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

Á Dual possibilities at end of normal well-life production

- Á Geothermal resources
- Á 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
- R

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

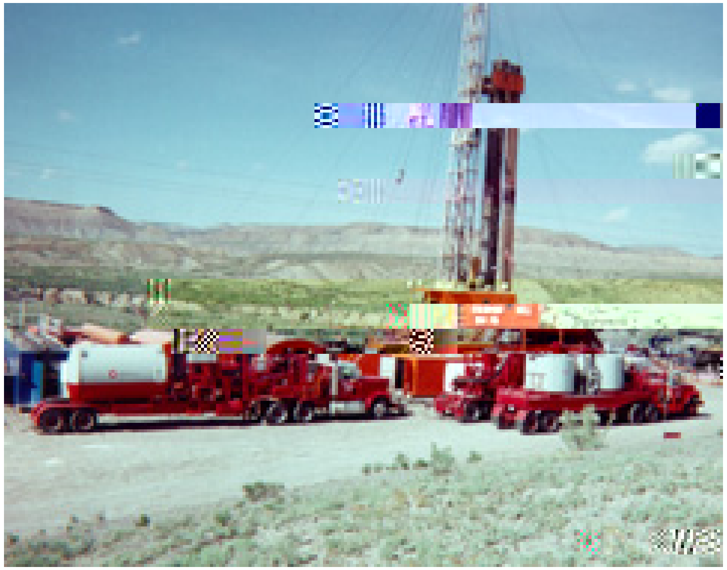
Wellbore Integrity Solutions for extended Well-life

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

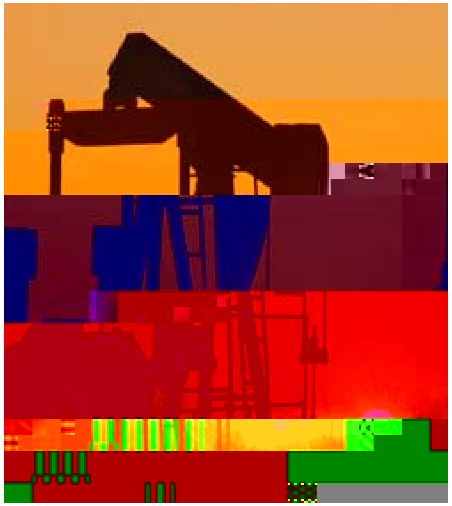
Addressing Completion Methods
Past & Present

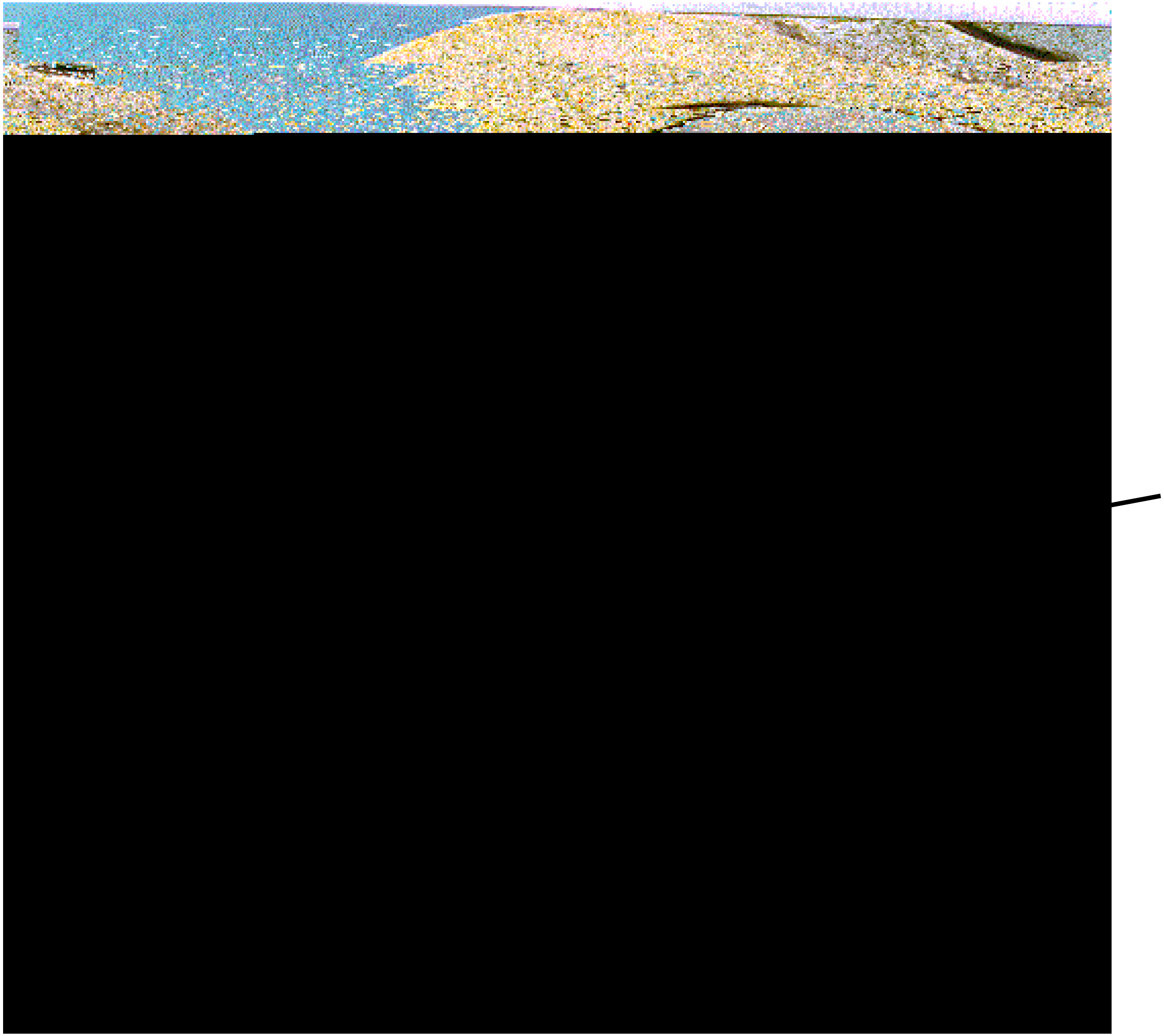
- Cemented Casing with Perforated Intervals
- Open Hole Completions
- Gravel Pack Completions
- Slotted Liners
- Deviated & Horizontal Wells
  - Cased & Cemented
  - Slotted Liners
  - Open Hole Completions
  - Drilling Orientations
    - Lateral or Transverse

