assets
- First Tubing Punch w/GL Packoff installed at Ursa TLP

Ram/Powell

- 1st Deepwater asset to implement lift
- 1st Approved GL HSE Case Supplement
- Topside Design Guideline Created
- Completion Design Guideline Created
- DW GL Training Course Created
- Deepwater GL Operating Philosophy/Procedures Established

New Technologhy

- CTR/Funding Approved for R&D of High Reliability GL equipment
- High Reliability Checks near Shell Qualification
- Hydraulic VR Checks to be installed

Challenges

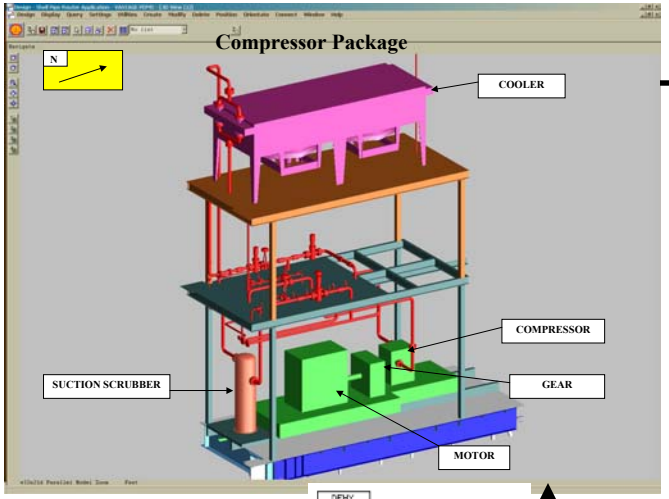
- Implementing GL on Ursa, Mars, and Brutus
- Retrofitting existing TLP Wells for Lift (Tubing Punch w/GL Packoff)
- High Reliability GL Equipment Shell Qualified & Ready to Install
- Operating Large scale HP (3000psi) Gas Lift
- Regionalizing GL Approach/Creating Standards
- Paradigm shift (to install lift right off the bat)
- Interventions (need experienced GL wireline hands - getting rare)

Deepwater Gas Lift
What's Different vs. the Shelf?

- **Floating Platform**
  - Wells held by Production Riser Tensioners (PRT's)
  - Relative movement of Wellhead affects tree hookup
- **Deep set SCSSV's**
  - Keep all valves below SCSSV
  - Higher GL system pressures needed
- **Fewer Casing Strings**
- **Crews unaccustomed to Gas Lift**
- **Higher Intervention Costs**
- **Larger Tubing**
  - Higher GL injection rates needed
- **Higher HSE exposure**
  - Personnel (100+ POB)
  - Environment (Higher rates= large spill/release potential)
  - Assets ($Billion+)

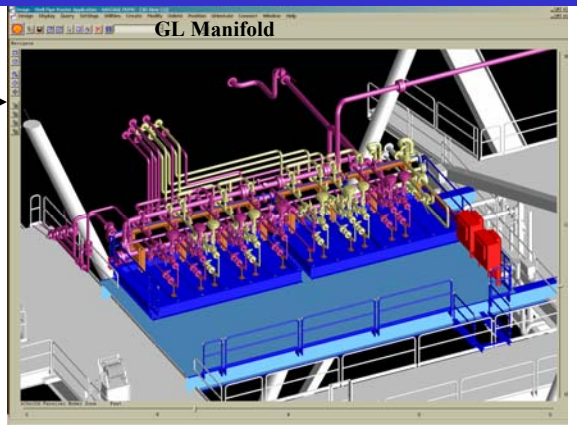
VS.

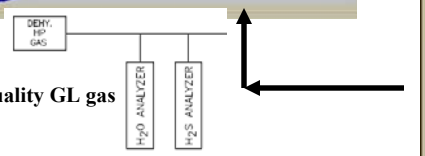
Integrated Solution – Need a Holistic Approach/Design



