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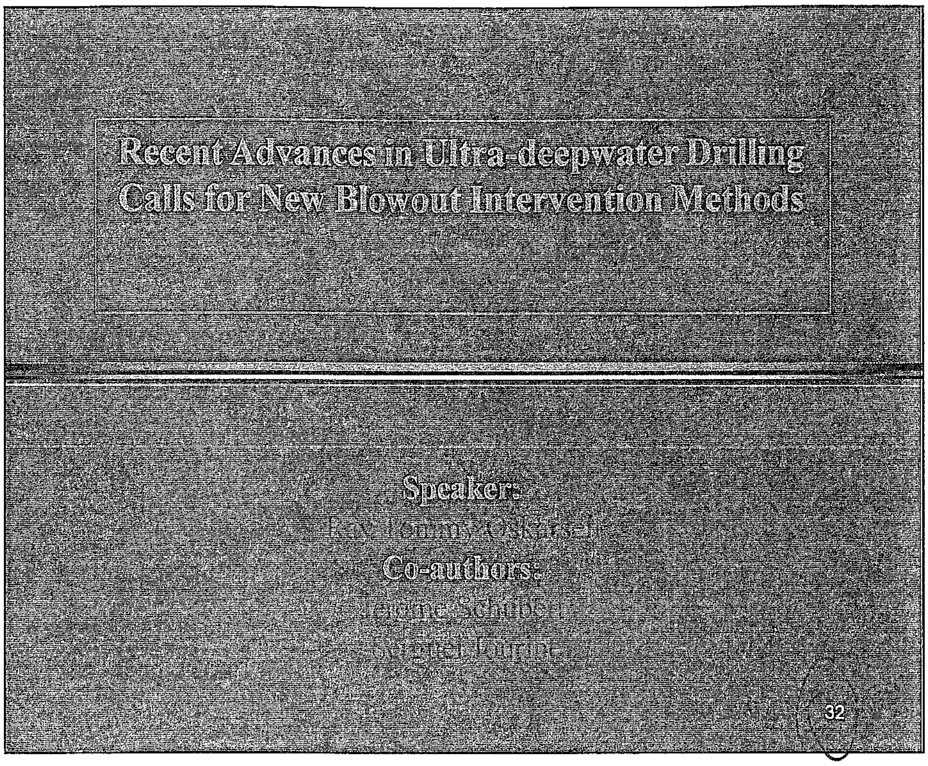
Well Control Procedures for Dual Gradient Drilling as Compared to Conventional Riser Drilling

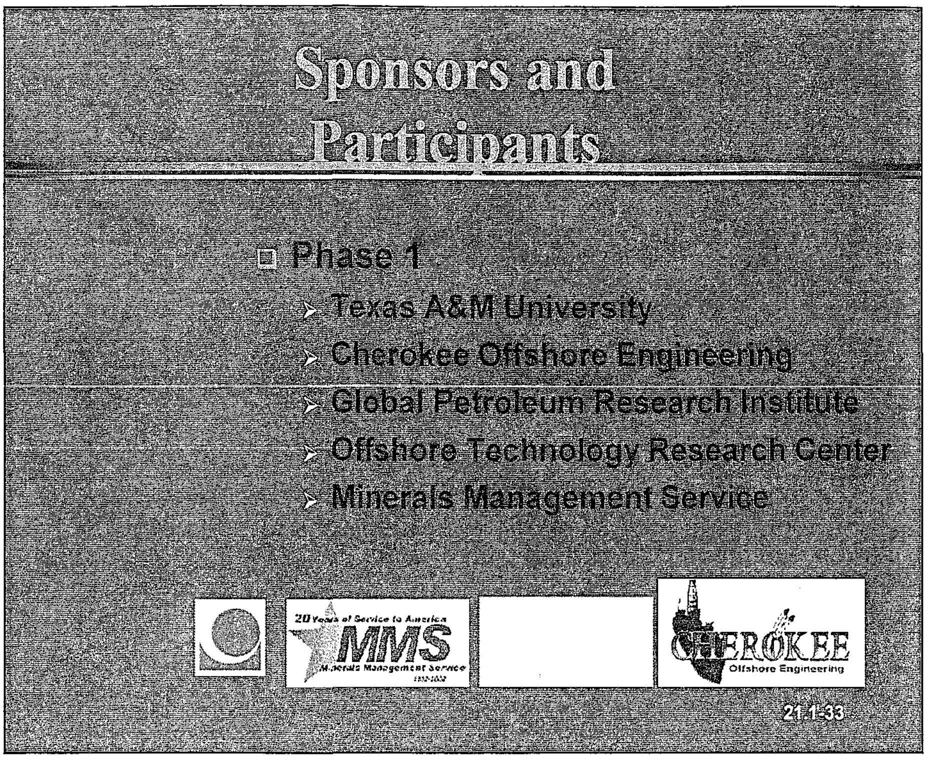
February 21, 2003



IADC Workshop Galveston 06.18.2003. “Deepwater Drilling: Where are we headed?”

Good morning ladies and gentlemen.

As a continuation of the SMD project a study on study on blowouts occurring in deepwater was undertaken at A&M.



The project was initiated by Texas A&M University and Cherokee Offshore Engineering.

MMS and OTRC are funding phase 1 of this project. We are looking for industry participation for phase 2. Several operators and service companies have shown interests. Phase 2 will be a JIP.

Drilling in ultra-deep water

- Window between pore pressure and fracture pressure gets narrower
- High pore pressures and low fracture pressures lead to more casing strings
- More casing strings leads to more time spent on location
- This leads to larger wellheads, even larger and heavier risers, and finally to bigger and more expensive rigs
- With a standard BOP and many casing strings, you may not reach target.
- Well control is more difficult - because of the pore pressure / fracture pressure proximity, and long choke lines with high frictional pressure drops

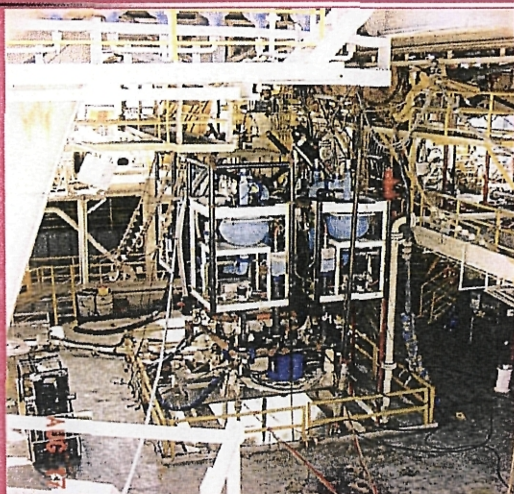
21.1-34

Industry believes major reserves are present in deepwater and ultra-deep water.

There are many problems with drilling in ultra-deep water, which most people are aware of.

The main problems are; you need large rigs, it is expensive, and well control is difficult.