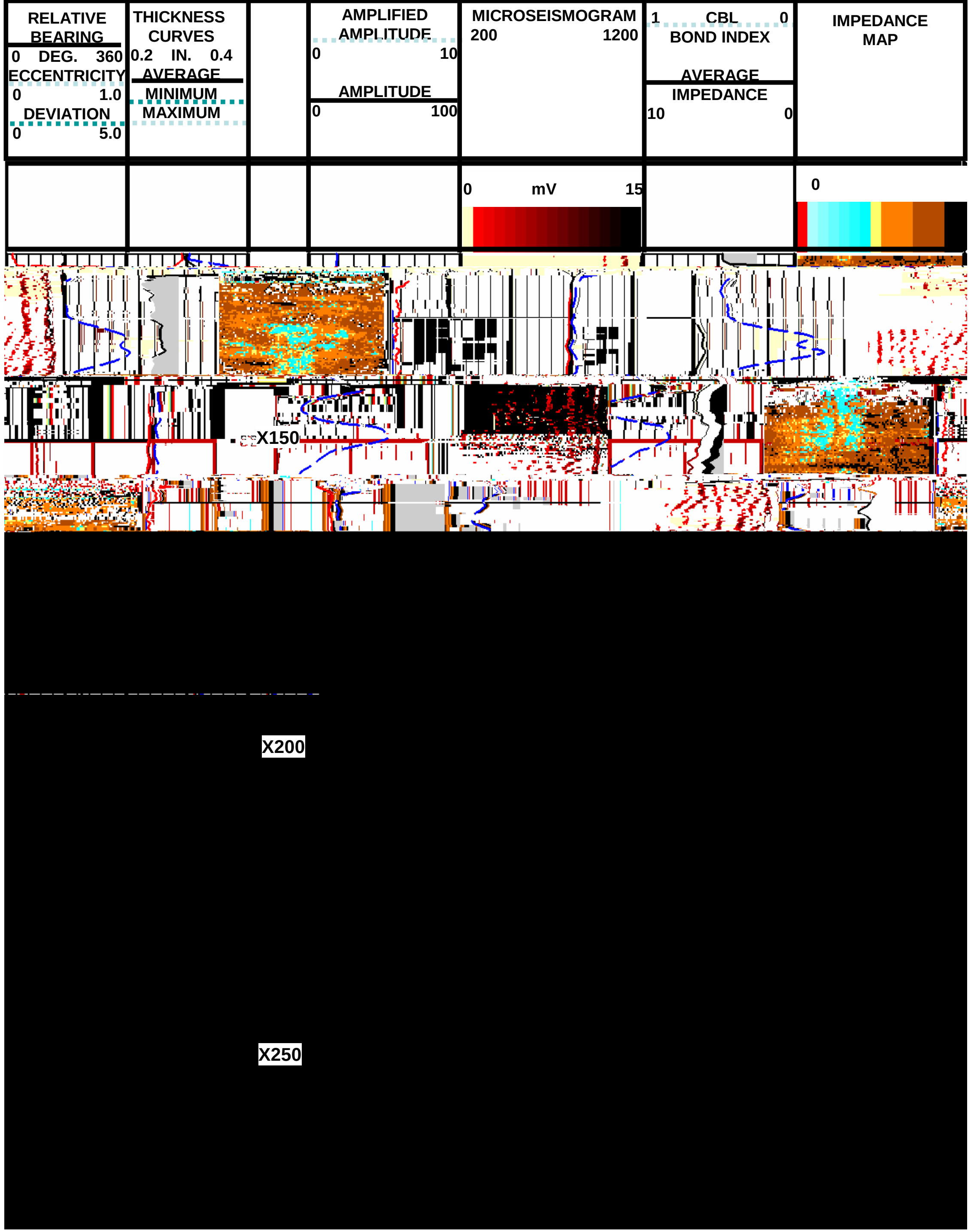


Lack of Integrity and its Causes
Production Operations

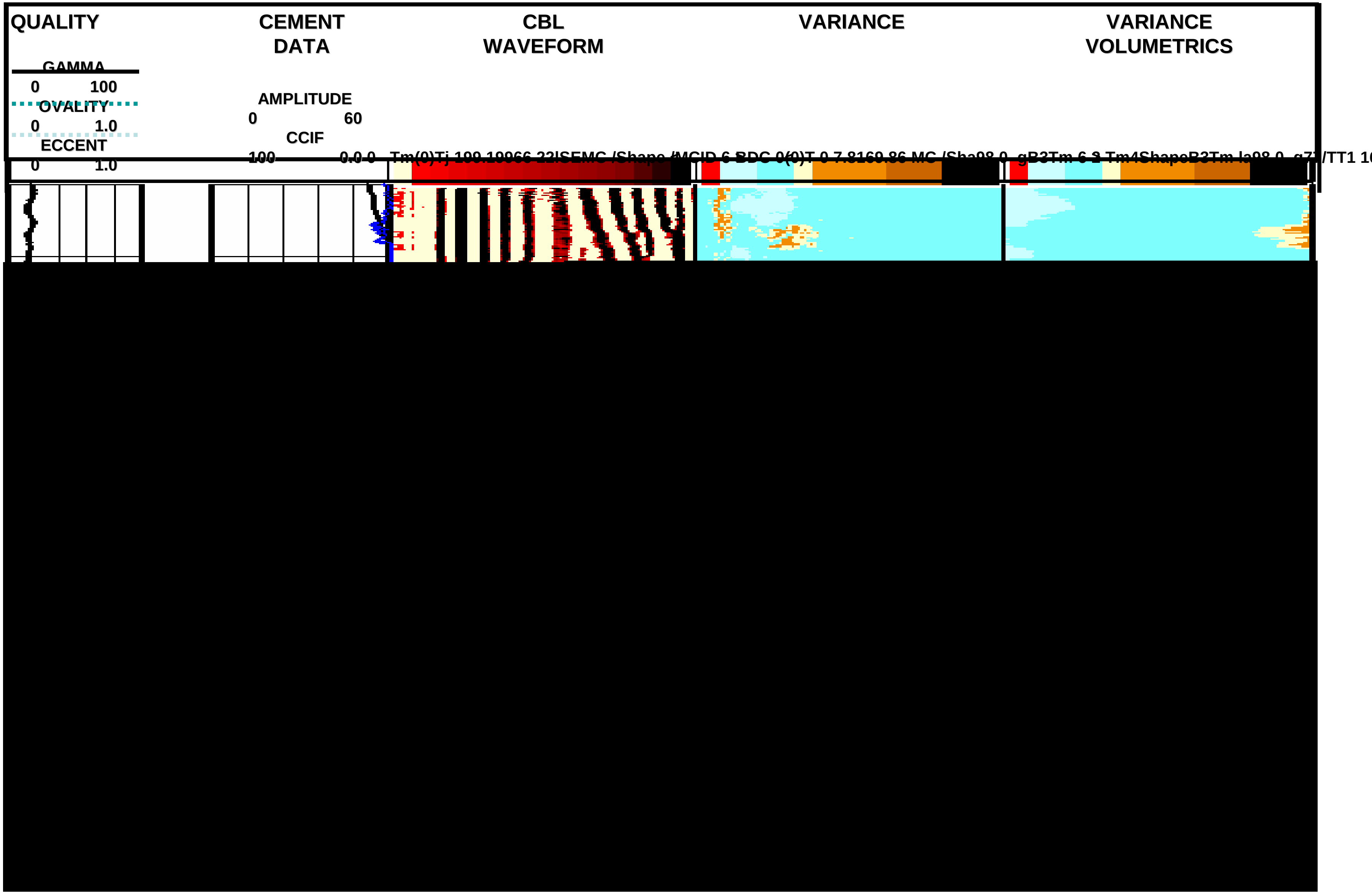
- Influxes continuing following primary cementing
- Annular pressure differences causing cross-flows
- Casing pressure cycling during the well's productive life
- Perforating and initial acid breakdowns
  - Cracking cement sheaths
  - Removal of formation barriers
- Stimulation treatments going out of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




Cracked
Cement
Sheath


RELATIVE BEARING
0 DEG. 360
ECCENTRICITY
0 1.0
DEVIATION
0 5.0
THICKNESS CURVES
0.2 IN. 0.4
AVERAGE
MINIMUM
MAXIMUM
AMPLIFIED AMPLITUDE
0 10
AMPLITUDE
0 100
MICROSEISMOGRAM
200 1200
0 mV 15
1 CBL 0
BOND INDEX
AVERAGE
IMPEDANCE
10 0
IMPEDANCE MAP
0
X150
X200
X250