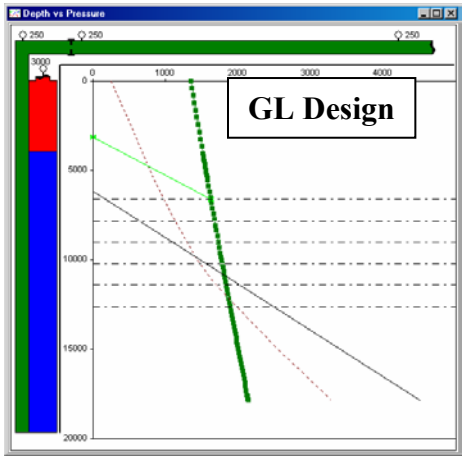
Topsides Modifications

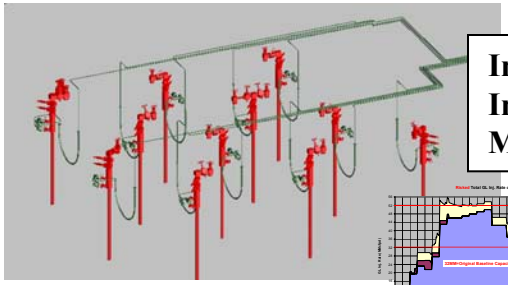
HSE (Major Risk to TLP)
Operational Readiness



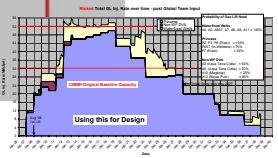


Quality GL gas

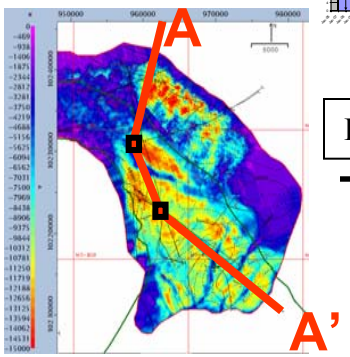




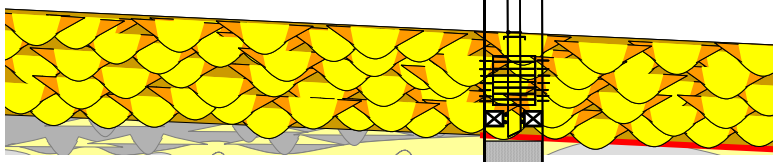
Integ Production/
Injection Sys
Modeling/Design