Deepwater drilling projects

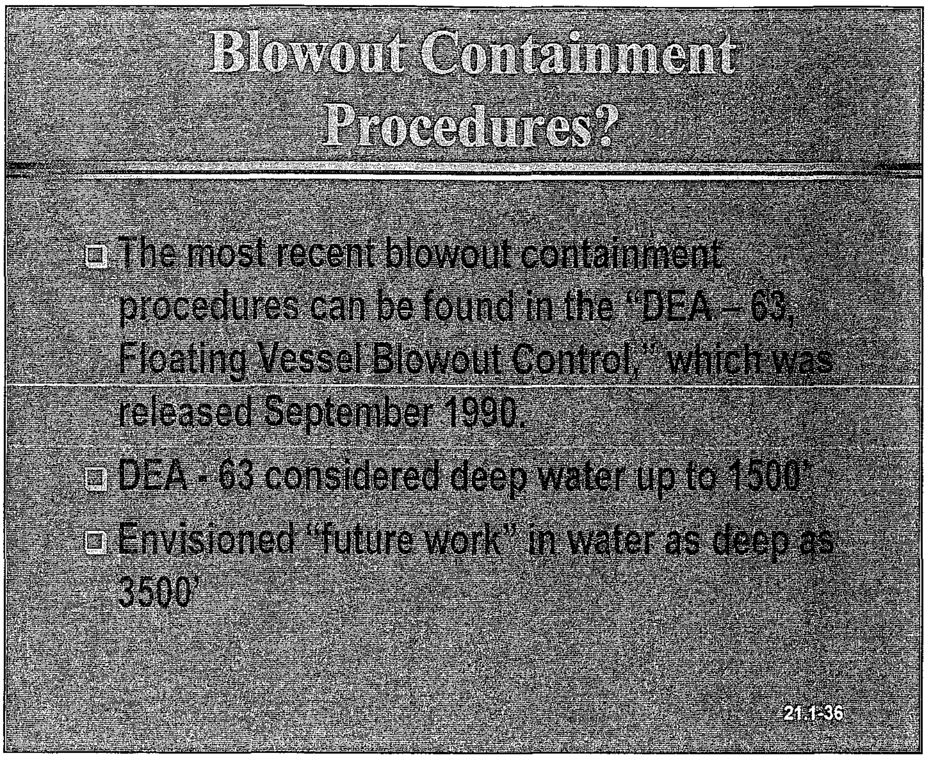


- Dual Gradient Drilling
- Casing Drilling
- Expandable Casing
- SX-riser

21.1-35

Many projects has emerged the last decade to overcome the previous mentioned challenges. These projects aim to drill faster, safer, and cheaper.

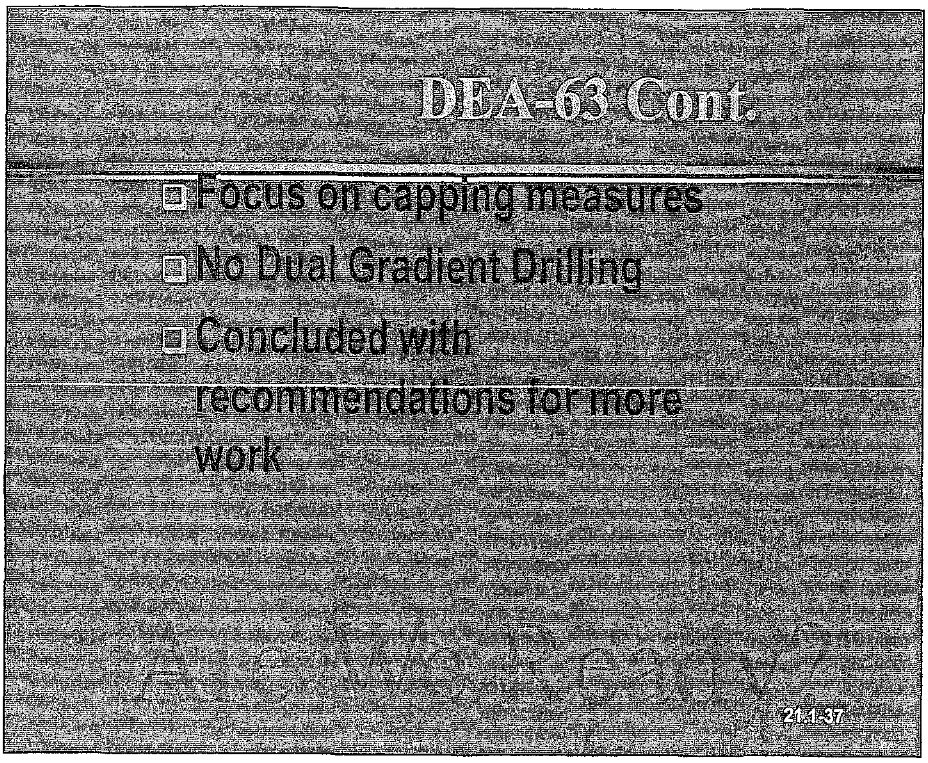
The picture shows the mudlift pump that was used during the Subsea Mudlif Drilling (SMD JIP) test well last year. It proves that dual gradient drilling is no longer a thing for the future.



As seen many projects has been undertaken to guide us into the ultra-deep waters. What about blowout containment procedures….. Have they been keeping up with the current technology?

The last major work completed on deepwater blowout control was DEA 63, completed in 1990.

It was good work, but the work never considered drilling in water depths greater than 3500'.

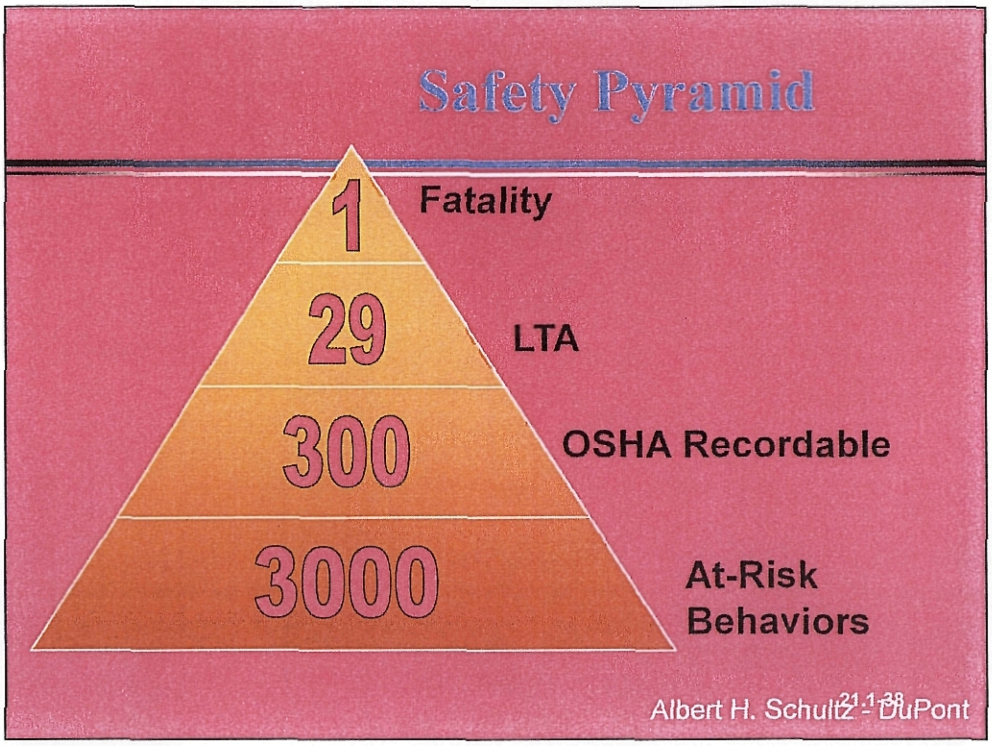


DEA63 phase II was proposed in 1998 but didn't get off the ground.

The concern was proper as the original DEA had understood and explained.

The objective of DEA63 was to develop innovative capping techniques. Today's wells may not require these techniques as the downhole mechanisms are much better understood, particularly in view of the fragile formations which could not hold the resultant pressures from a well capping operation.

Other techniques are required and must be developed so that the problem can be solved in a logical, consistent manner.



Do we need to study blow-outs? Should we be worried?

The slide is the graphic of the Safety Pyramid. This concept is familiar to the entire drilling industry and is used to present the idea of statistical probability of an incident. (It is simplified from its original version as presented by the International Loss Control Institute)

The phrase "work the bottom of the pyramid" is used to explain the methodology of reducing the number of qualified events by focusing attention by all levels on the potential severity, were it not for some factor, of a given incident.

Behavioral-based safety programs are becoming widely used in the industry with measurable success, but-even more importantly for this presentation-it's a standard which an instant identification can be made to well control issues.