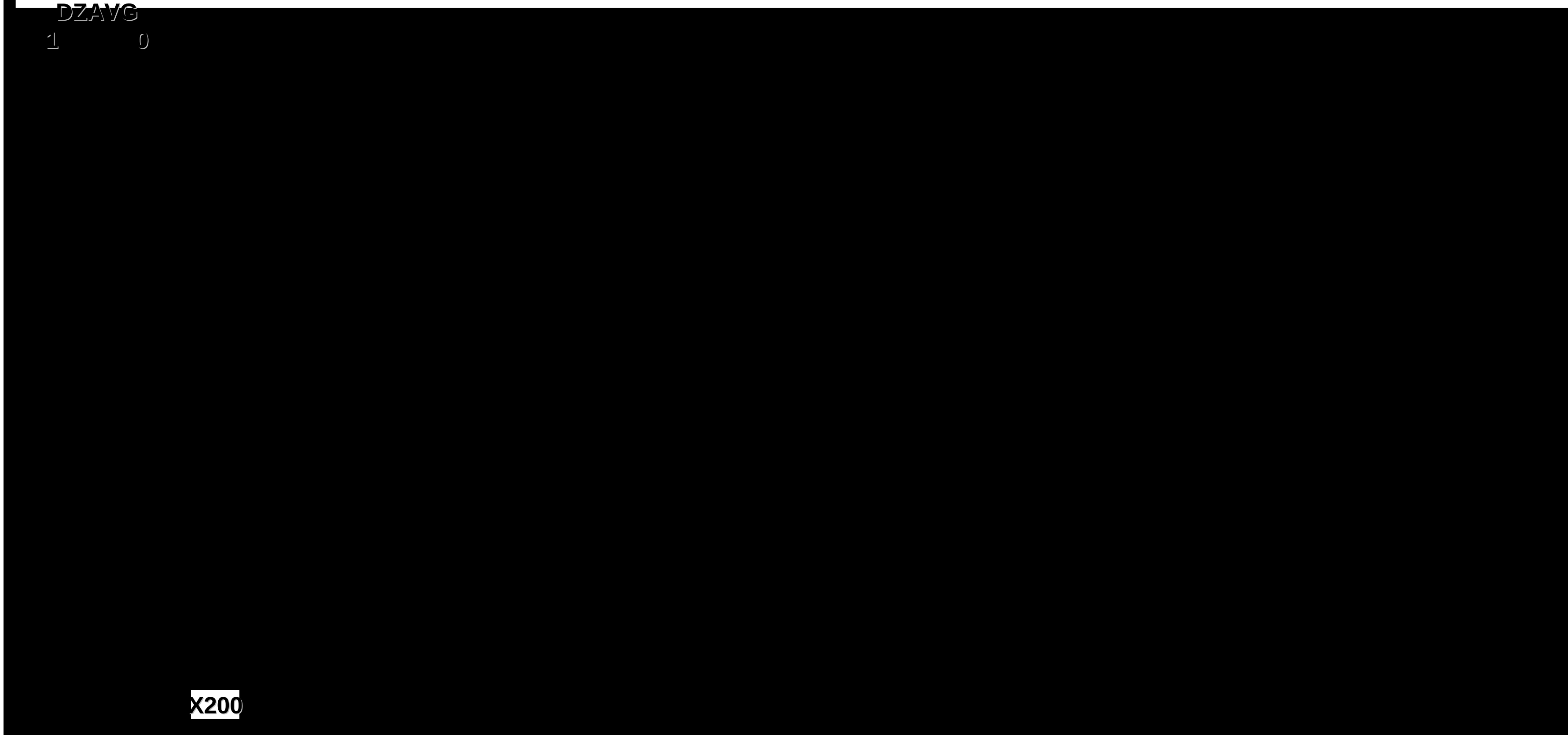
Example of Cement Evaluation Logs



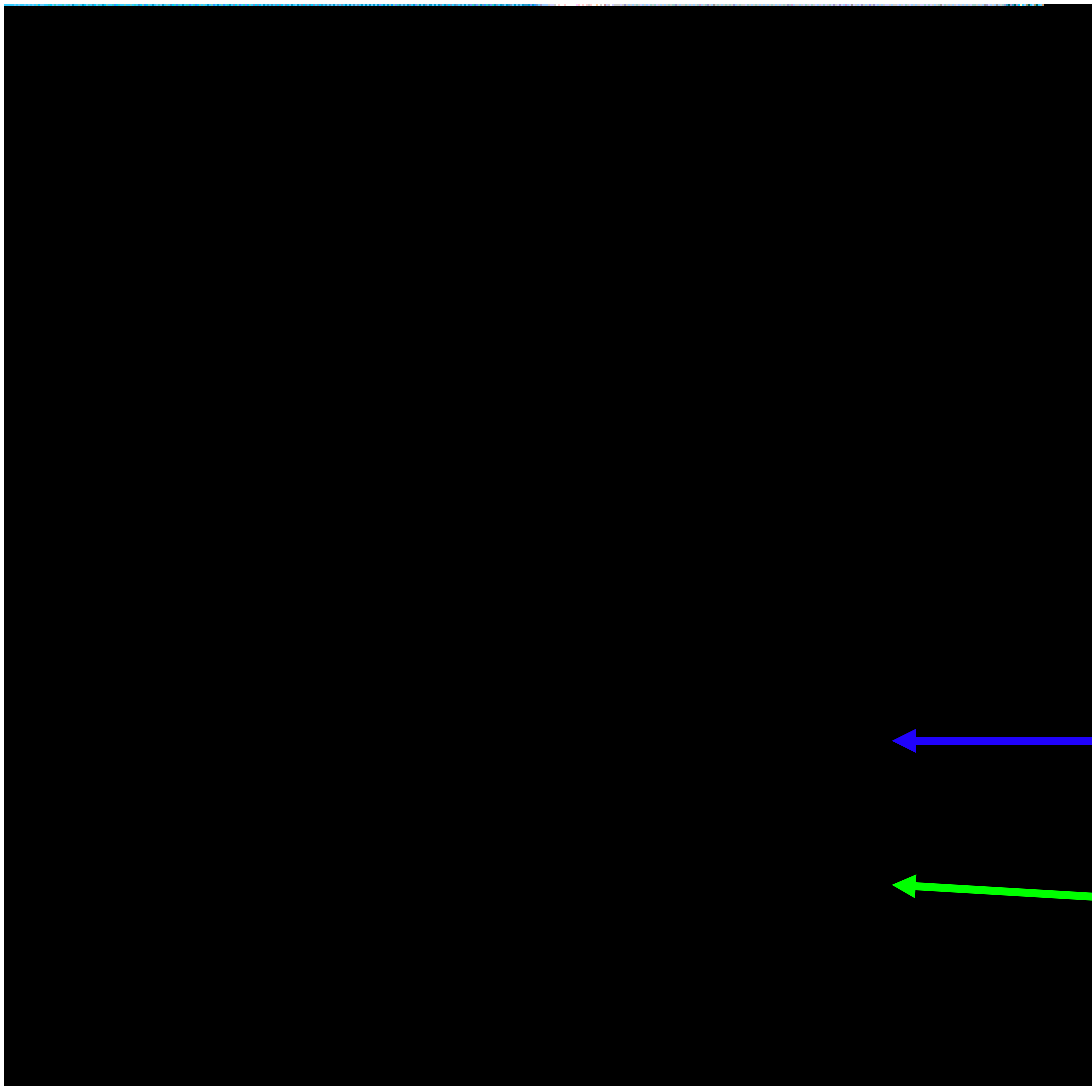
Foamed Cement Analysis in Bonded Pipe

AMPLIFIED
AMPLITUDE

GAMMA
0 150
AVZ
10 0
DZAVG
1 0



Analysis of Results on Casing Integrity



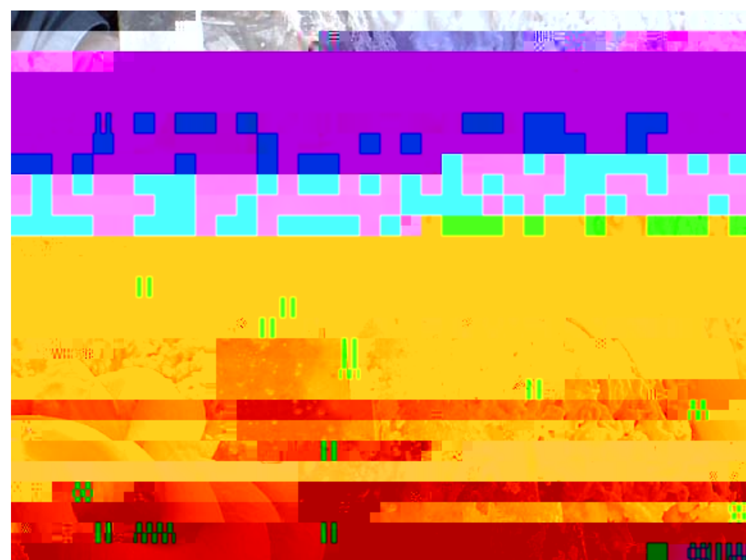
- Bond Log
- Measure Displacement Efficiency

Cement

Mud Filter Cake

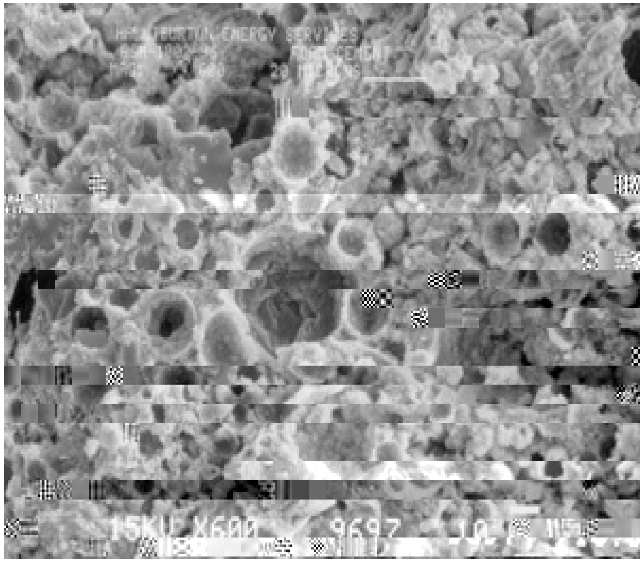
What is ZoneSeal Cement?