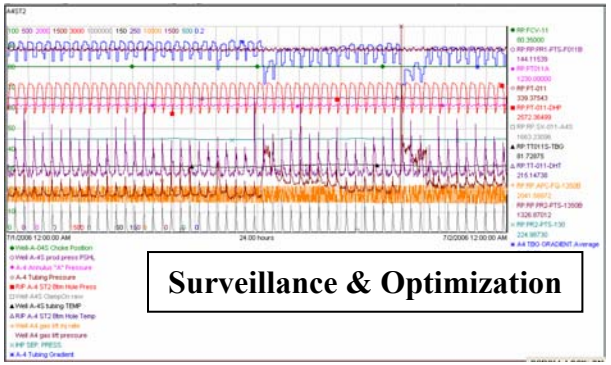


Well Design



Reservoir Modeling

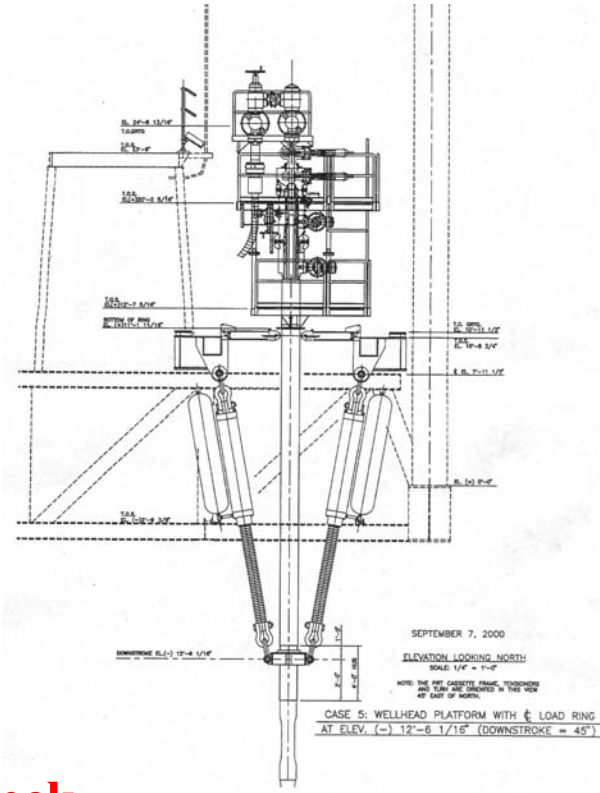




Surveillance & Optimization

Safety Issues
Major Hazard is Loss of Containment

- **Loss of Containment = Major Hazard**
  - 200 – 1000 Mcf of gas inventory in a single well
    - Equivalent to the entire topsides inventory!
  - Jet fire from release of inventory could compromise PRT's
    - "Dropping" of wells could result in insufficient time to abandon platform!
    - PRT Waterspray system being evaluated
- **Complicating Factors**
  - Blowing down casing inventory = not practical
  - Reducing csg inventory using an ASCSSV or Dual String = not practical
    - Failure rates, Small csg diameters & risk of hoop stress fatigue
  - ~~Single barrier exists at the casing valve~~ → **New: VR Check**
  - Only one riser outside of Production Casing
- **Maintaining Tubing, Casing, PRT, and Tree Integrity is Key**



Safety Hazards, Threats, & Consequences

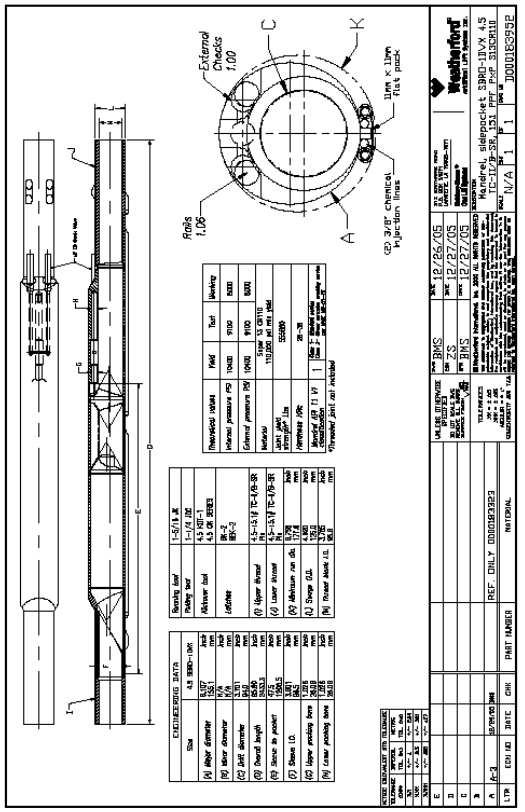
- **Loss of Containment = Top Event**
- **Hazard Threats**
  - Sustained/Excessive Casing Pressure
  - Seal Failure
  - Compromised Tubing Integrity
  - Reservoir Souring
  - Corrosion (H2S, CO2, H2O Content)
  - Fatigue/Fretting
  - Acid Jobs
  - Impacts/Dropped Objects
  - Bleed down of Annulus
  - Well Collision/Riser Impact
- **Hazard Consequences**
  - Fire
  - Explosion
  - Loss of Stability

Well Design
Studies and Standards: Deepwater Gas Lift

- **Materials & Corrosion Assessment**
  - Tbg, Csg, & Tree material tolerances to H2S, CO2, & H2O understood
  - Injection Gas Quality Standards Set
  - New well materials selected to be fit-for-purpose
- **Deepwater Guidelines for Gas Lift Completion Systems**
  - Tubing Integrity Matrix dictates when High Reliability GL equipment is needed
  - Dictates when GLV's allowed above SCSSV
  - Quality control & testing standards for equipment set
- **Tubing Integrity Testing Standard for Deepwater Gas Lifted Wells**
  - Tubing Integrity testing frequency/procedure
- **Elastomer Study**
  - Testing tree seals to determine fit-for-purpose limit when bleeding down annulus to maintain integrity and avoid explosive decompression issues
- **Failure Modes & Effects Analysis**
  - Assess well & tree configuration for adequate # of Barriers