Using widely-accepted concept of the Safety Pyramid, these linkages exist among incidents of increasing severity

1 fatality = 29 LTAs (Lost Time Accidents)

=300 Recordable Incidents (Occupation Safety & Health Administration)

=3000 At-risk Behaviors

Sometimes called Near Misses

"Work the Bottom of the Pyramid"

Statistics

- Podio Study of OCS Blowouts, 1996
  - 1 Blowout for every 285 wells drilled
  - 2.7% of the wells studied deeper than 15,000 ft
  - These accounted for [illegible]% of the blowouts
- Wylie and Visram, 1990
  - 1 Blowout for every 110 kicks
- SINTEFF Deep Water, 2001
  - 52 kicks for every 100 wells drilled
  - 79% of kicks had significant problems
  - At least 21% of kicks resulted in loss of all or part of the well
- 1992 to 2001 we drilled 1015 wells in water >1500 feet deep

21.1-39

We can gather data from literature to create a safety pyramid for blowouts.

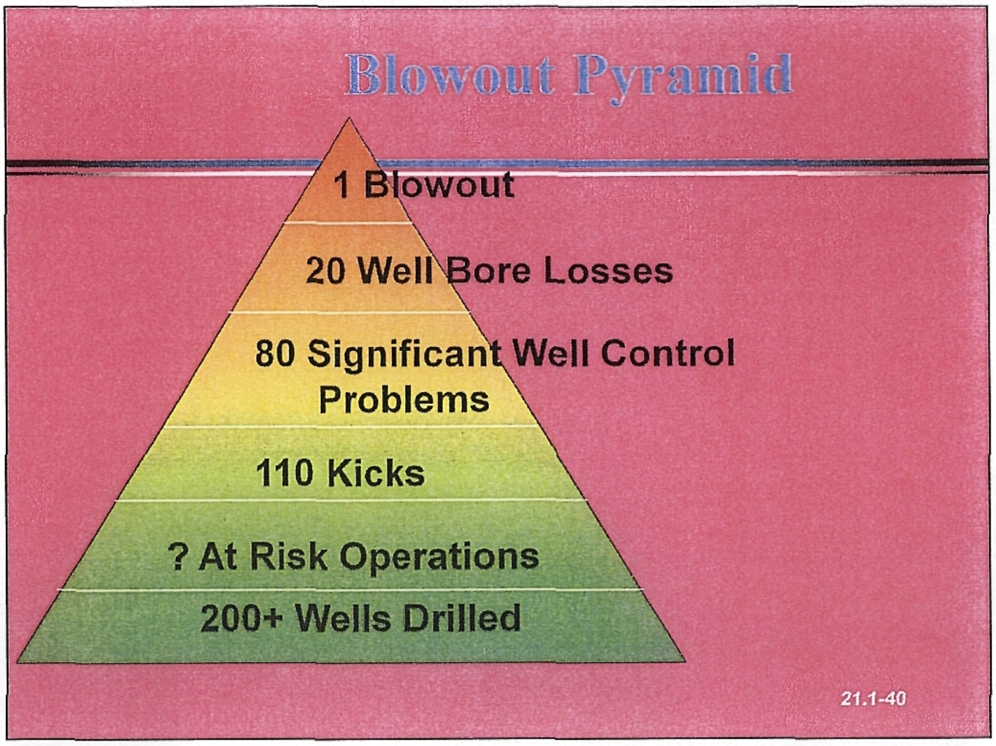
SPE Paper 39354 "Trends Extracted from 1200 Gulf Coast Blowouts During 1960-1996" Also, noted in the conclusions: Blowouts continue to occur at approximately a constant rate.

Database has not been updated since that time.

Here we are trying to work the bottom of the pyramid and we don't have much of a clue about the severity of the problem or how many near misses there are to address, or even kicks.

This is the reason we've requested the weekly report data from MMS which appear to have well control or other extraordinary events in them. Besides sifting this data, we have requested as-built drawings vs. APDs so that anamolies might be investigated to see whether a well control event caused the change, and also a review of Sundry Notices which should give a good clue as the condition of the well at any point.

This is a very significant gathering of data even with these relatively conservative sift points.



When the pyramid is applied to deepwater well control, the relative severity of the incident can be classified much as other incidents.

For instance, a blowout is the most catastrophic event and can be viewed for these purposes as the top of the pyramid.

The second level would correspond roughly with an LTA and would consist of lost hole sections, lost wellbores, production and data.

The third level would consist of an official well control event which was handled by closing in the preventers without loss of any hole section.

The bottom level would correspond with the Near-Miss level of incident reporting and consist of well control events which did not require BOP shut-in to handle.

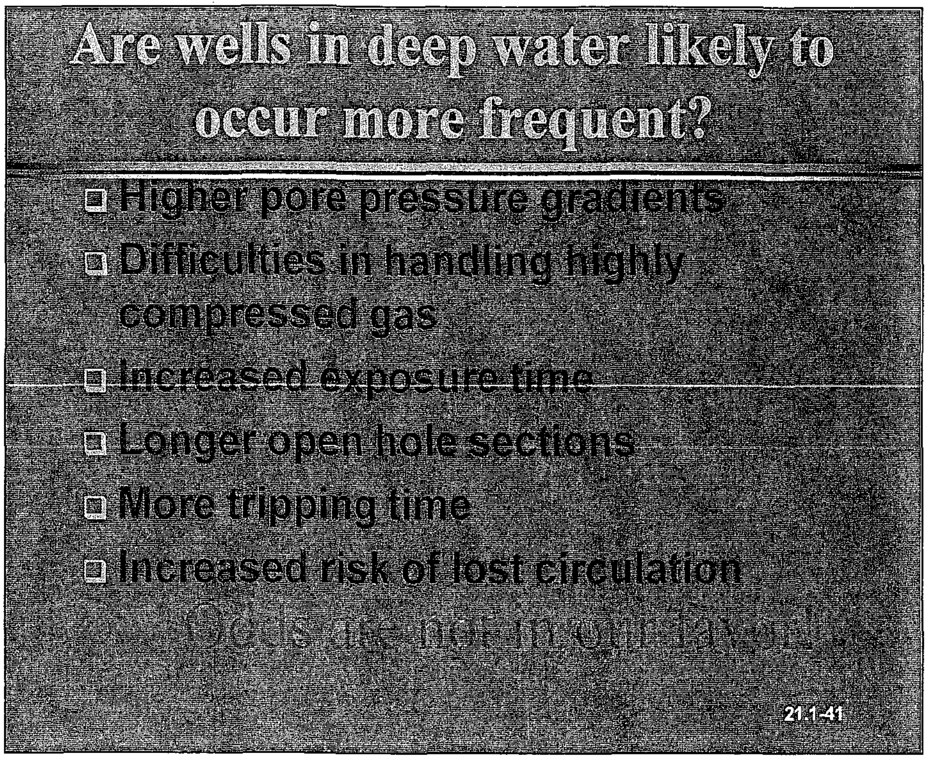
The safety pyramid is really an incident pyramid and is applicable to non-productive activity

1 Blowout for every 110 kicks

20% lost hole sections (SINTEF)