- 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

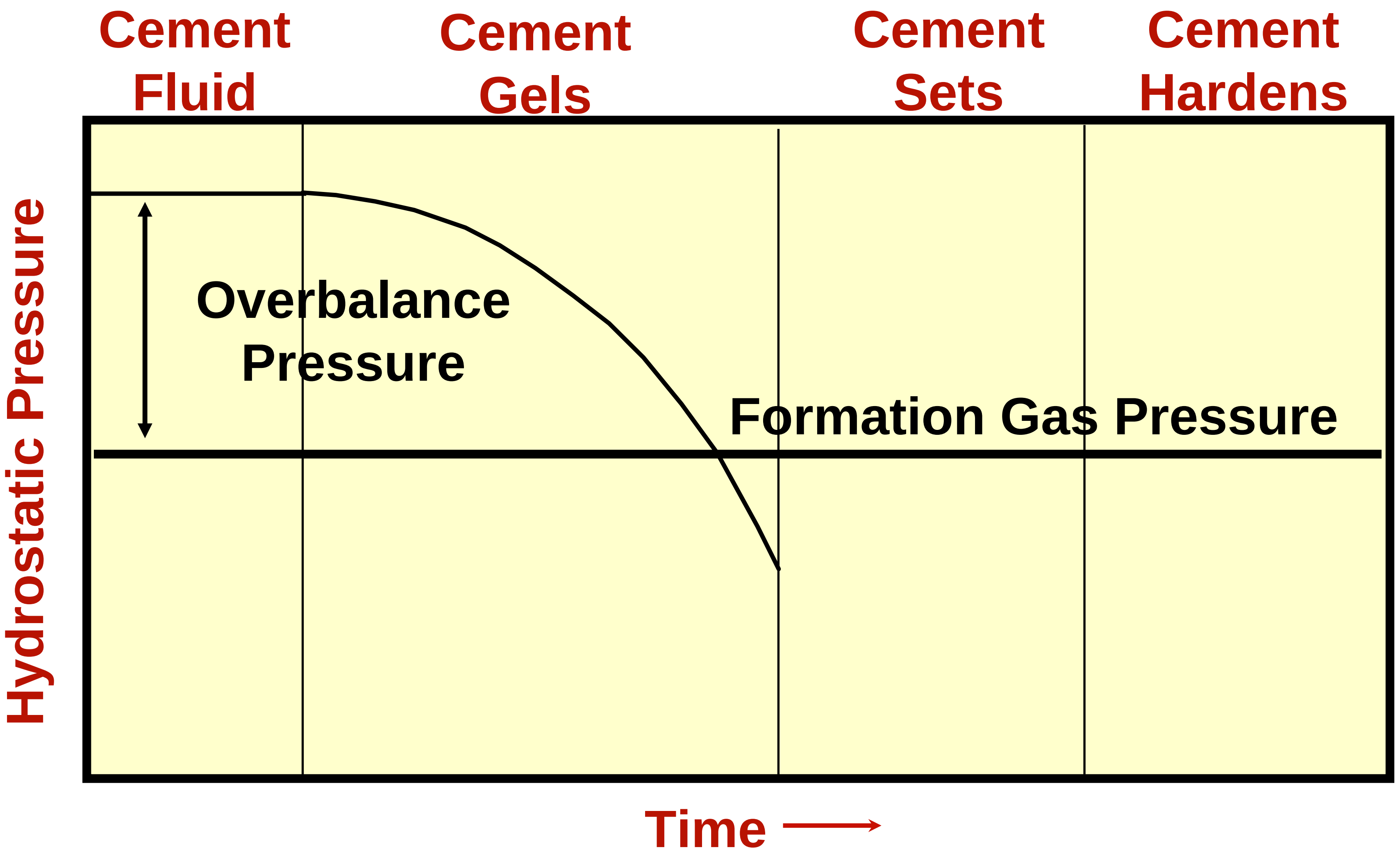
- High strength for low density material
- Virtually zero fluid loss & free water
- High viscosity
  - enabling thorough filling of channels, vugs, and voids
- Excellent displacement properties
- Properly produced foams are:
  - stable and have desired texture
- Greater resistance to stress cracking 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”

