



# Objectives on Well Integrity Management

- Create value by extending the economic life of the well and optimizing the hydrocarbon produced, through **fit for purpose well construction and repair**
- Engineer **sealant properties** for the wellbore, reservoir and loading conditions
- Design **suitable sealant** from services' portfolio
- Deliver the sealant – **simulation analysis** via Opticem®
- Monitor, Control and Document the well performance, in **RealTime**
- § **Dual possibilities at end of normal well-life production**
  - § Geothermal resources
  - § Heat exchange for lifting assist via electricity generation

# Reservoir Description and Characterization

First understand the potential

- Geological data
- Petrophysical data
- Well completion data
- Production/injection

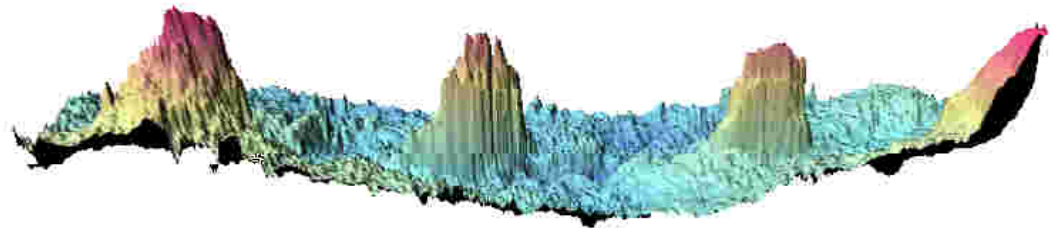
# Data Collection

- Existing Data
  - Geological Description and Reservoir Understanding
  - Production and Injection History
  - Completion History and Well Construction
  - Production Equipment and Facilities
- Additional Data for Better Understanding
  - Production Tests
  - Tracers
  - Cased Hole Logging
  - Injection Analysis
  - Down Hole Video
  - **Research and Developments**



# Data - Geological Description

- Depositional Environment
- Reservoir Geometry
- Fluid Saturation Distributions & Contacts
- Faults and Barriers
- Stratigraphic Boundaries
- Sedimentary (Laminates, Cross Bedding)
- Microscopic (Clays, Texture, Pore Geometry)
- **Temperature Resources - Data**





# Flooded Field with Fracture Communication



# Abandonment Costs Equal Salvage Costs

- **Concept may no longer be true**
  - 20,000 ft well plugging cost \$75,000 – \$ 250,000 ???

## Prepare now for Abandonment

- **Identify tasks required to meet regulatory and lease requirements.**
- **Conduct lease remediation and clean up activities as part of routine lease operations.**
- **Document your activities and lease conditions.**



# **Factors to Consider when Determining Abandonment Costs**

- **Regulatory Requirements**
- **Lease Requirements**
- **Operational History**
- **Surrounding Environment**

## **Other Considerations**

- **Advancements in technology**
- **Scientific discoveries related to human health and the environment**
- **Changes in public opinion**

## Have good practices

- **Evaluate Abandonment Issues**
- **Incorporate remediation and cleanup activities into routine operations**
- **Minimize waste and impact on the area surrounding the field operations**
- **Document activities and field conditions**

How about selling to another Operator  
seeking usage of your wellbore

# *Remedial Technologies*

*Wellbore Integrity Solutions for extended Well-life*



# Current Casing Parameters

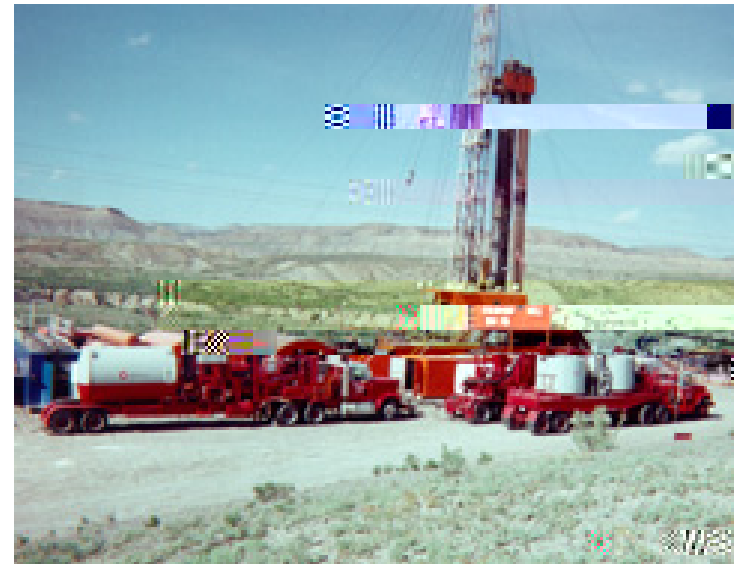
- Was the casing string cemented to surface ?
- Is there cement behind the casing ?
- Where are water influx intervals ?
- Where are fragile intervals with possible associated fractures ?
- What is the extent and length of casing with erosion, pitting, and leaks ?
- What is needed to give an extended well-life with production considerations or sources of new economic benefits



# Addressing Completion Methods

## Past & Present

- Cemented Casing with Perforated Intervals
- Open Hole Completions
- Gravel Pack Completions
- Slotted Liners
- Deviated & Horizontal Wells
  - Cased & Cemented
  - Slotted Liners
  - Open Hole Completions
  - Drilling Orientations
    - Lateral or Transverse