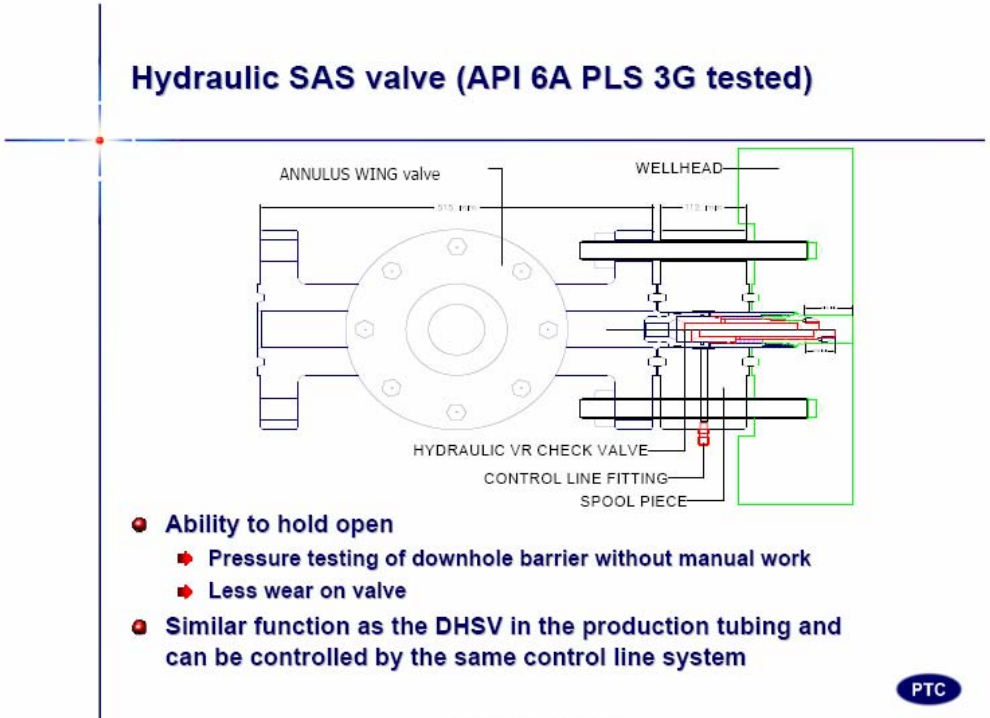
Well Design Considerations– TLP Gas Lift

- **Gas Lift Design**
  - Design system for full Field/Well Life Cycle (WC & Res Psi)
  - Balance minimizing # of GLV's (leak points) with having flexibility in design
  - Prefer to keep all GLV's below SCSSV
  - Prefer 1.5" GLV's for higher injection rates in big tbg
  - Initial Unloading Using High Pressure Nitrogen can avoid need for compressor
- **High Reliability GL equipment installed in sour potential environments**
  - Installed GLM with externally mounted high reliability check valves
  - Hydraulically controlled GLV employed
- **Completion Equipment (minimize interventions)**
  - Downhole Pressure Gauge
  - Fiber Optic Line for Temperature Profile
  - Chemical Inj Line to prevent Paraffin Buildup (also 1 MeOH)
  - Dual tree barriers required with at least one M2M seal
    - Install Hydraulic VR Check Valve in casing valve
    - Install VR plug in valve for MLTH control line
- **Model PRT Adjustments**
  - Starting gas lift requires adjustment to PRT cylinder pressures to maintain target tension
  - Consider temperature effects on well system given gas in annulus



Hydraulic VR Check Valve for GL!!!!!!
(aka Hydraulic Surface Annular Safety Valve (H-SAS))

- Provides secondary barrier to annulus gas volume!
- Basically, a check valve that goes into the already existing VR profile of the casing valve with hydraulic control that allows annular access (bleed downs)
- Used in the North Sea when ASV fails
- Specifically designed for high rate/high pressure GL
- Step change improvement in safety for the GL project
- Potential to eliminate need for the PRT Waterspray Sys



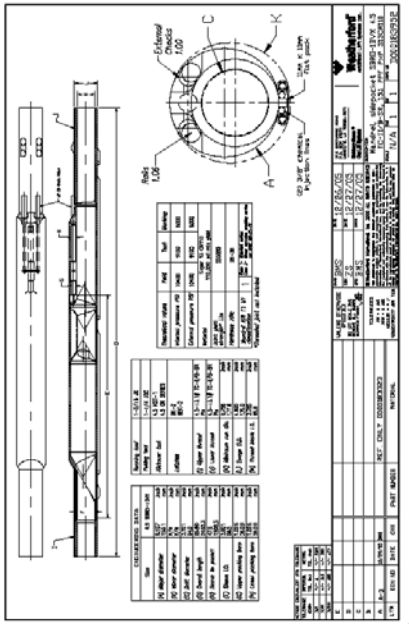
** Shell is working with PTC to modify this for more dropped objects resistance

New Technology Development/Application

External Mounted Check Valve (FAST-TEC™)