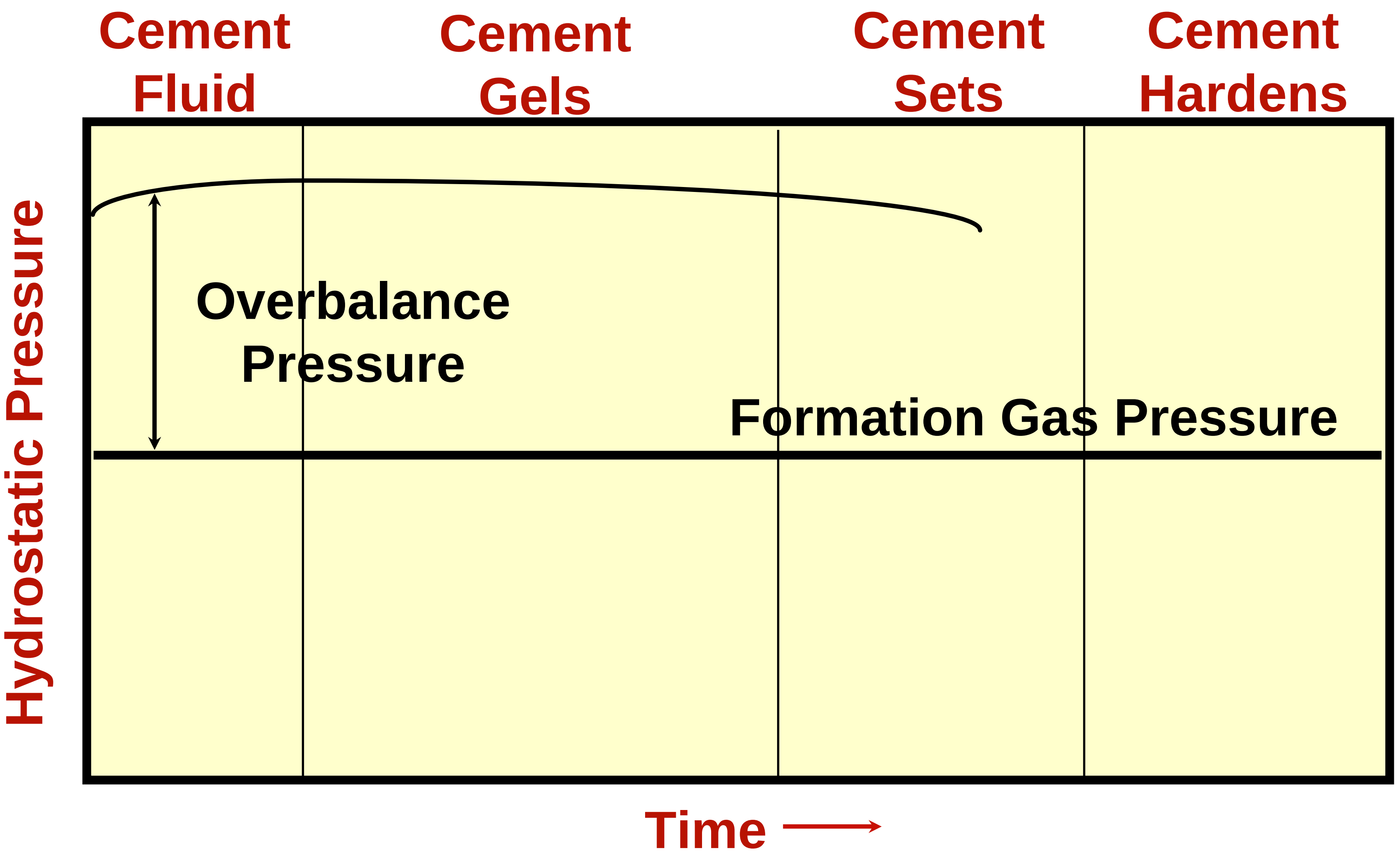
- Is it easier to fix an invasion or loss circulation problem by changing directions annular placement is conducted ?
  - Where are gas influx intervals ?
  - Where are water influx intervals ?
  - Where are fragile intervals with possible associated fractures ?
- What is the extent and length of problem 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