1 Kick = dozens At Risk Behaviors

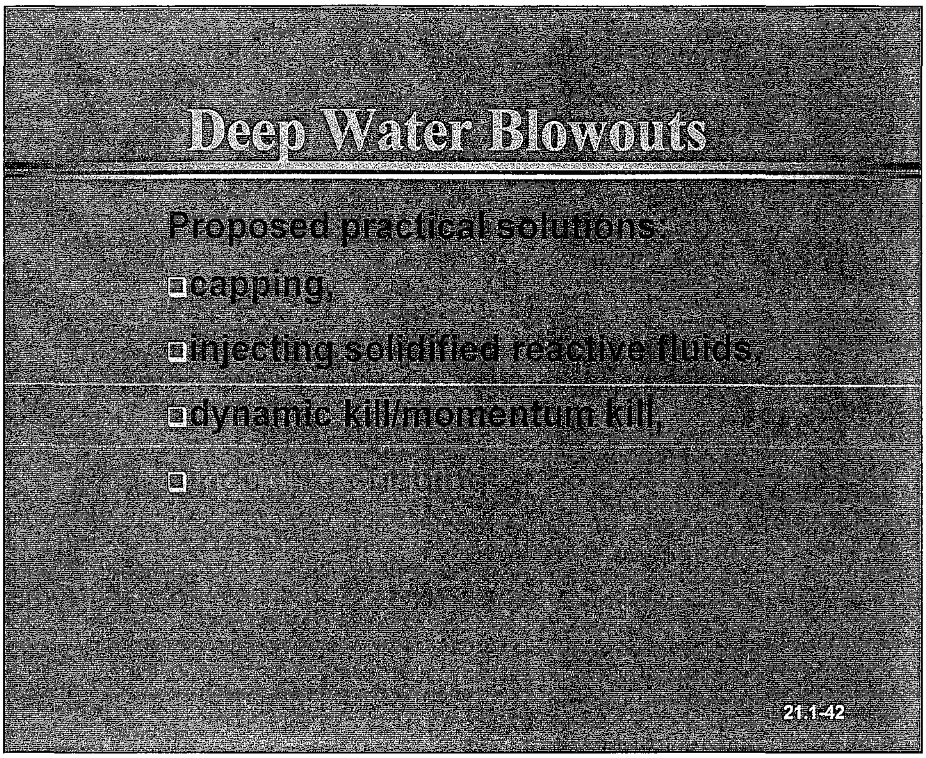
High gas, ballooning, improper fill



Blowouts has been occurring regularly throughout the petroleum history. As shown by Podio: deepwater wells accounted for only 2% of all wells drilled, yet they account for 8% of the blowouts. Why do blowouts occur more frequently in deepwater?

It goes back to well control problems which arise as we move into deeper water.

No blowout has yet occurred in ultra-deep water (water depths of 5000ft or greater) but statistics show it is likely to happen. Are we ready to handle it?



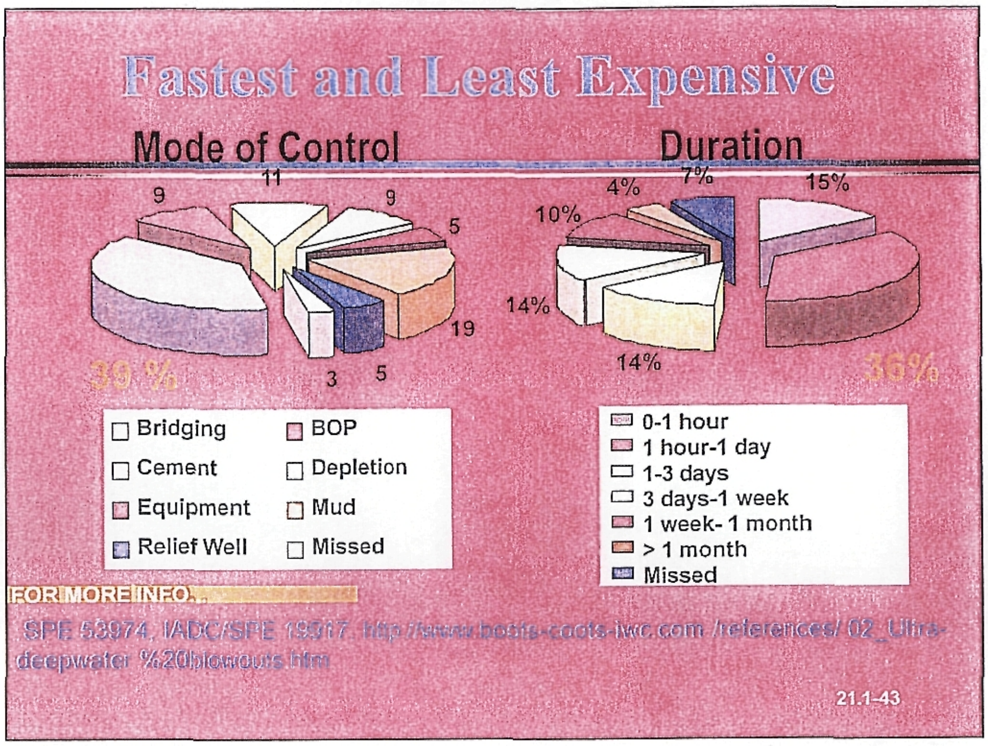
There are four ways to gain control of a blowing well.

No blowout in deepwater has yet to be successfully capped. The stab has to be guided by rovs, which are not designed to be maneuvered against the streams of a blowing well. Industry are working on underwater belt-vehicles, much like the ones used to cap land wells, to be used for deep-water stabbing operations.

Gunk (diesel & gel) or a cement with instant setting time can be used to kill a blowout.

A dynamic kill or momentum kill can be attempted either from relief well, or from drill string in well if it is in place.

We want to look at a new technique; induced bridging.

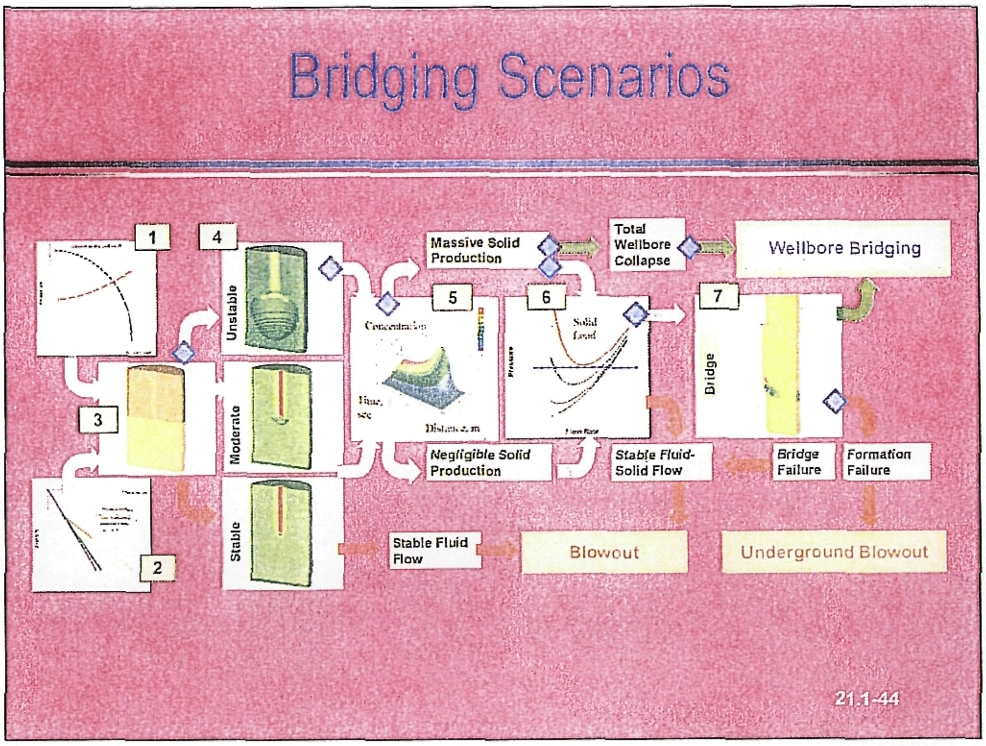


Skalle : Bridging is the most common method of blowout control in OCS (39.6%).

Flak : Natural well bridging would shut off most blowouts.