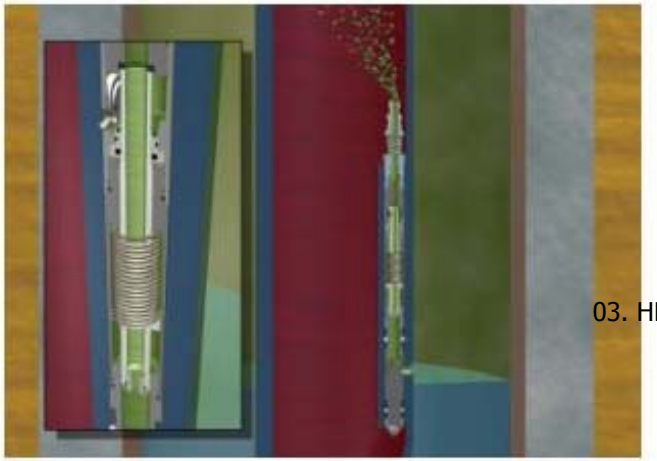
5

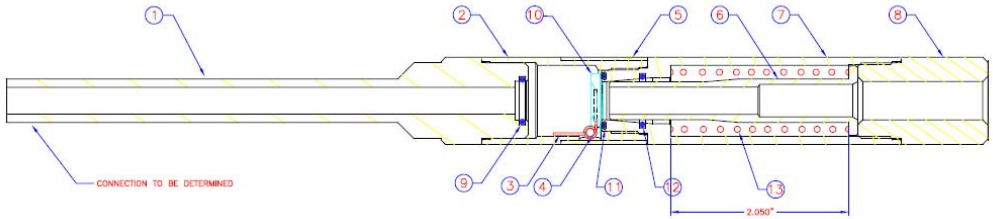
← High Reliability Checks/Mandrel →



High Reliability GL Valve/Orifice

In Progress (see chart)