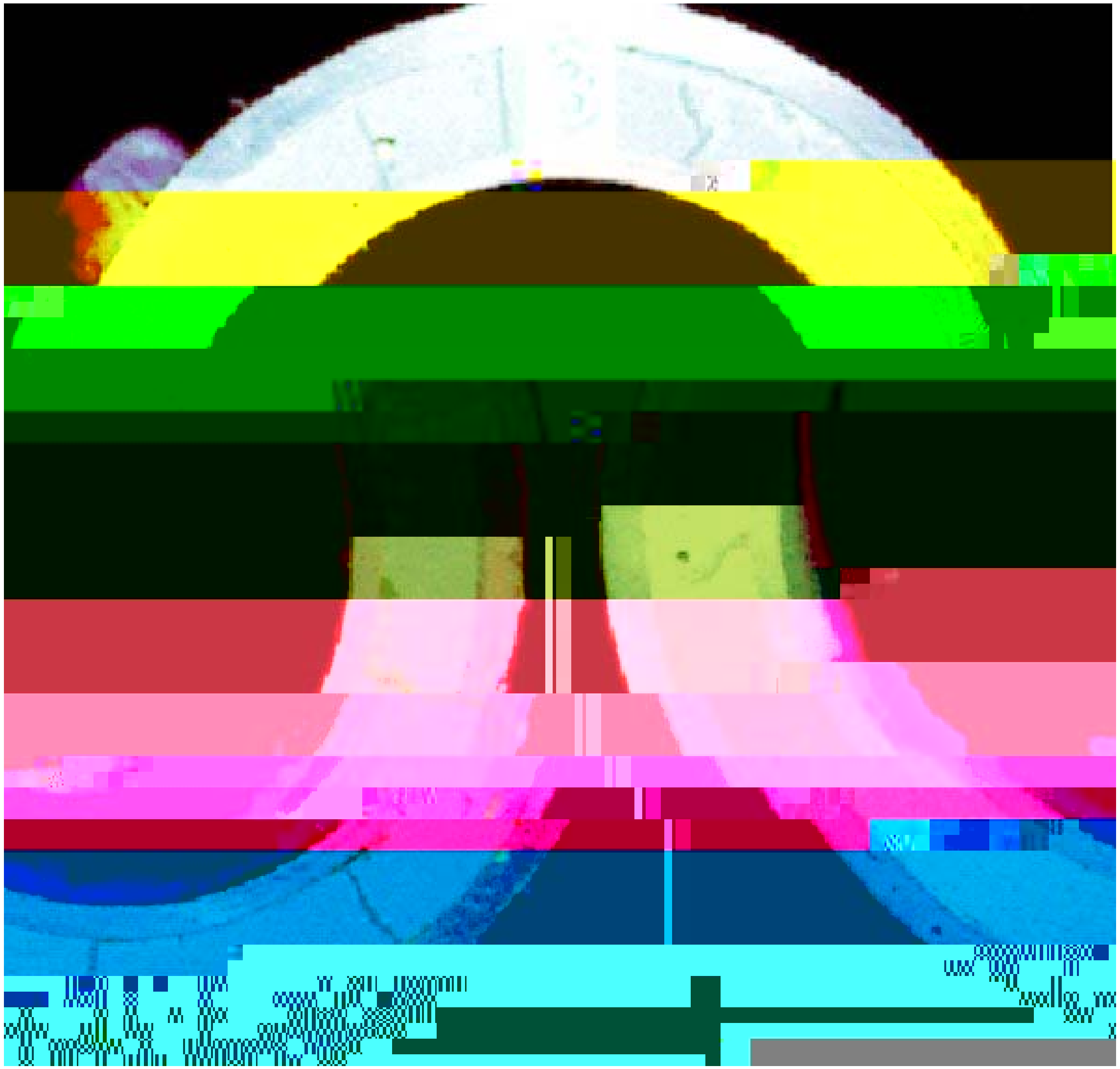
Large Scale Stress Testing

Conventional Cement

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

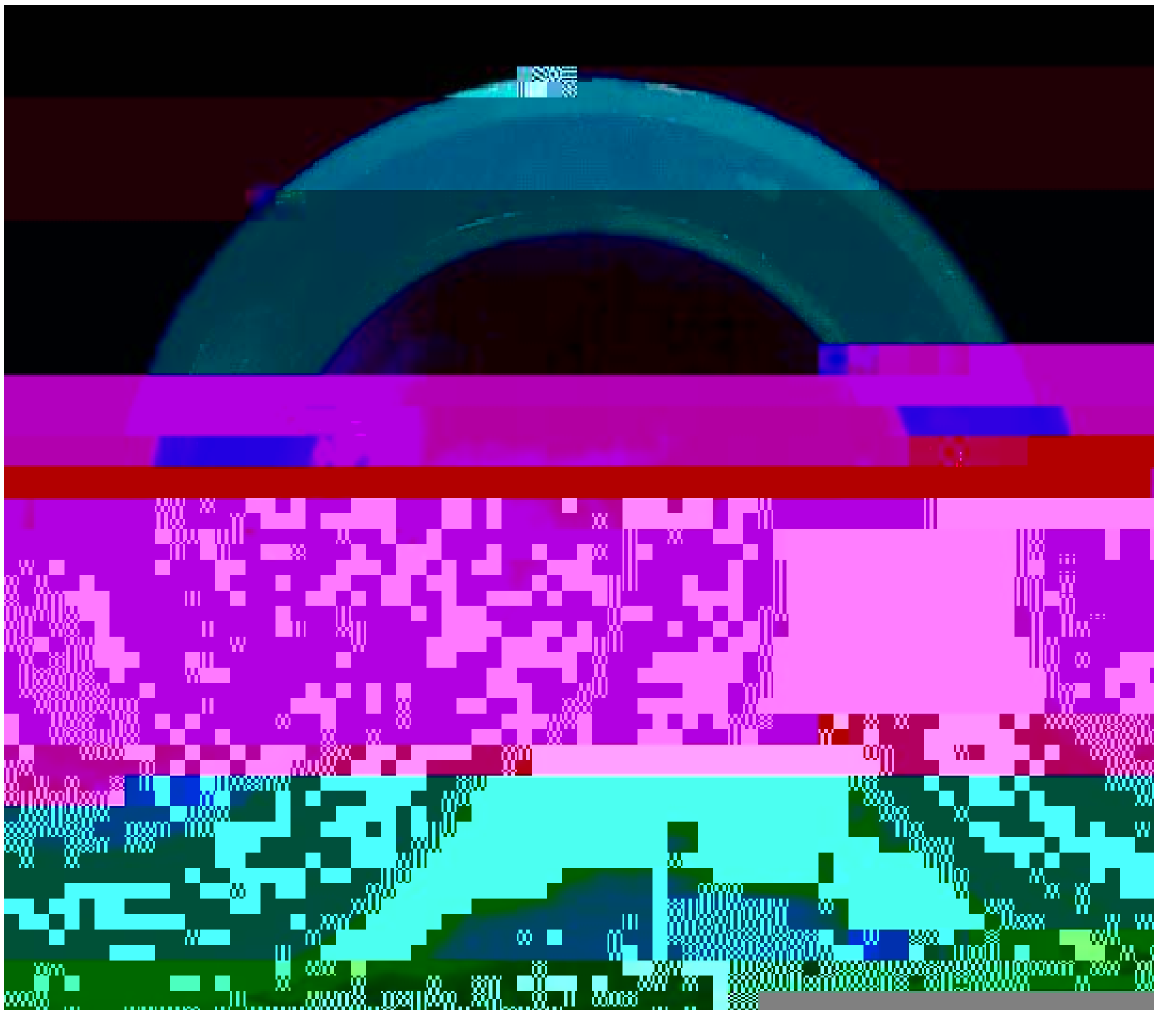
Large Scale Stress Testing

Conventional Cement

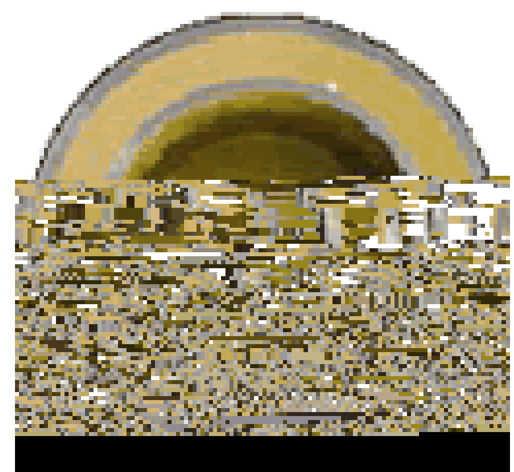


- Cement became brittle
- Radial cracks formed
- Longitudinal communication occurred
- Cement bond failed creating a microannulus

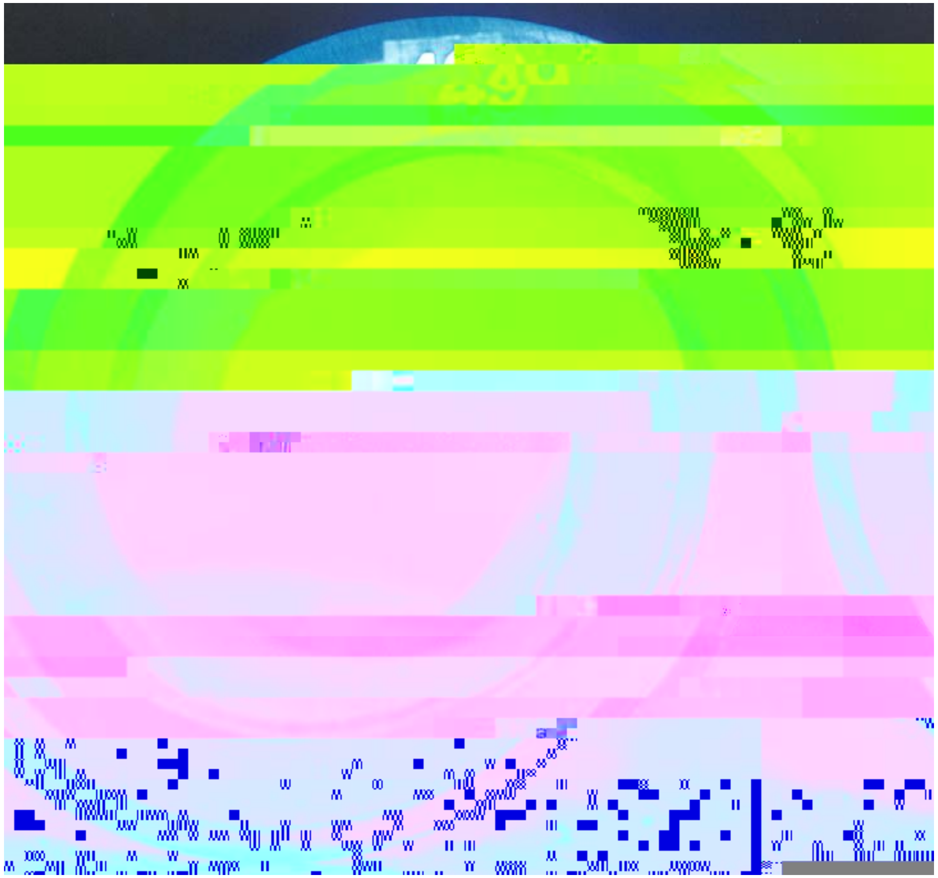
Large Scale Stress Testing
Foamed Cement