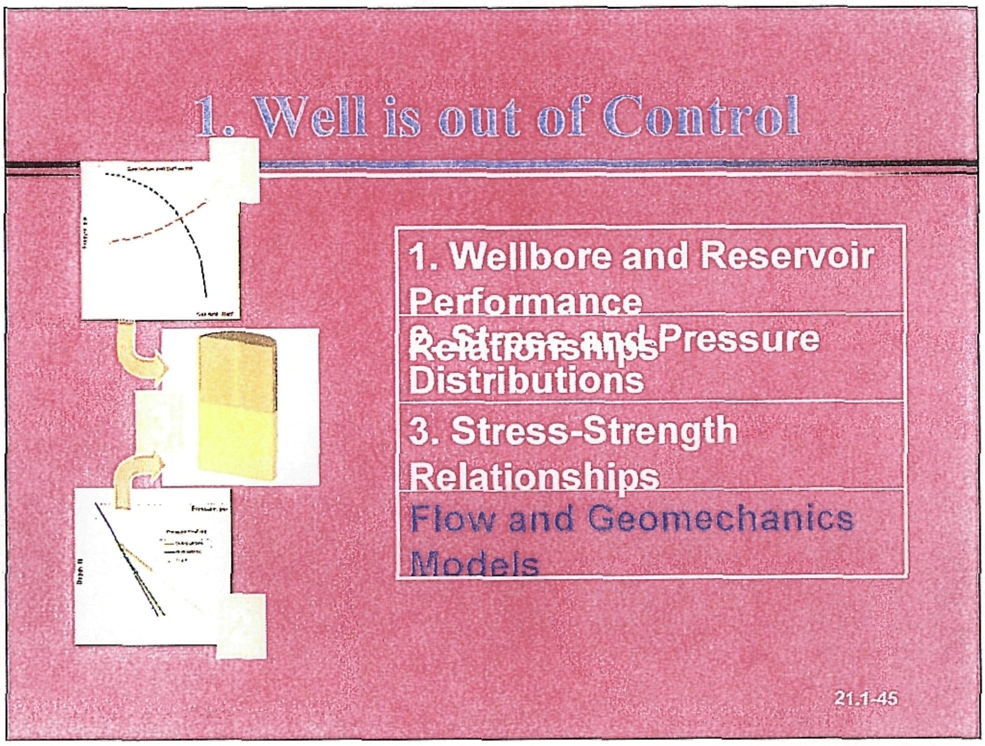
Adams and Kuhlman : Formation bridging is responsible for stopping many shallow blowouts.

Literature has shown that the fastest and cheapest method of blowout control is bridging. Can we induce it? And more importantly; do we want to induce it. Will an induced bridge lead to an underground blowout? Will it leave us in worse condition?



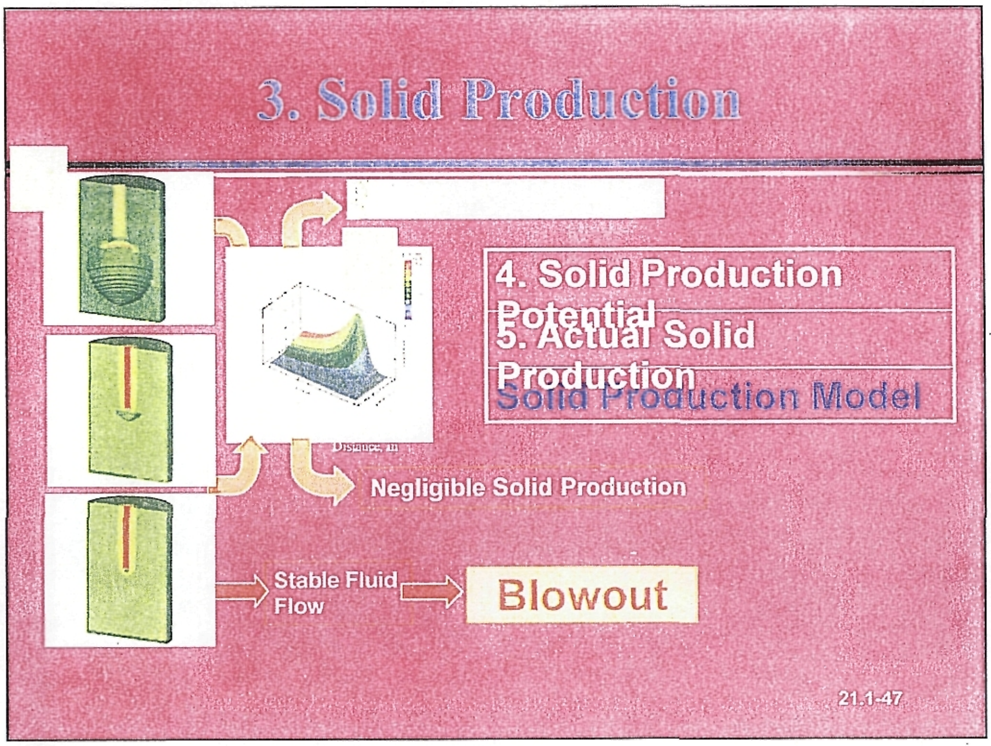
Sergei Jourine has completed pioneering work on the bridging problem. His model is still in development, but it has already shown promising results.

This slide shows the general concept of his model, and all the factors that need to occur for a bridge plug to kill the blow-out.

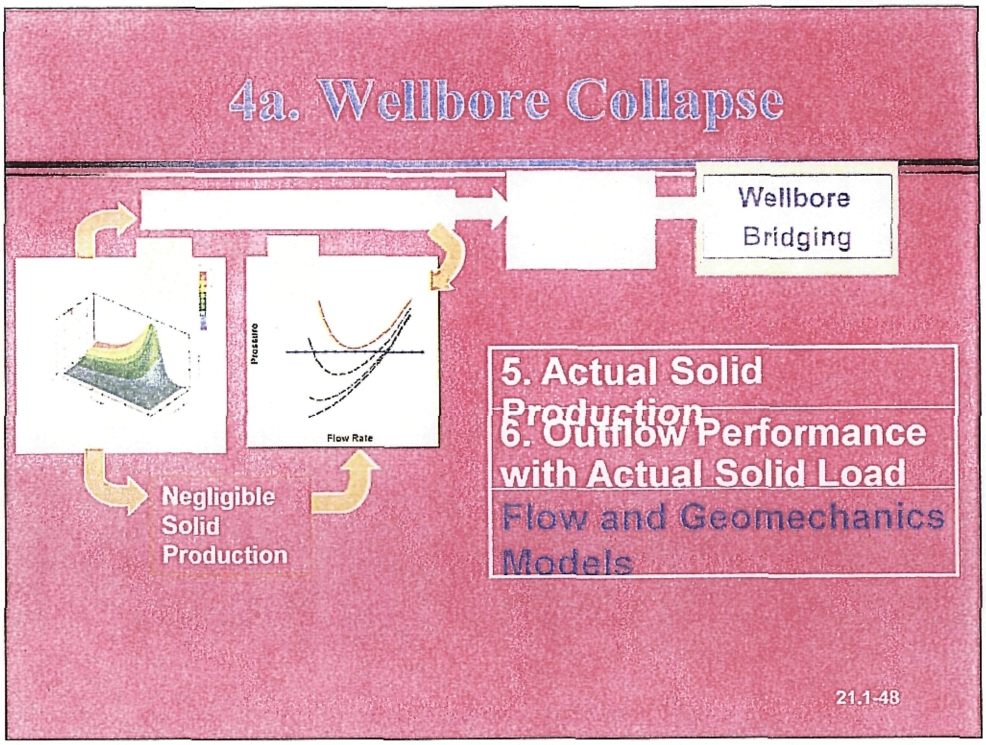


The first step to calculate if bridging is to occur is to calculate the pressures in the well. This slide show the the wellbore and reservoir performance curve.