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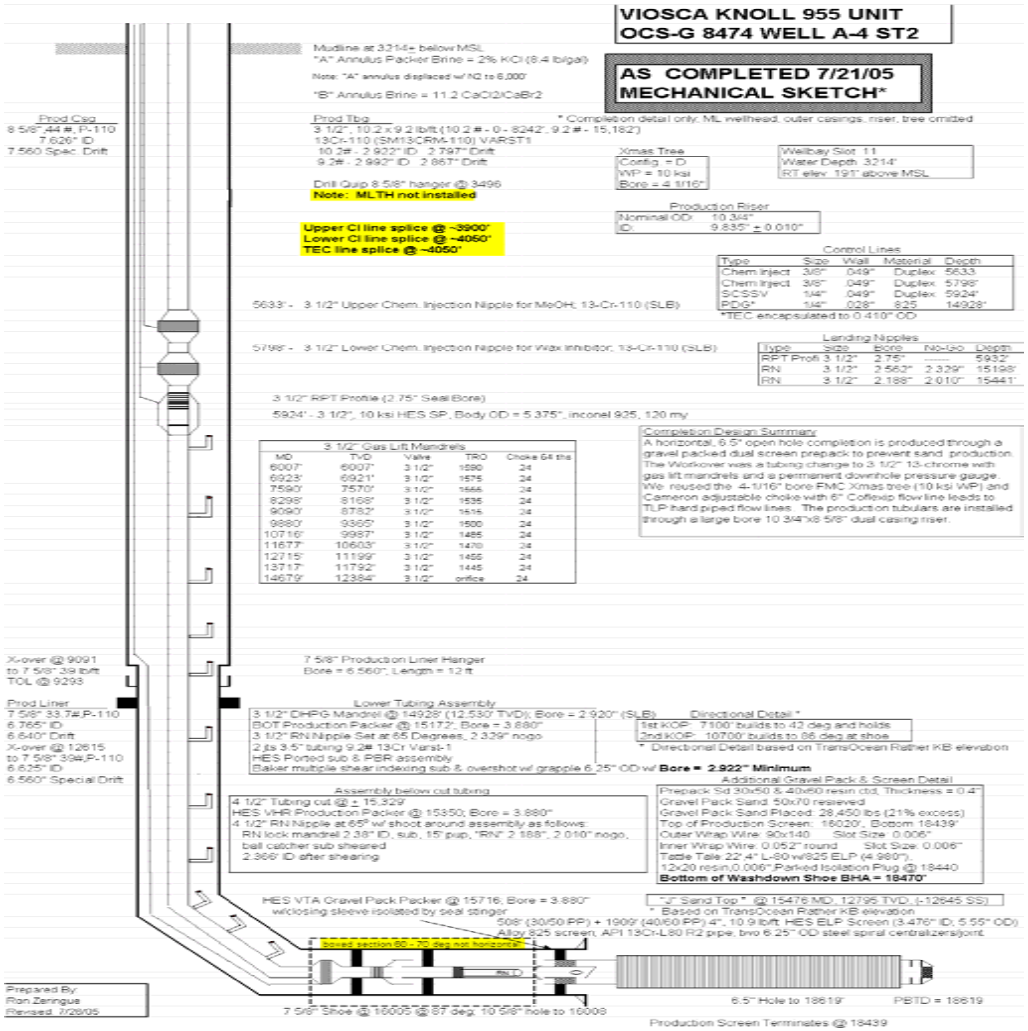
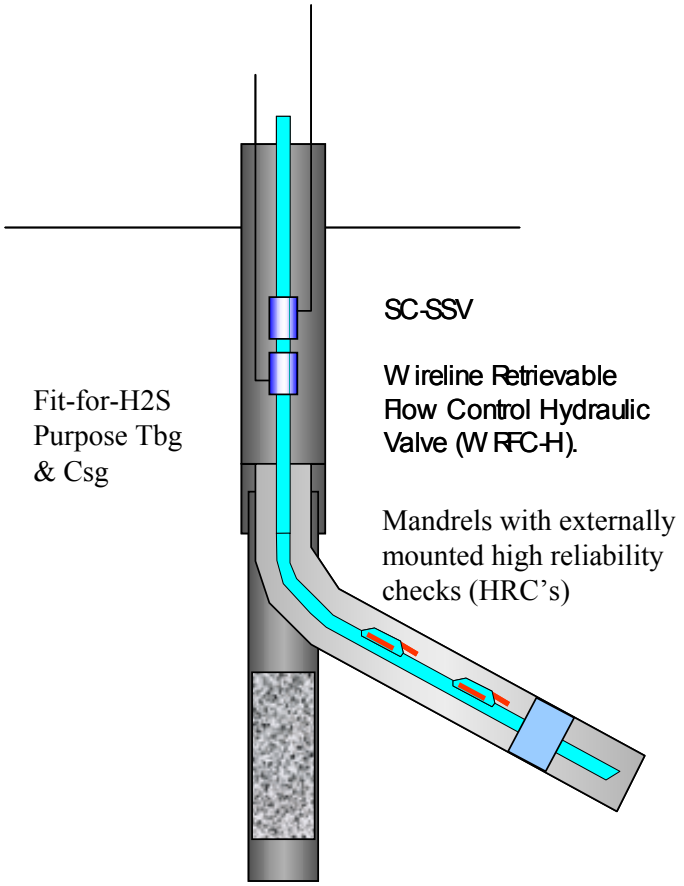
Example Well Designs