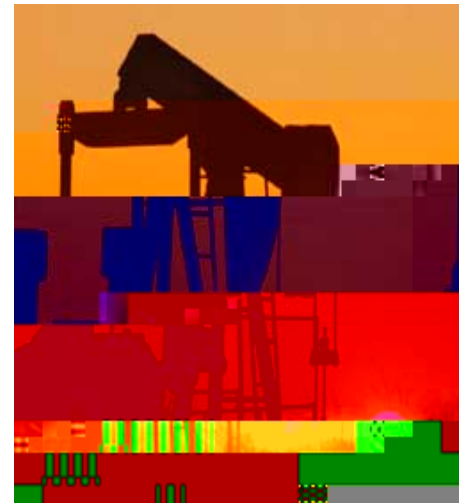




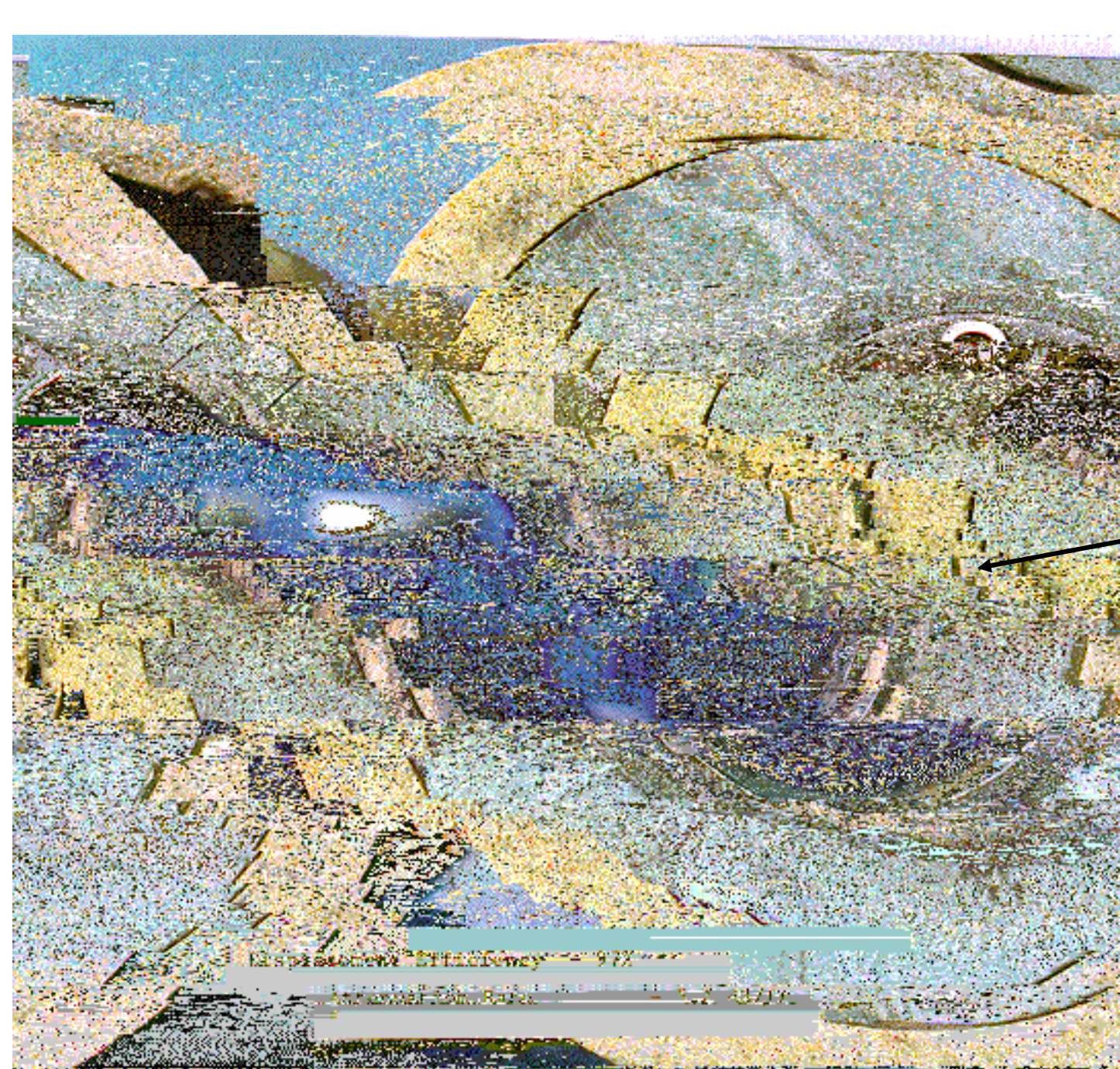
# Lack of Integrity and its Causes

## Production Operations

- **Influxes** continuing following primary cementing
- Annular pressure differences causing **cross-flows**
- Casing **pressure cycling** during the well's productive life
- Perforating and initial acid breakdowns
  - Cracking cement sheaths
  - Removal of formation barriers
- Stimulation treatments going out of zone
- Injectants **dissolving** and **eroding** rocks





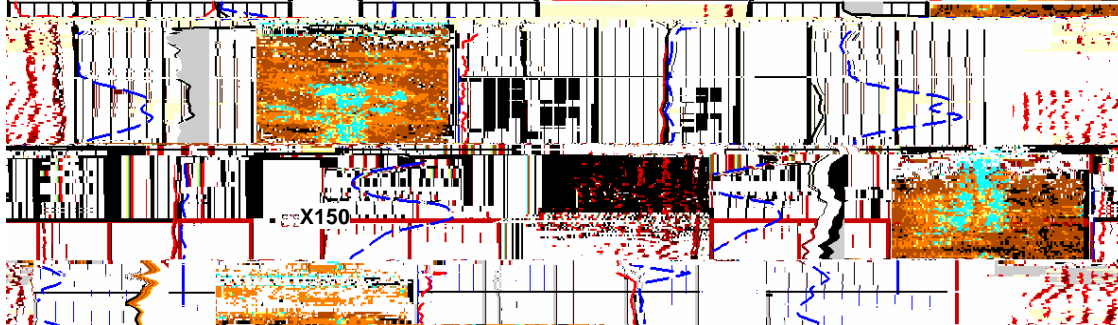
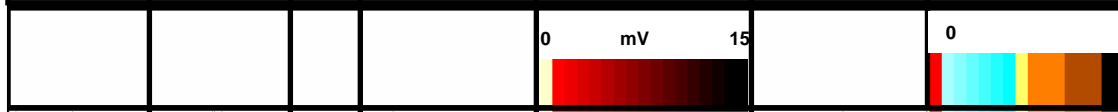


**Cracked  
Cement  
Sheath**



Displacement Efficiency = 97%  
Average Com. Ratio = 1.2 48/19

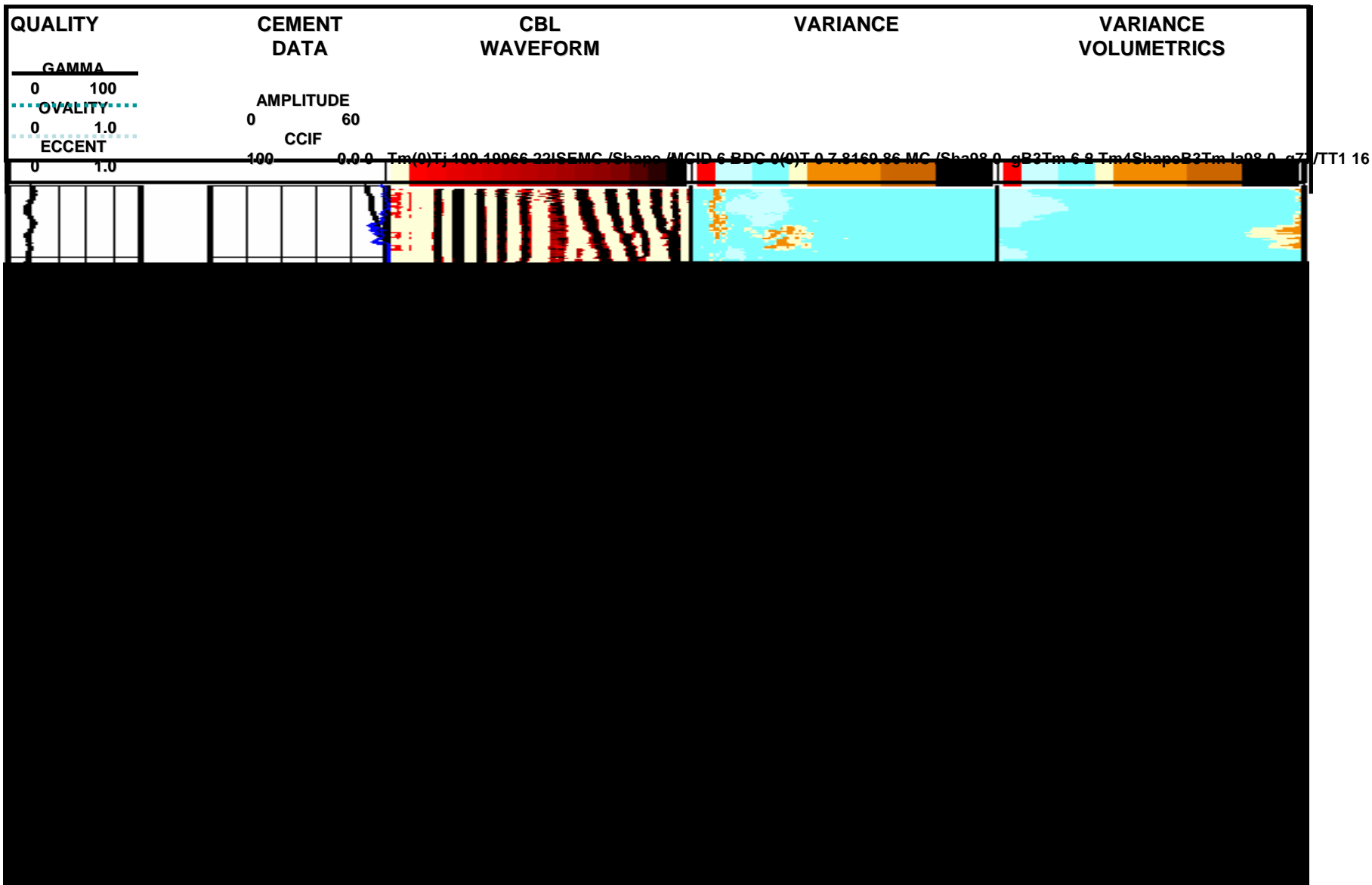
RELATIVE BEARING	THICKNESS CURVES	AMPLIFIED AMPLITUDE	MICROSEISMOGRAM	CBL BOND INDEX	IMPEDANCE MAP
0 DEG. 360	0.2 IN. 0.4	0 10	200 1200	1 0	
ECCENTRICITY	AVERAGE	AMPLITUDE		AVERAGE IMPEDANCE	
0 1.0	MINIMUM	0 100		10 0	
DEVIATION	MAXIMUM				
0 5.0					