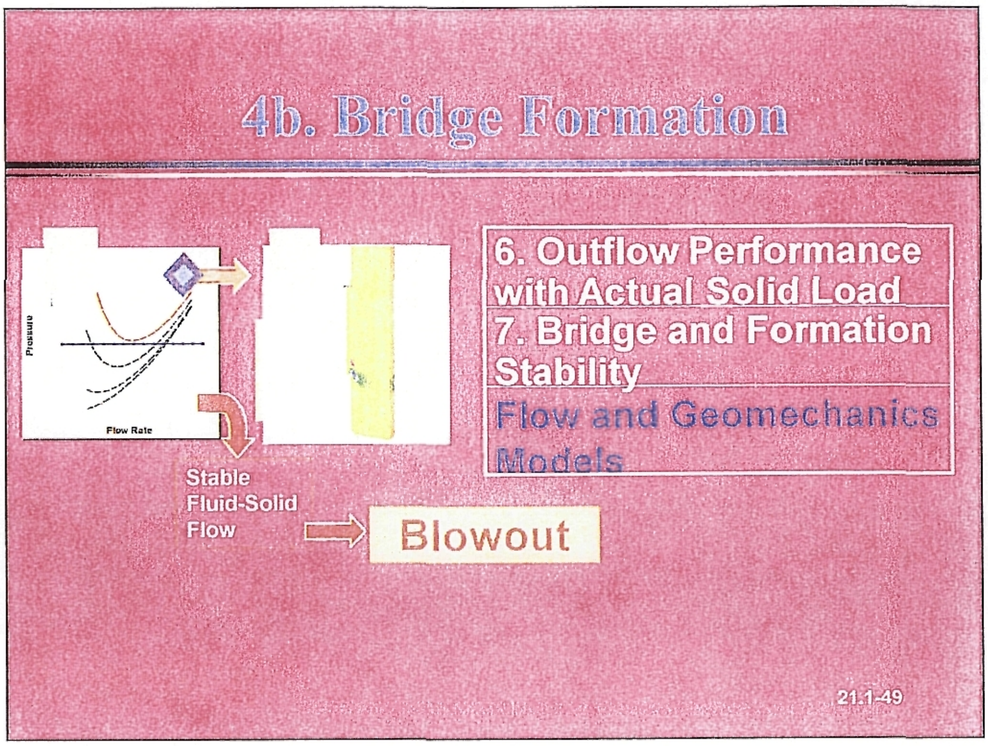
Depending on the formation surrounding the wellbore, the solid production potential may be determined.



If the formation is highly unstable you may get massive solid production which is the building stone for a bridge plug.

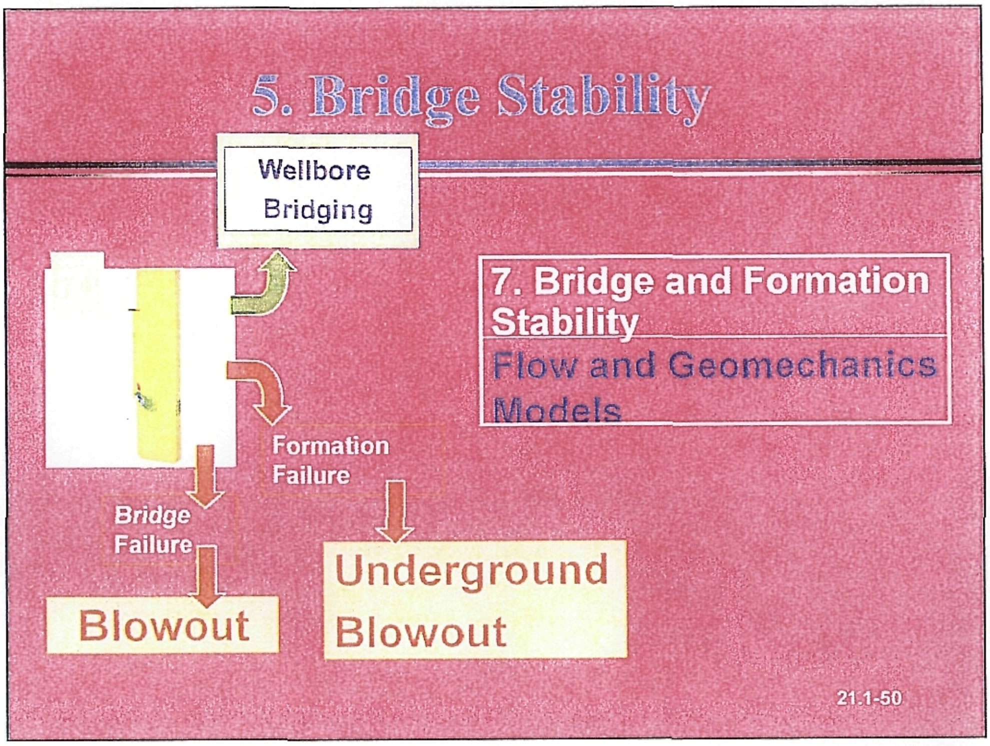


As solids are being produced from the walls of the wellbore they are circulated out.



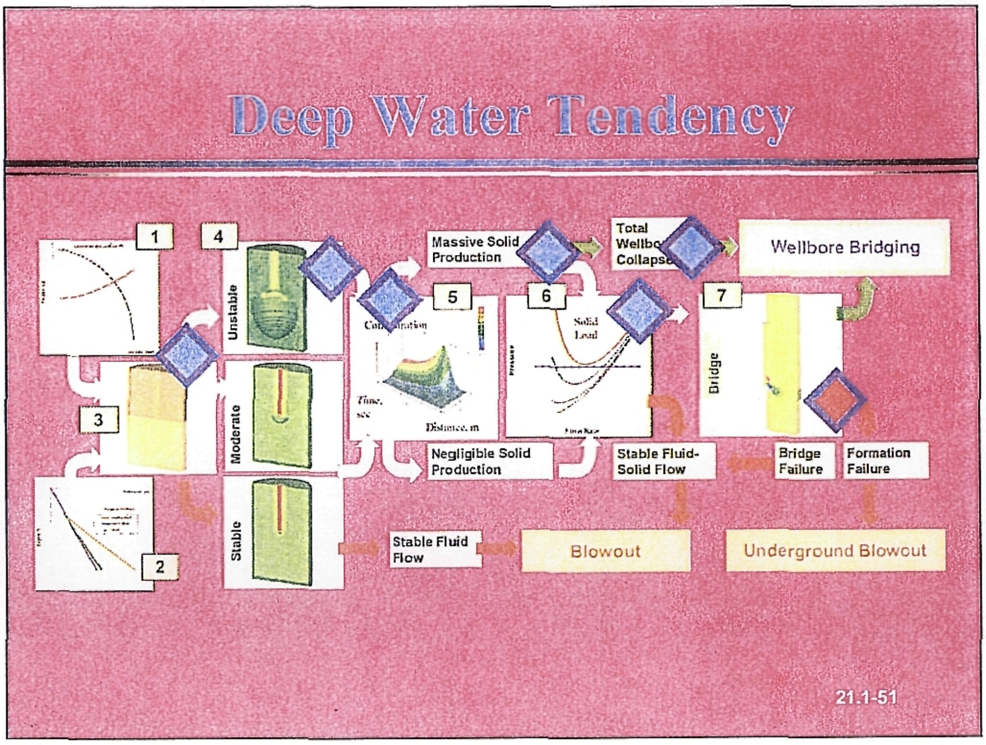
If the flow rate is sufficient to transport the solids out of the well the well will continue to flow.

However, if the flowrate is not sufficient to transport the solids out of the well bore a bridge plug will be set.