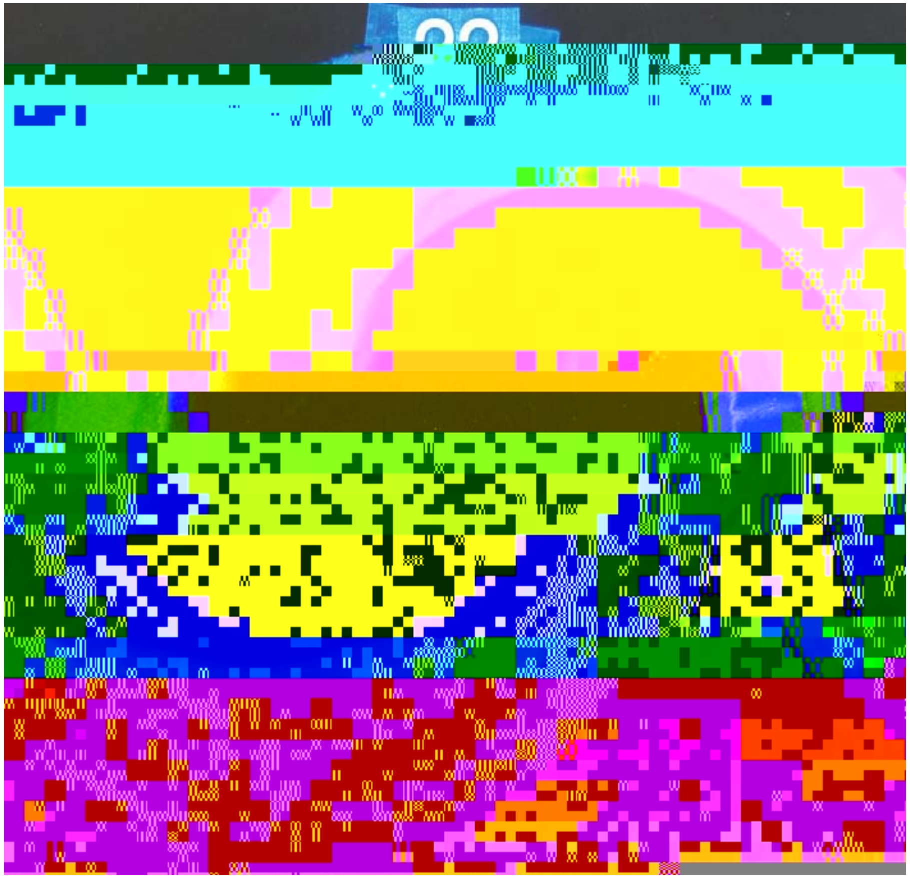


- No radial cracks
- Only slight debonding
- Foamed cement deformed and absorbed the expansive energy without failure due to its elastic nature



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

Modes of Annular Sealant Failure

Modes of Cement Failure

- De-bonding

@ cement-casing interface

De-bonded

Strategies for Reducing Oil Field Power Costs

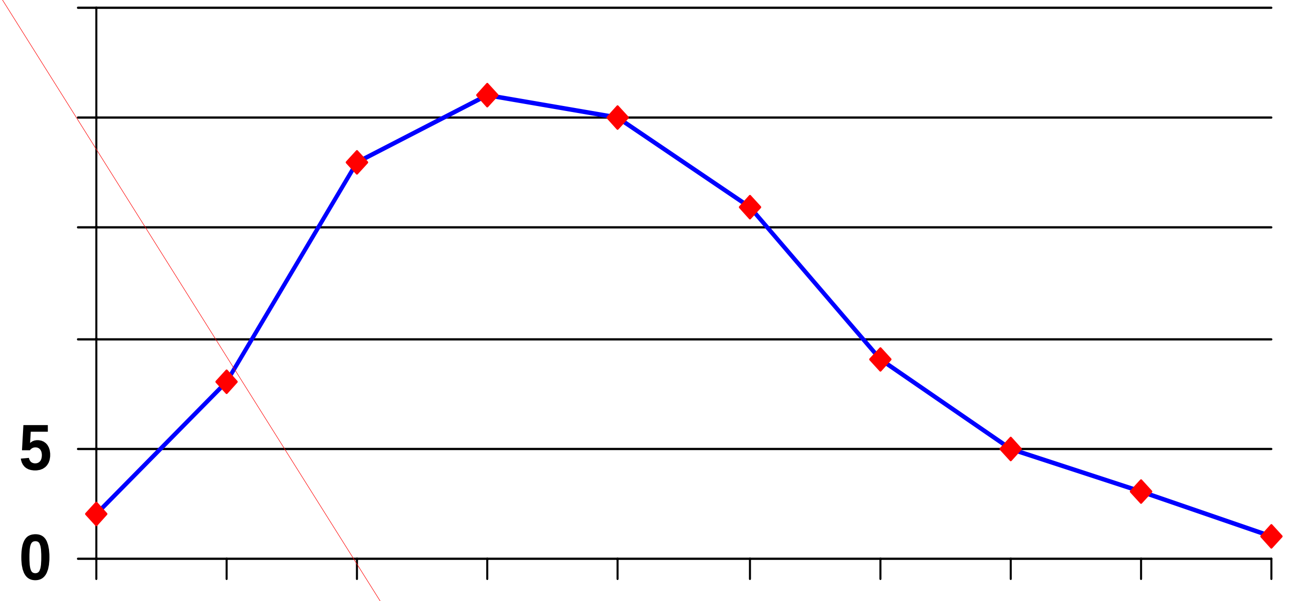
- Electricity is a large percentage of operating costs in the production of oil and gas **(up to 40-50% in 2000) (up to 55% in 2005??)**

- 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

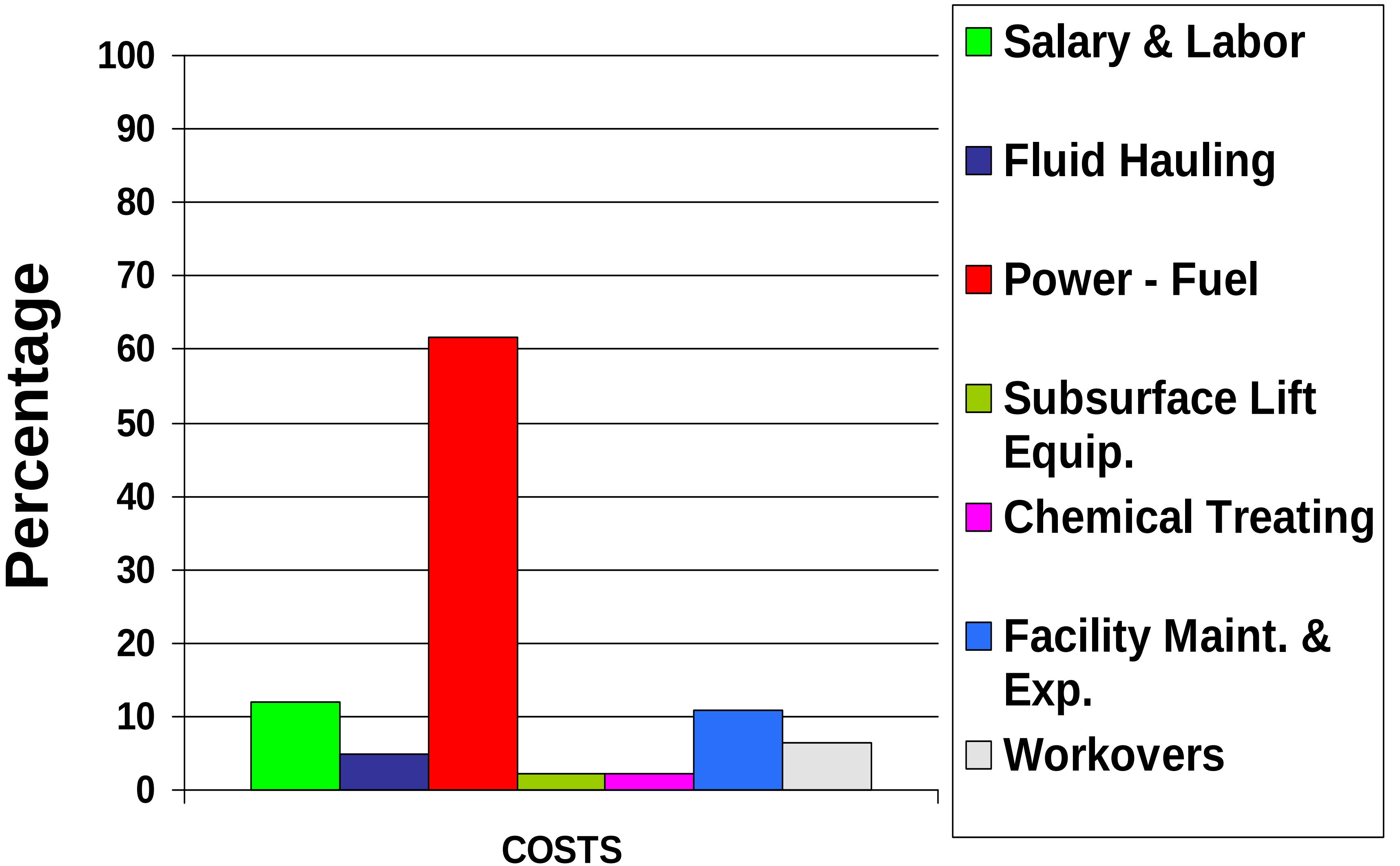
- What will happen in future developments ?