- Sweet Well



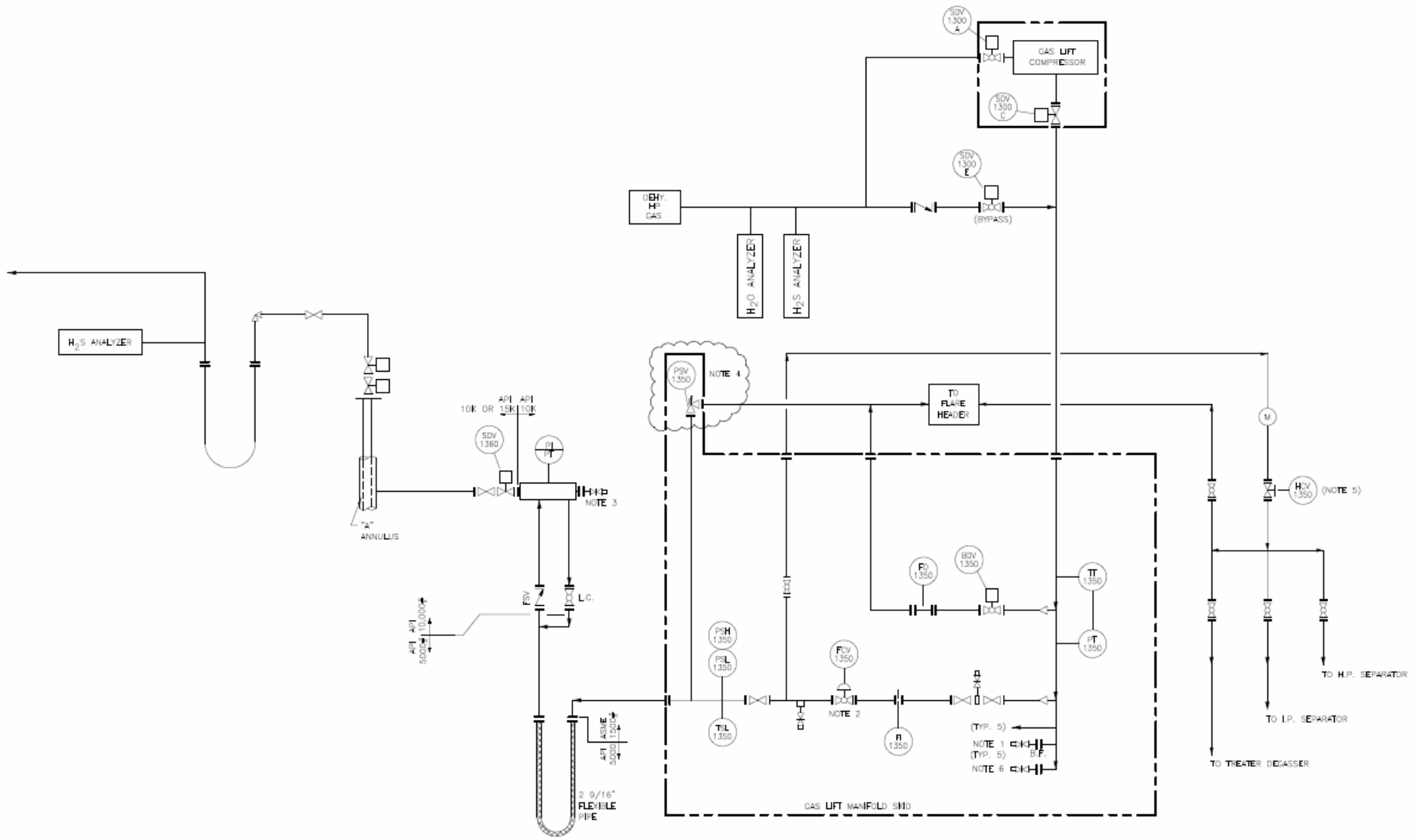
- Sour Potential Well



Facility Design Considerations
TLP Gas Lift

- **Topside Gas Lift System**
  - Booster Compressor may be needed if GL sys pressures required are over sales gas psi
  - Metering and realtime monitoring/trending of injection rates/pressures
  - FCV maintains injection rate at setting even with injection system gas psi fluctuations
  - Flexible hose for injection umbilical (be careful of temp effects here)
  - ESD Blowdown to Tree (depressures umbilical)
  - Allow Manual rapid bleed down of casing
    - Bypass around check valve available
    - Method to recapture gas (route into system vs. flare)
- **Injection Gas Quality**
  - Inject Dry Non-Corrosive Gas!!!
  - Monitor & maintain injection gas quality per agreed functional specs
    - Moisture analyzers
    - H2S analyzers (on injection gas and production stream of any potential H2S wells)
    - Inspection & Maintenance Routines
- **Wellhead Interface**
  - SDV at the Casing Valve (More reliable vs. Check only)
  - Installation of extra valves on wellhead creates moment stresses
  - Install support system for extra wellhead assembly
  - Provide extra dropped object protection over the casing valve

Topsides - P&ID Cartoon



Operational Readiness
Making Our First Deepwater GL Happen!!!

- **Assigned Operational Readiness Focal Points Early in Project**
  - One from Shell's Operational Readiness team so learnings could be shared among assets
  - One came in from offshore for site specific support
  - Provided offshore commisioning support
- **Developed Deepwater Gas Lift Operations Training**
  - 2 day offsite course
  - Trained all 4 crews
  - Covered differences in Deepwater Gas Lift, Safety Issues, New Standards & Equipment, and GL Surveillance & Troubleshooting Techniques
- **Operations Manual Developed**
  - System Operating Procedures (Normal Ops, SI, ESD, etc.)
  - Monitoring Injection Gas Quality
  - Functional Specs Set including Alarm Points
  - Maintenance Procedures/Schedules and Backup Procedures
- **Operating Philosophy or "Big Rules" (<2 pages)**
  - Outline critical points and expected response concisely

Thanks!!!!

- Any questions?