X200

X250

# Example of Cement Evaluation Logs



# Foamed Cement Analysis in Bonded Pipe

AMPLIFIED  
AMPLITUDE

GAMMA

0 150

AVZ

10 0

DZAVG

1 0

# Analysis of Results on Casing Integrity

- Bond Log
- Measure Displacement Efficiency

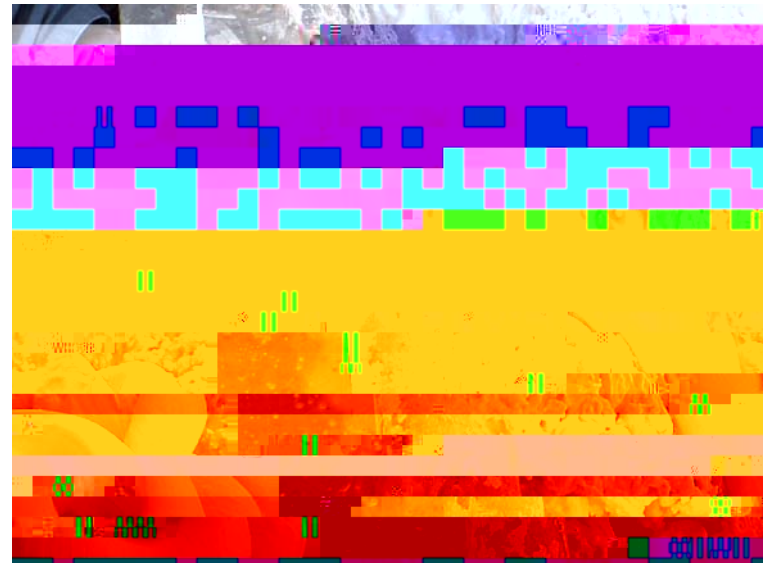


**Cement**

**Mud Filter Cake**

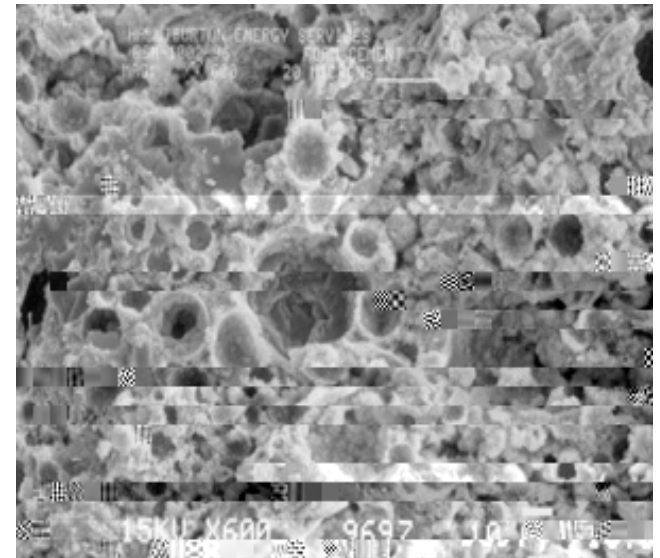
# What is ZoneSeal Cement?

- A mixture of cement slurry, foaming agents, and gas (usually nitrogen)
- It visually resembles gray shaving cream
- It is a low-density cement matrix with low permeability and relatively high strength



# Advantages of Foamed [Energized] Systems In Set Cement

- Key to preventing annular pressure
- Compressible system with elastic properties
  - Bubbles allow crystalline bonds to flex without breaking
  - Greater resistance to stress cracking
  - Bond remains intact
  - Eliminates micro-annulus



# Foamed Cement Attributes and Benefits

- **Elastomeric Cement Systems**
  - Improves Bond Characteristics
  - Resilient/Withstands Pressure Cycling
  - Helps Maintain Zonal Isolation
- **Help Prevent Gas & Water Migration**
  - Withstands influxes during transition state
  - Compressibility
    - Is **compressible or expandable** in nature
  - Energized and Stable
  - Uniform **true solution** (maintains system integrity)
- **Improved Fluid Displacement**
  - Primary and Remedial Cementing
  - Repair Casing and Providing Zonal Isolation
- **Simplified Material System**



# Foamed Cement Characteristics and Properties

- **High strength** for **low density** material
- Virtually zero fluid loss & free water
- **High viscosity**
  - enabling thorough filling of channels, vugs, and voids
- Excellent **displacement properties**
- Properly produced foams are:
  - **stable** and have **desired texture**
- Greater **resistance to stress cracking** caused by cyclic activity
- May be developed to serve as an **excellent production and perforating cement**
- Foam matrix provides space for crystalline growth associated with temperature retrogression