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

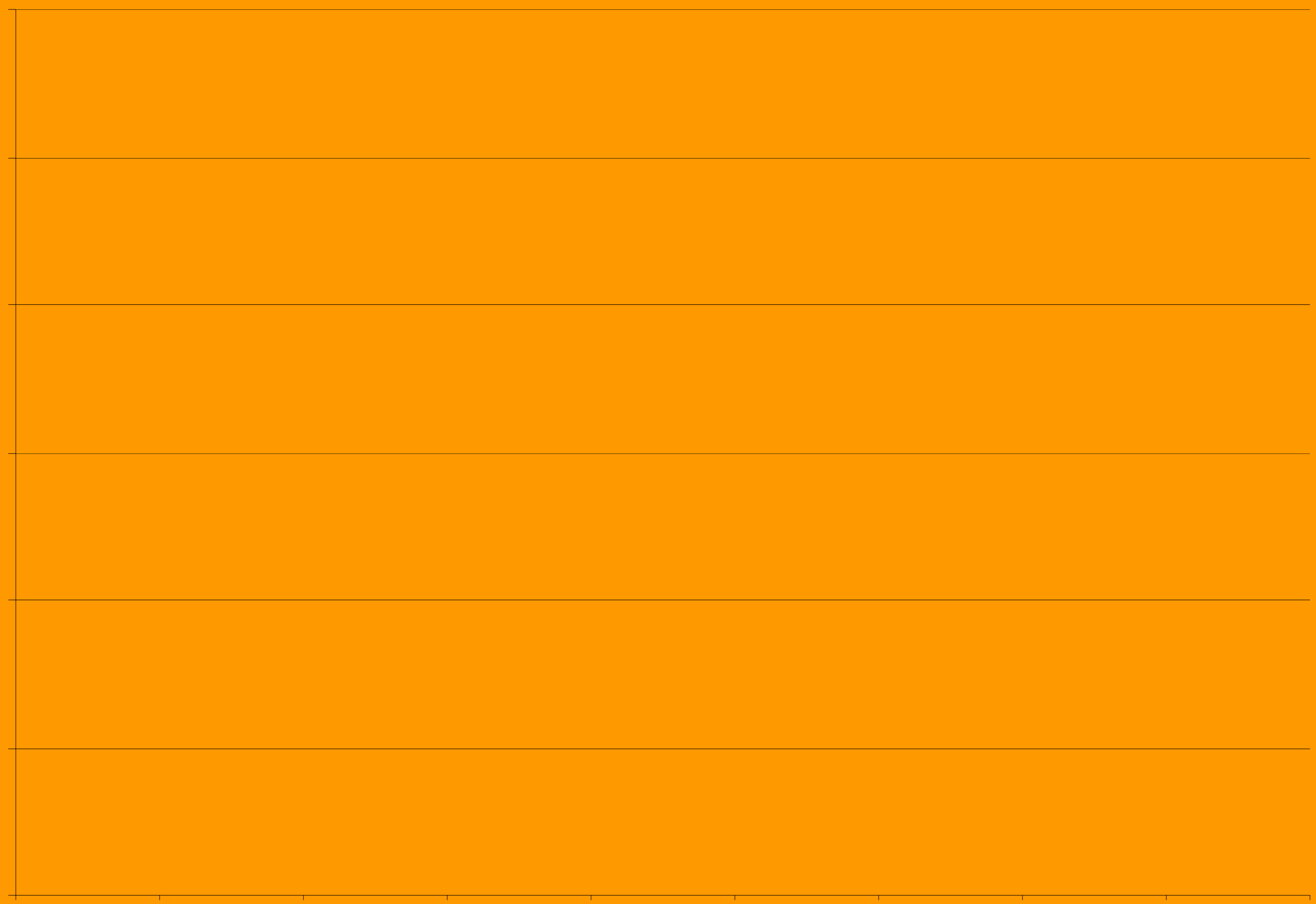
In cents/Kw-hr	**Cost of Conversion**	**Fuel Cost**	**Total Cost**
Flared Gas	2.5	0	2.5
$2.00/mmBtu	2.5	2.2	4.7
$4.00/mmBtu	2.5	4.4	6.9
$5.00/mmBtu	2.5	5.5	8.0

In-field Generation – Past Considerations

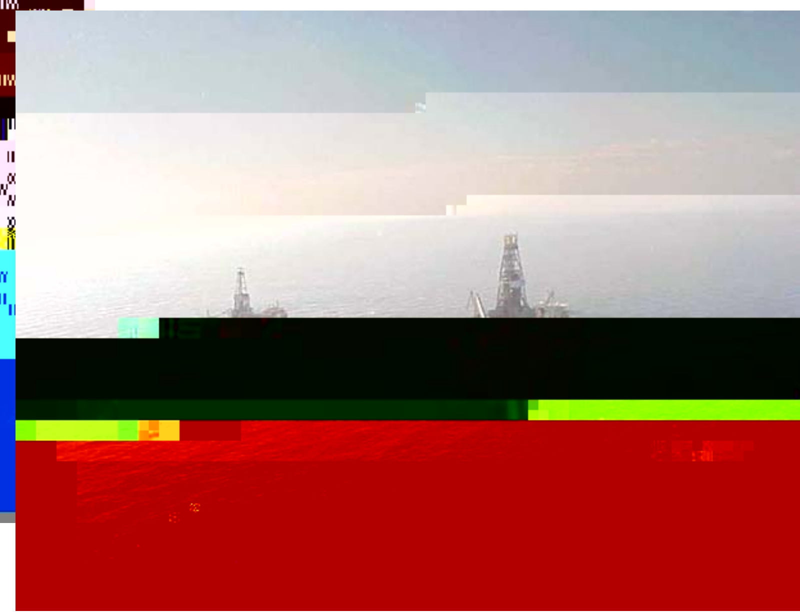
- If operator can generate power for less than purchasing from the grid then in-field generation can make sense
- With deregulation more options exist for selling power generated in excess of the load
- Monetizing stranded or distressed gas
  - Gas that has reduced value because of some kind of physical 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

Water & Gas – Hydrostatic Head Relationship



Technology Barriers



Reservoir Life Cycle