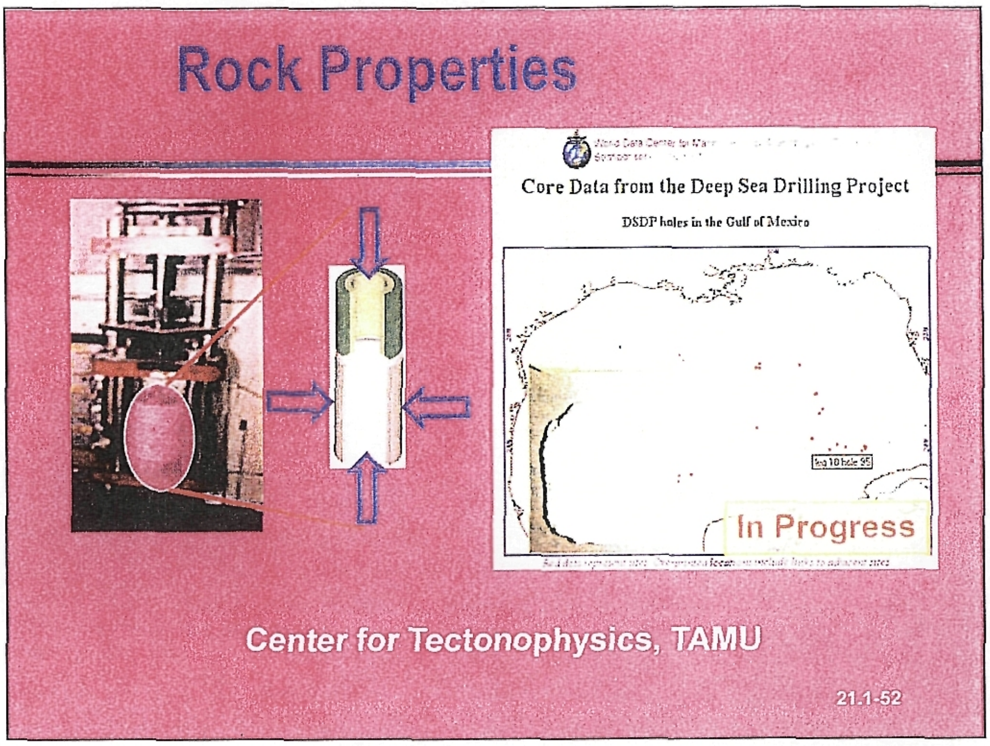
If a bridge plug is set high above the flowing formation, an underground blowout may occur.

Alternative, pressure build-up may break the bridge-plug and the well is flowing again.



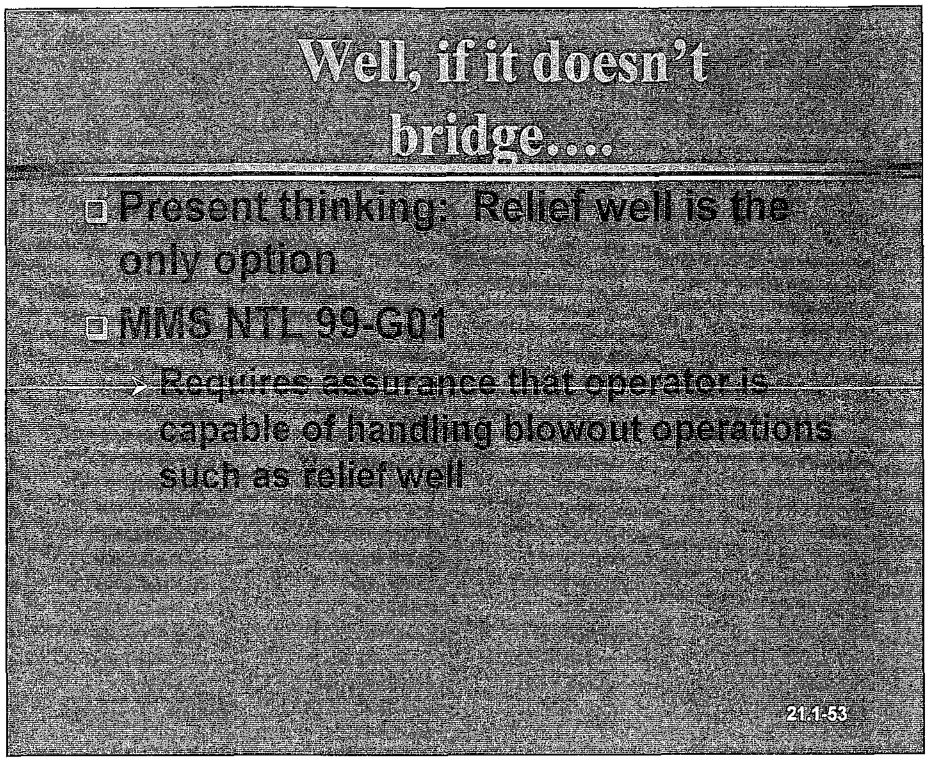
From field data a most likely scenario can be constructed from our model. The blue dots illustrate the most likely path for deepwater and ultra-deep water wells.

This is in agreement with data from litterature.

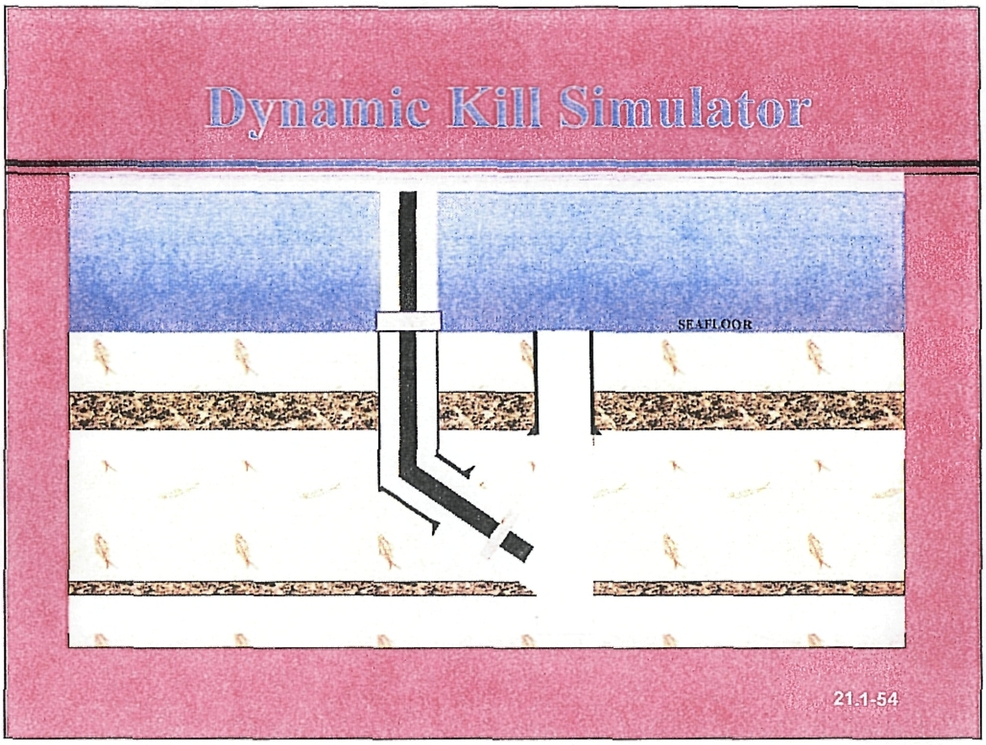


Currently the model is being tested with cores from the deep sea drilling project.

The solid production model has other applications in production, such as sand control and cavity like completions.