# Casing Cementing Parameters

## “Making a Decision”

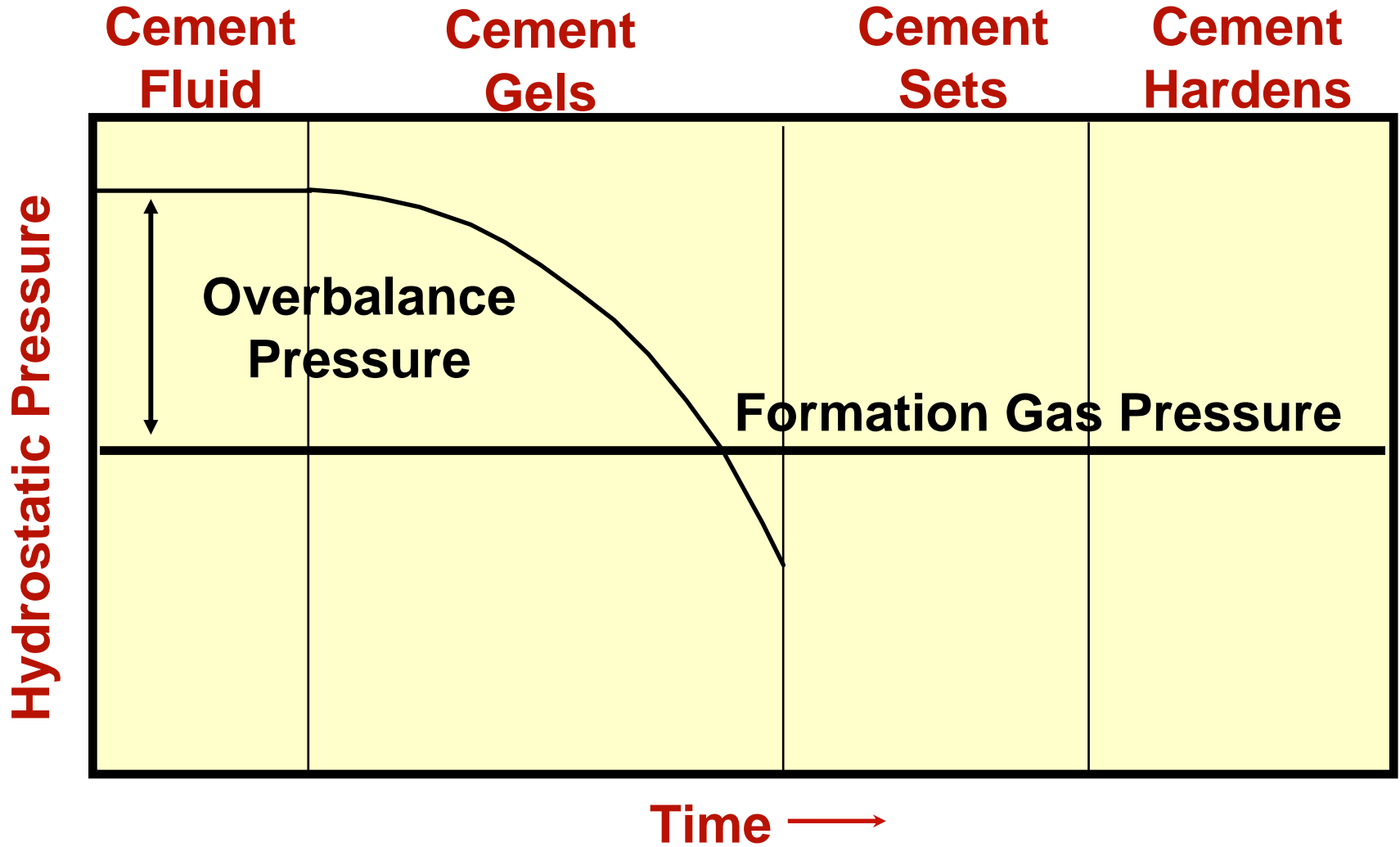
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- Is it easier to fix an invasion or loss circulation problem by changing directions annular placement is conducted ?
  - Where are gas influx intervals ?
  - Where are water influx intervals ?
  - Where are fragile intervals with possible associated fractures ?
- What is the extent and length of problem zones ?
- What is the easiest way to achieve zonal isolation ?
- What attributes are needed to achieve a successful remedy ?

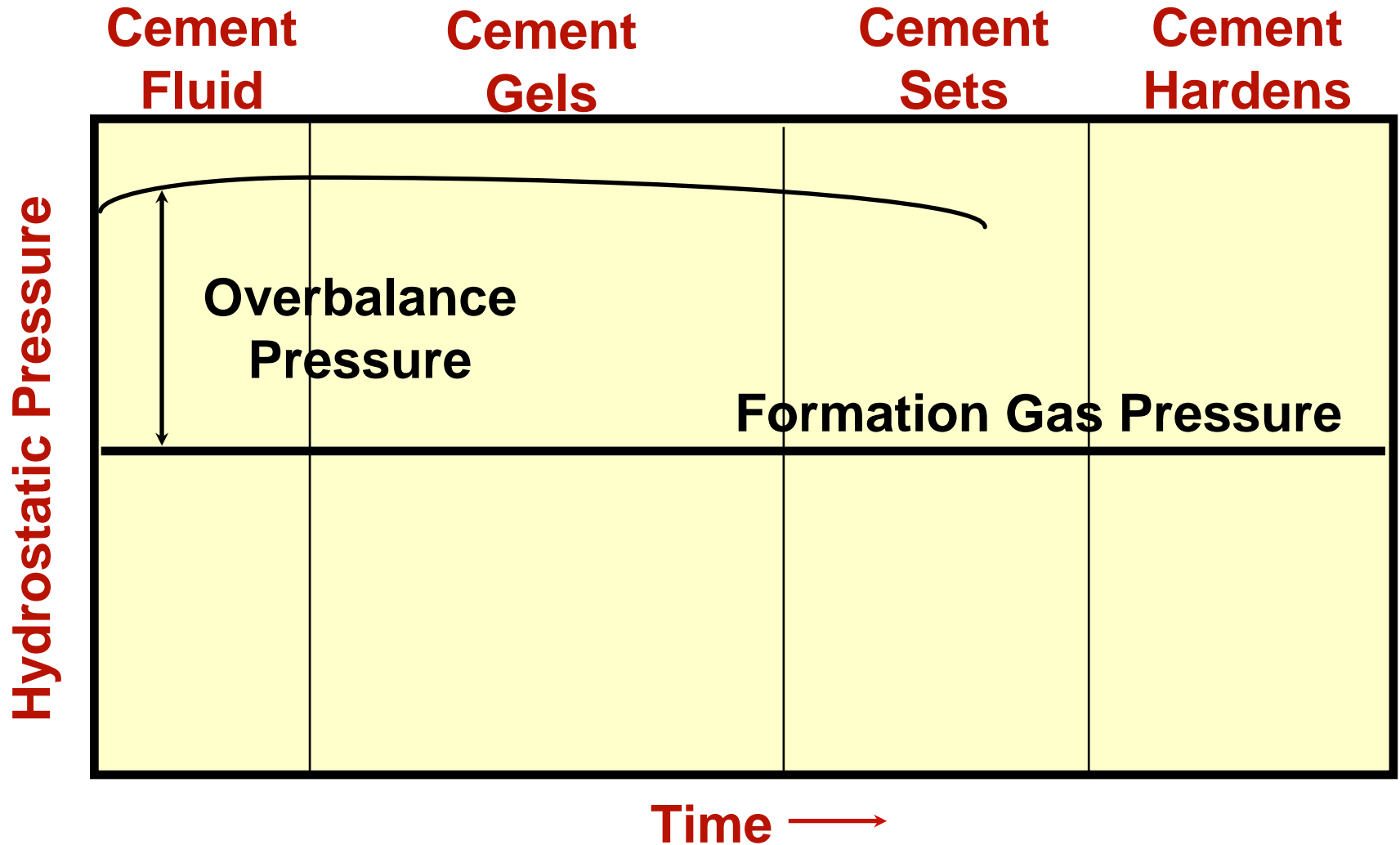
Best Practices: Find and utilize the focal points in applications and placement methods



# Hydrostatic Pressure Loss



# Energized Cement



# Large Scale Stress Testing

## *Conventional Cement*

- 5 1/2" pipe cemented inside 7 5/8" casing
- Inner pipe pres

# Large Scale Stress Testing

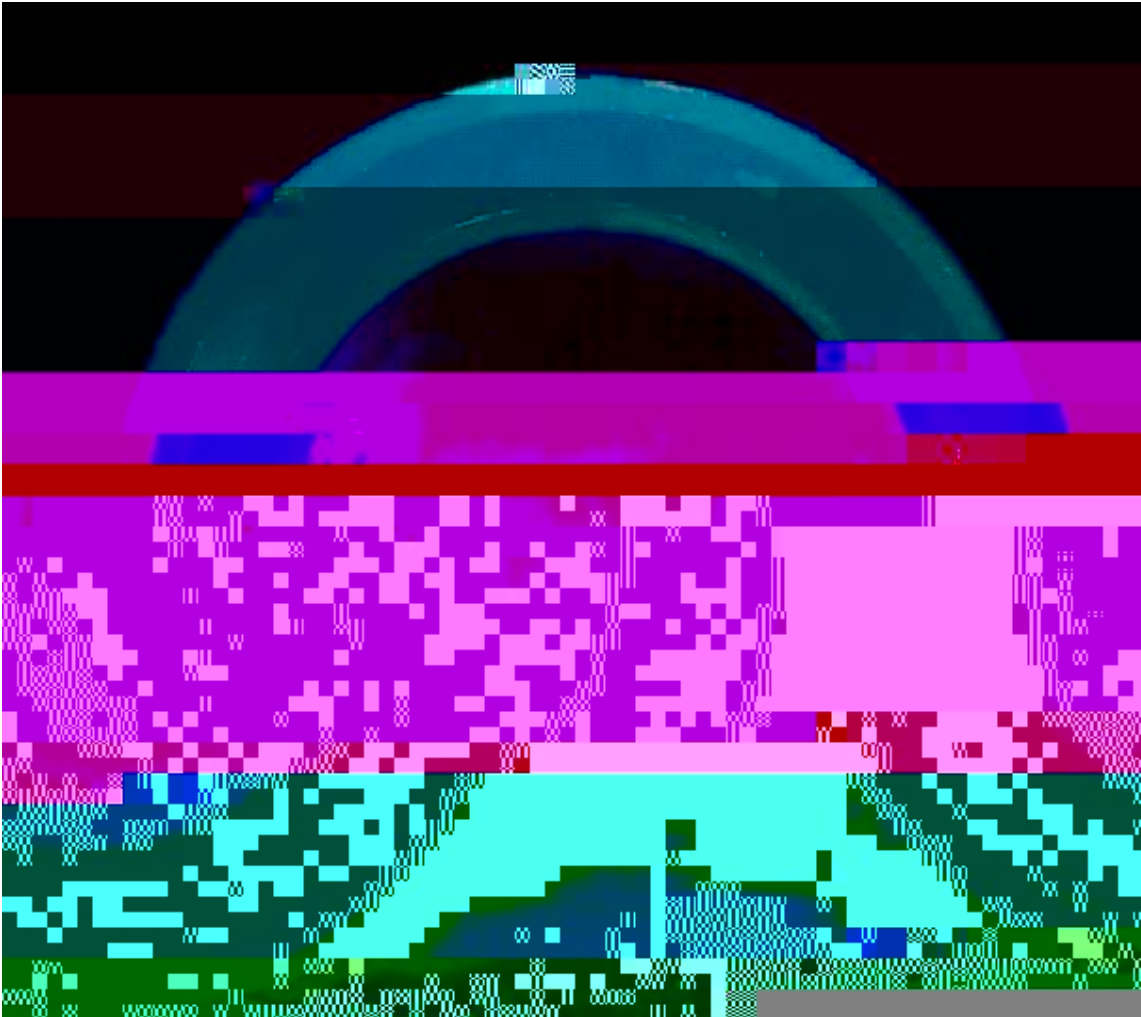
## *Conventional Cement*



- Cement became brittle
- Radial cracks formed
- Longitudinal communication occurred
- Cement bond failed creating a microannulus

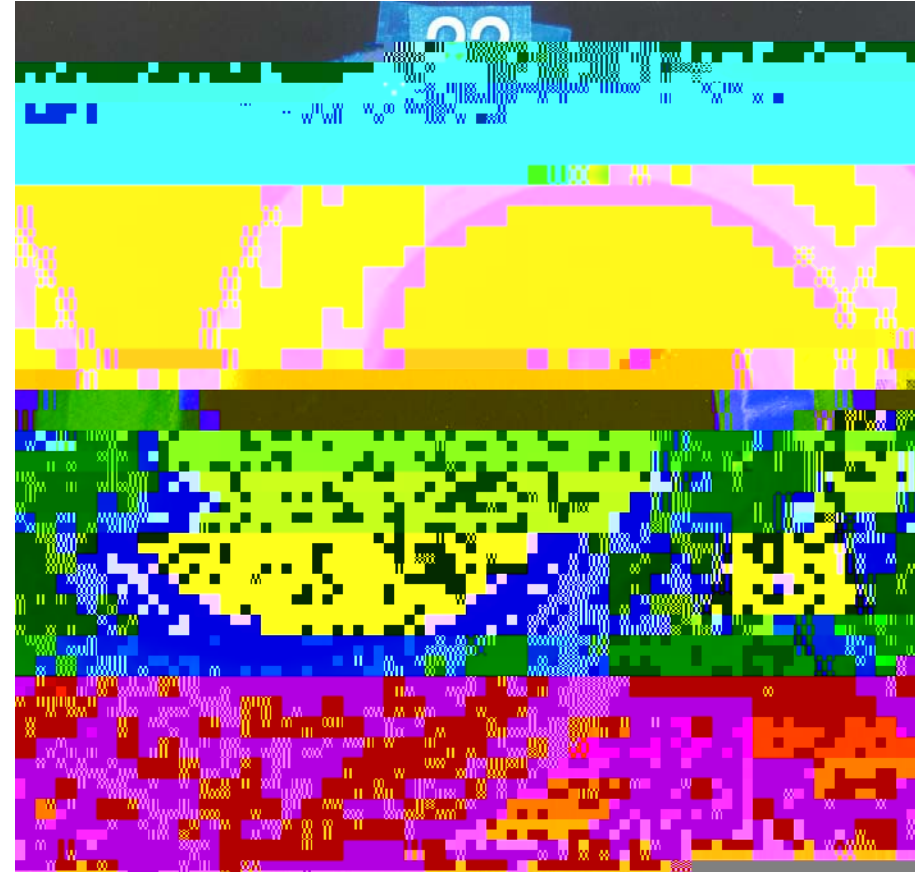
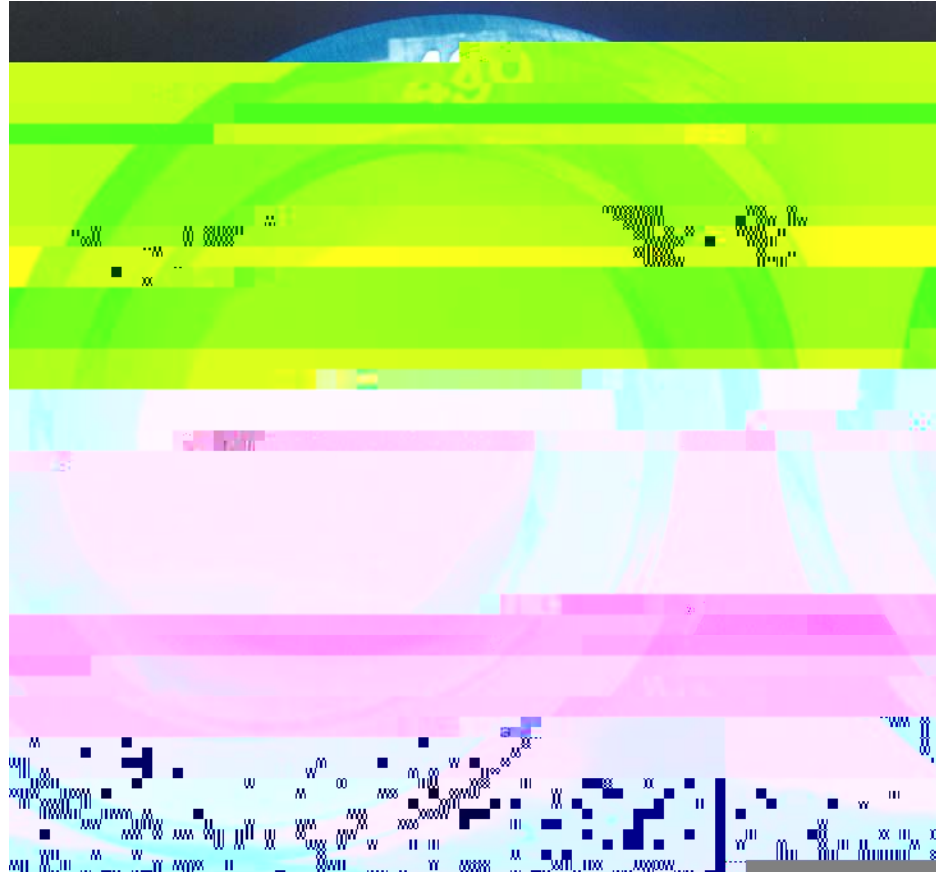
# Large Scale Stress Testing *Foamed Cement*

- No radial cracks
- Only slight debonding
- Foamed cement deformed and absorbed the expansive energy without failure due to its elastic nature





# ZoneSeal vs Conventional Cement



# Cementing High Temperature and Pressure Wells

- General Issues

- Zonal Isolation
- Support Casing
- Temperature Cycling
- Low Fracture Gradient Formations
- Exposure to Steam
- Variable Hole Sizes
- Long Well Life

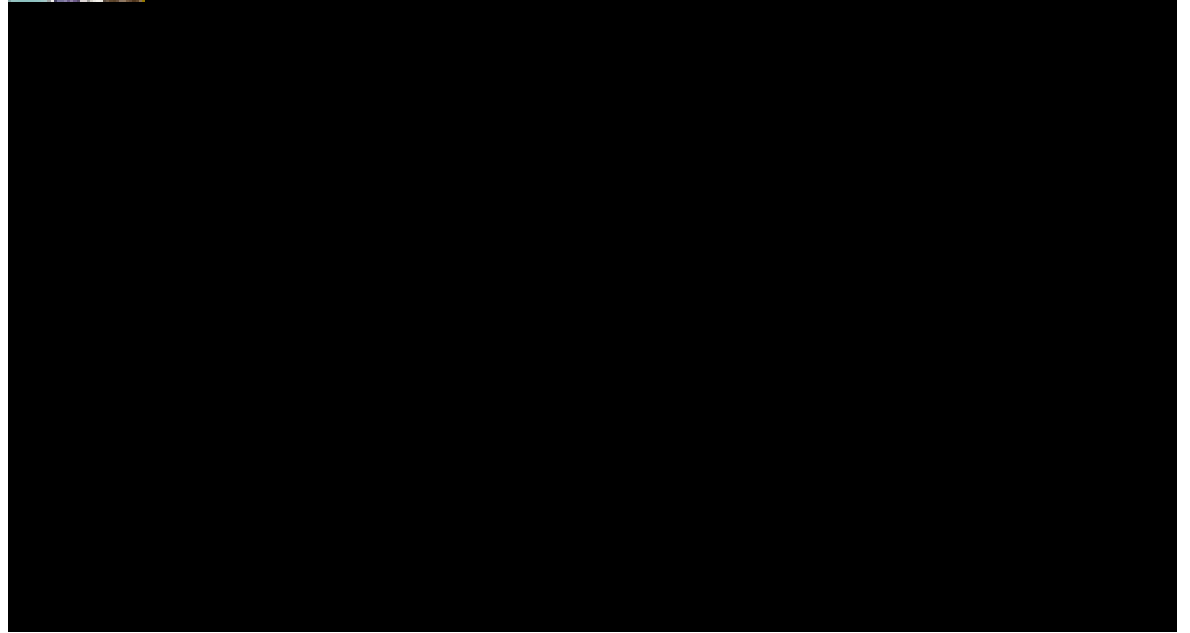
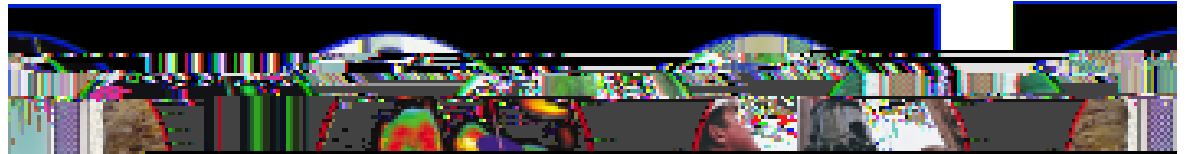
- Specific Issues

- High Steam Pressure
  - > Fracture gradient
  - 550 to 600 deg. F.
- Frequent Cycling
  - 10 to 15 cycles per year
- Long Pay Interval
  - ~1/3 of total well depth
  - Maintain zonal isolation for 2 or 3 intervals
    - 5 to 10 years each



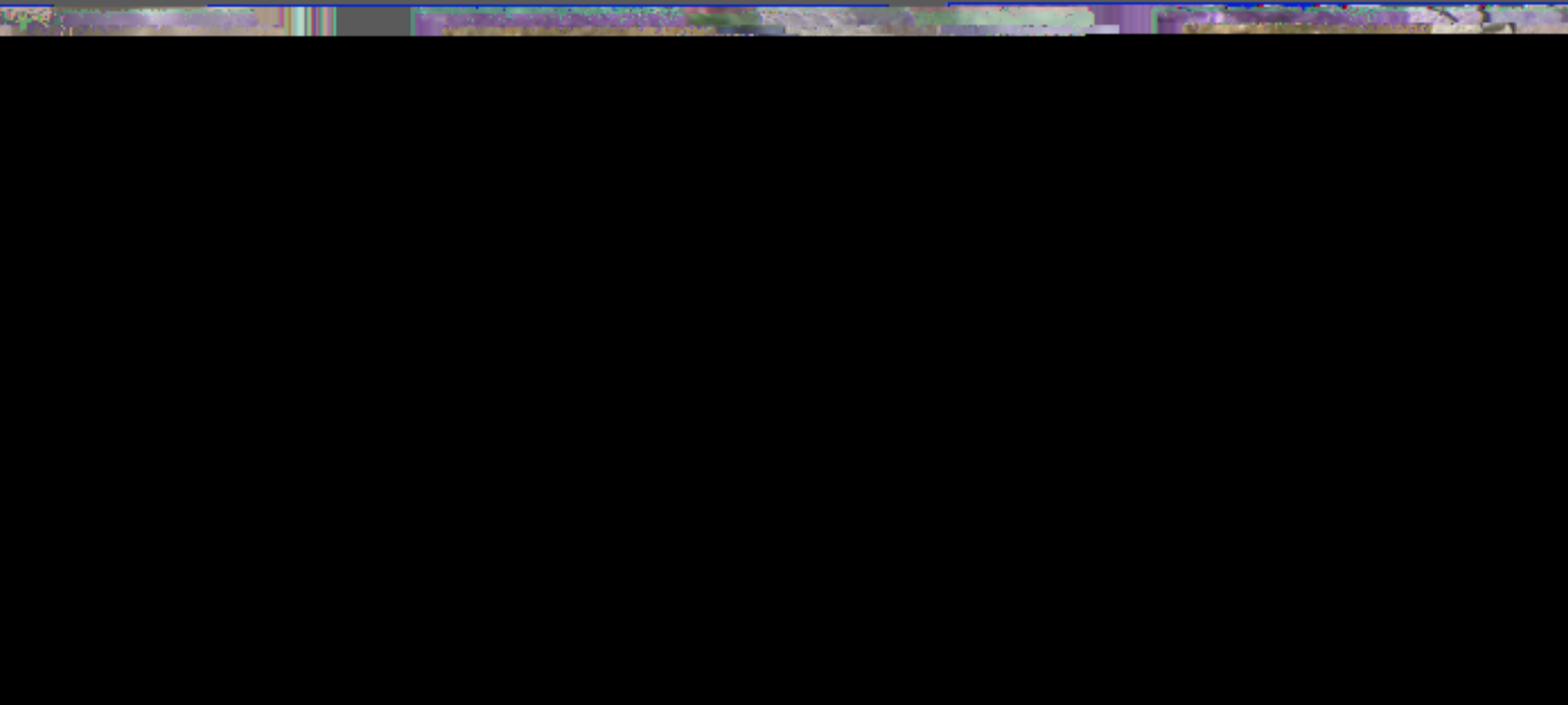
Wall Street

Wall Street



## Modes of Annular Sealant Failure

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# Modes of Cement Failure

- De-bonding

@ cement-casing interface

De-bonded





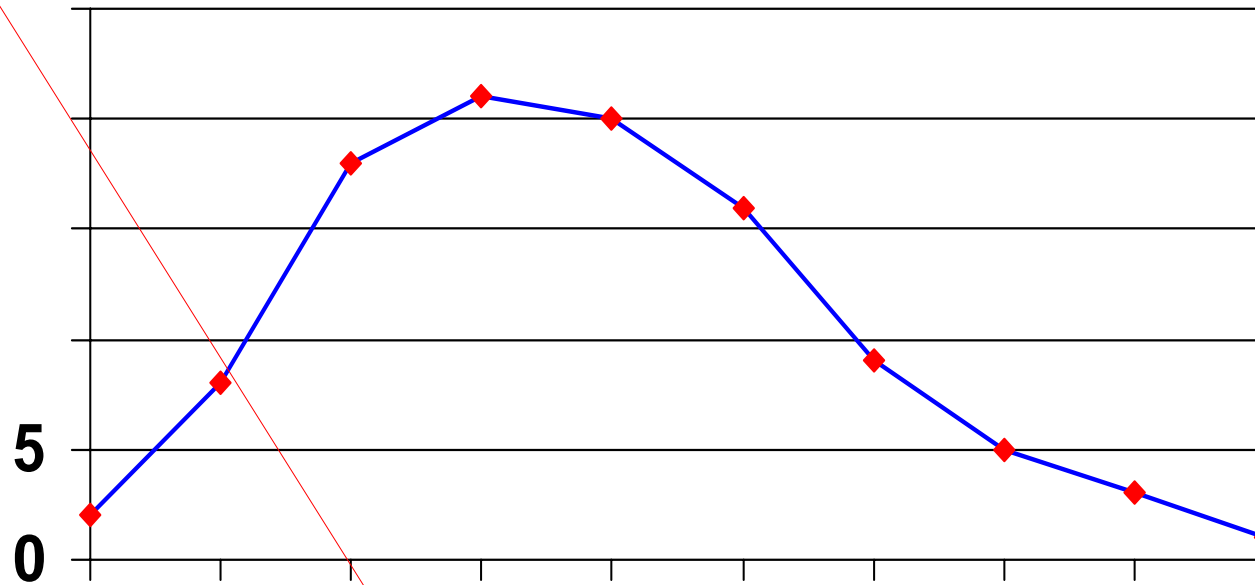




# Strategies for Reducing Oil Field Power Costs

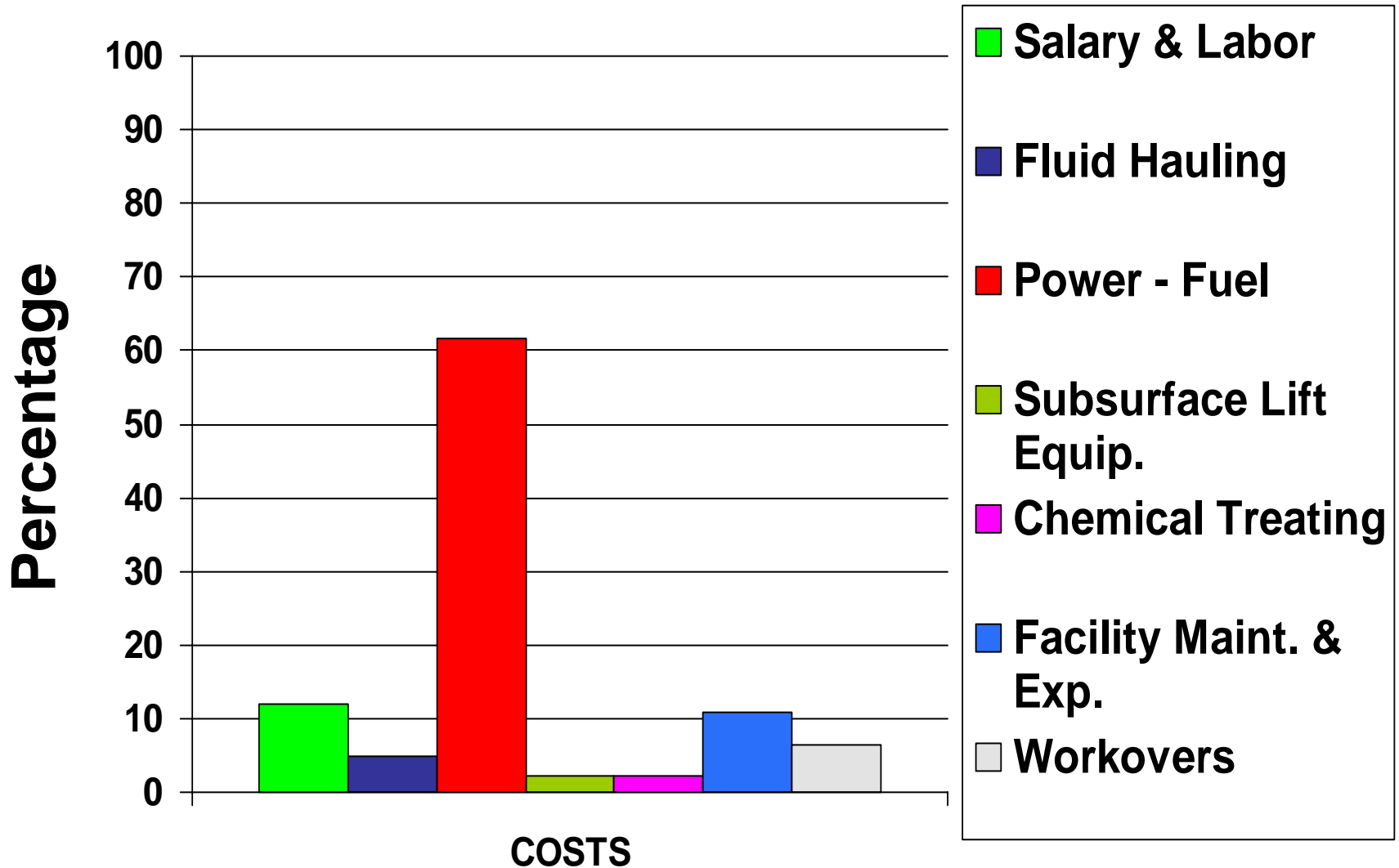
- Electricity is a large percentage of operating costs in the production of oil and gas **(up to 40-50% in 2000) (up to 55% in 2005??)**
- Historically power costs have received limited focus
  - Specialized, non-core technical skills
  - Conventional suppliers are regulated monopolies
- Several studies have recommended methods to reduce power costs
  - Optimize mechanical systems
  - Optimize electrical systems
  - Optimize usage against a regulated rate structure
- **What will happen in future developments ?**

# Average Lifting Costs in Permian Basin (\$5-6/BOE)



# Operational Expenses

Typical Permian Basin Operation w/ \$4.35 BOE Lifting Cost



## Largest Cost - Monitoring and Control

- The underlying cost of electricity is influenced by when it is consumed
- Loads with excessive peaks increase the cost of electricity
- Historically electricity has been priced independent of time
- With deregulation the end user will begin to see more of the underlying variation in the cost of electricity and either
  - Pay someone a premium to absorb this volatility
  - Manage volatility through load management

# In-field Generation

- Grew out of the Public Utility Regulatory Act of 1978 (PURPA)
  - **Required the utilities to purchase power generated by a “qualified” facility**
  - **Normally associated with co-generation or use of the exhaust heat at site**
  - **Purchase price of electricity in excess of load was most often not sufficient**
- Projects involve producing electricity with in-field generators
  - **Usually natural gas driven**
  - **Gas Engines or gas turbines**
  - **200 Kw to 10 Megawatt in size**
- Cost to generate is a function of gas price, capital cost and O&M

In cents/Kw-hr	<u>Cost of Conversion</u>	<u>Fuel Cost</u>	<u>Total Cost</u>
Flared Gas	2.5	0	2.5
\$2.00/mmBtu	2.5	2.2	4.7
\$4.00/mmBtu	2.5	4.4	6.9
\$5.00/mmBtu	2.5	5.5	8.0

# In-field Generation – Past Considerations

- If operator can generate power for less than purchasing from the grid then in-field generation can make sense
- With deregulation more options exist for selling power generated in excess of the load
- Monetizing stranded or distressed gas
  - Gas that has reduced value because of some kind of physical constraint that cannot be economically solved using conventional methods
    - **Too far away or expensive to hook up to a pipeline**
    - **Low volume or low deliverability wells**
    - **High impurities or low pressure**
  - A solution would be to burn the gas in a generator located at the source and consume or sell onto the grid
- In-field generation may make sense if the operator has low value gas, high field electricity rates, or thermal heat requirements

# Water and Gas

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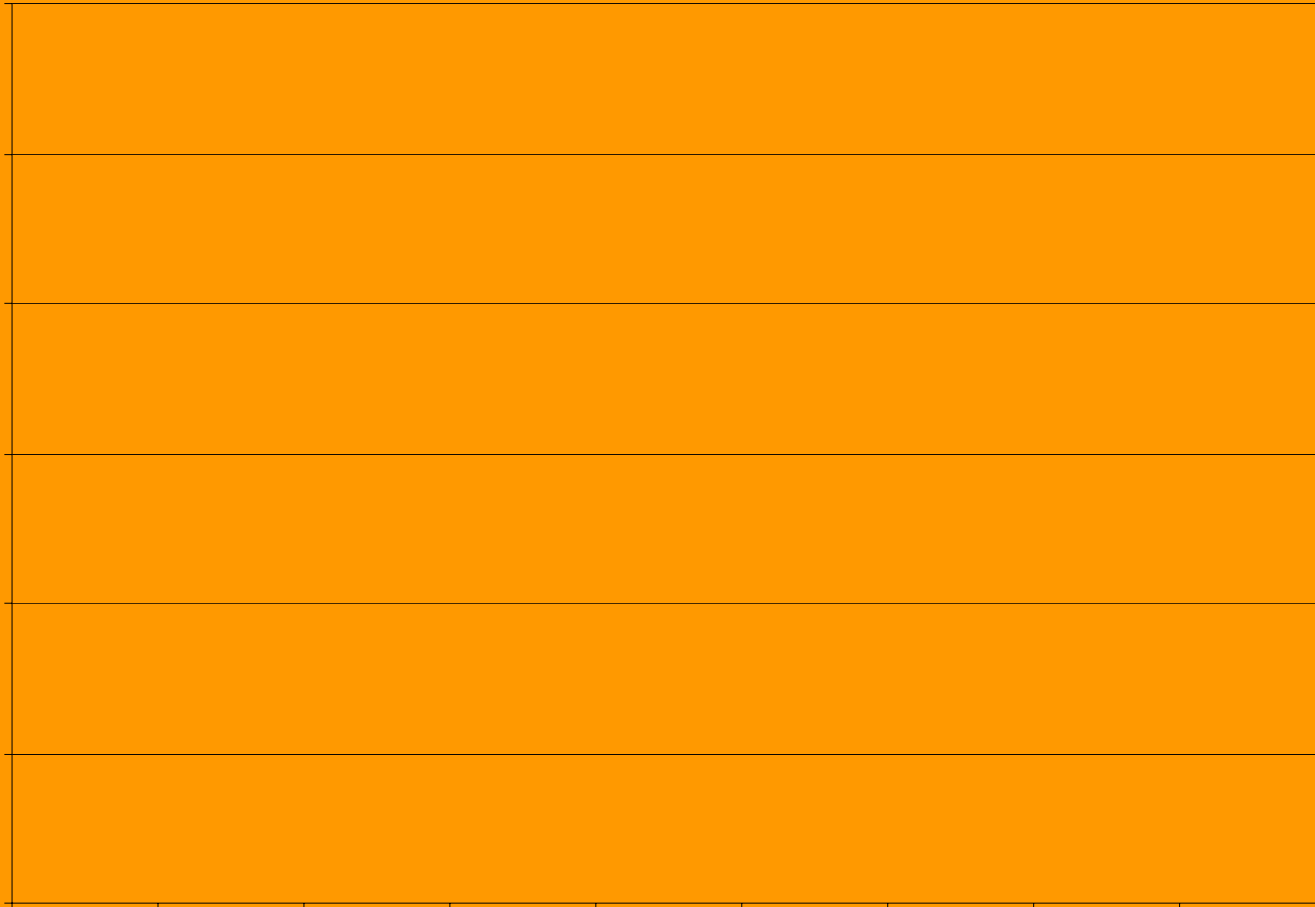
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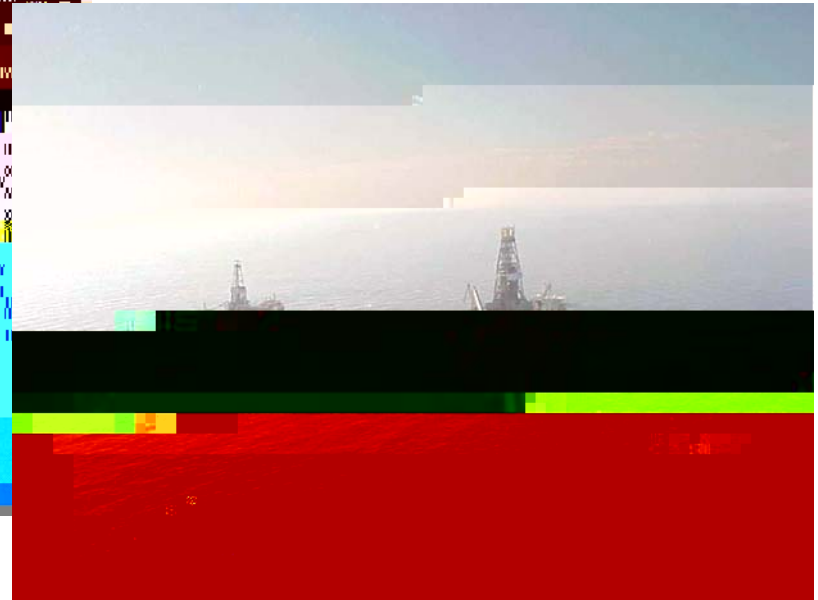
# Water & Gas – Hydrostatic Head Relationship







# Technology Barriers



# Reservoir Life Cycle