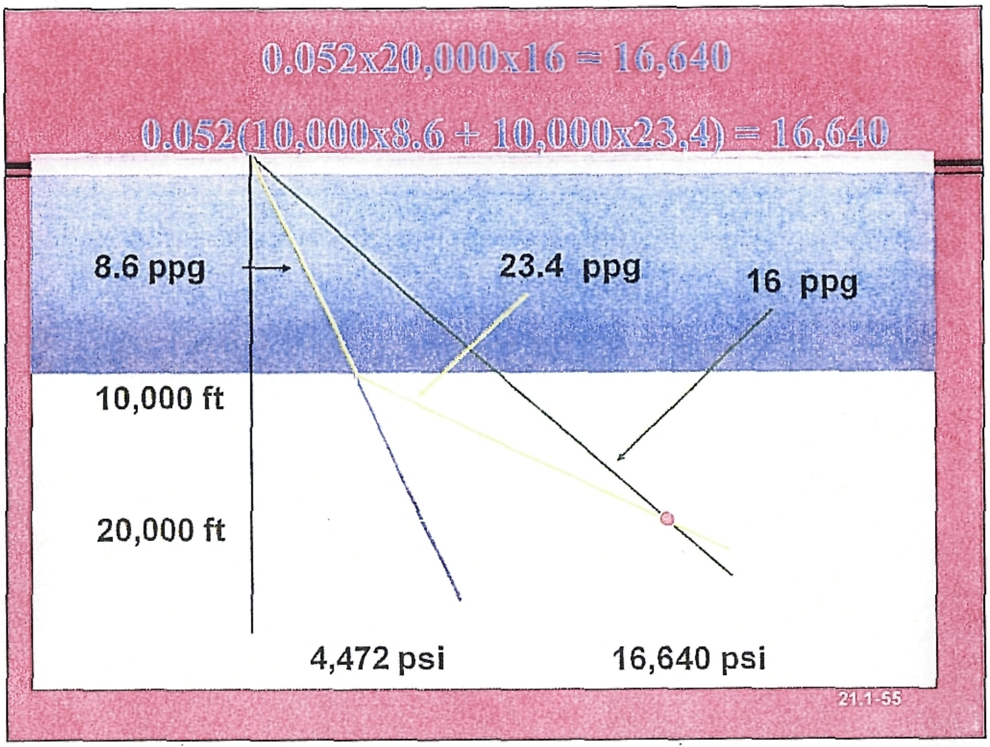
There is a fatalistic mindset in the industry that a relief well, due to the unique geometry of a deepwater well, is the primary well-killing option for a deepwater blowout.



A dynamic kill can be done from the drillstring in the well or by drilling a relief well. The objective of a dynamic kill is to create enough frictional pressure in the blowing well to choke the influx of formation fluid. Note that the frictional pressure is directly proportional to the length from the injection point to the seafloor.

To successfully plan a dynamic kill a dynamic kill simulator should be used. It is important to determine the flowrate required to kill the influx. The flowrate determines what kind of surface equipment we need. Also, the optimum injection point needs to be determined. If the pressure in the well is high, multiple relief wells may be required.

We need a dynamic kill simulator for case studies and to verify procedures.



What happens as we move into deeper water.

For a land well we would need a 16 ppg mud to control a 16640 psi pressure.

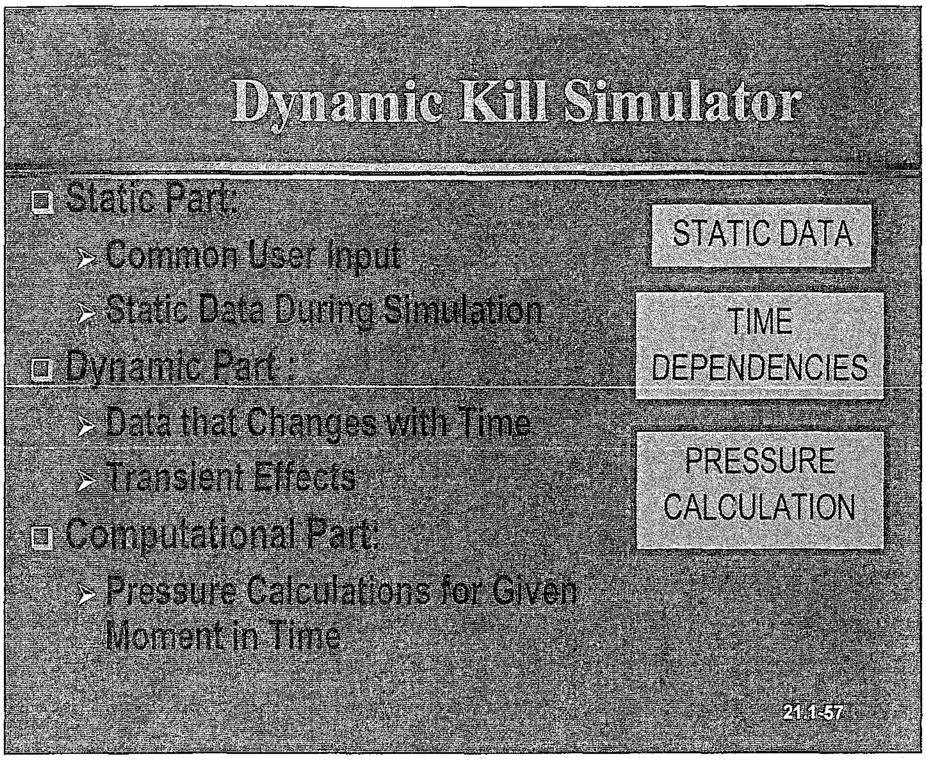
In ultra-deep water we need a 23.4 ppg mud to control a 16640 psi pressure. No muds available with this density.

The length of the blowing well is halved. The frictional pressure is proportional to this length, which means the circulation rate must be much higher for a deepwater well.

Same principle apply to a dual gradient well vs a conventional well, if the equipment above seafloor is still intact.

Dynamic Kill Comparison

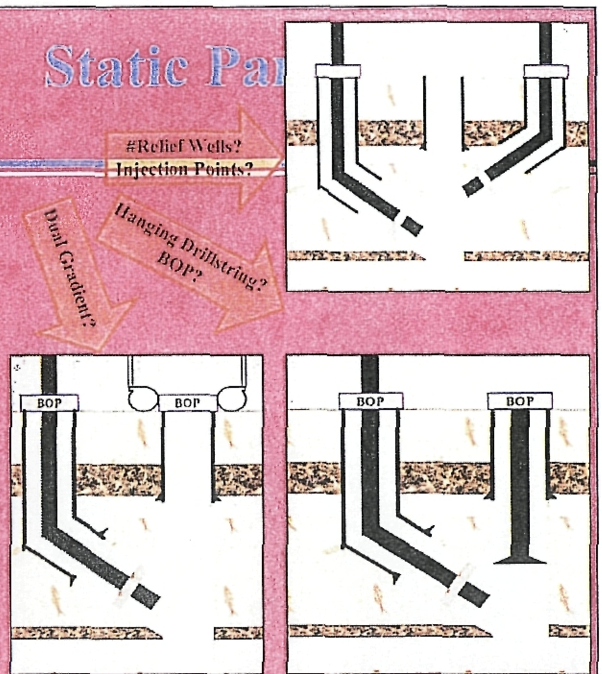
- 20,000' onshore well with 16 ppg
- 20,000' deepwater well in 10,000' of water with 16 ppg
  - 10000' of 8.6 + 10000' of 23.4 ppg?
- Friction pressures developed during dynamic kill could be much less in a deep water well
- Can we choke it back at the mudline?
  - How?



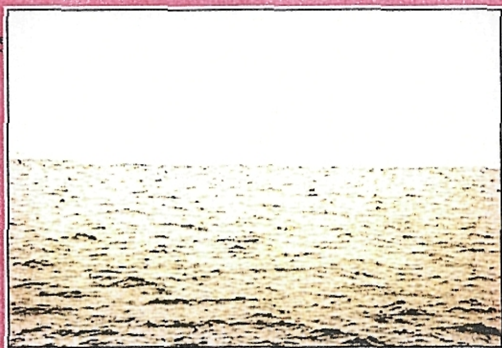
The dynamic kill simulator will be separated in 3 parts.

Static Pa

- Reservoir properties
- Formation fluid
- Well geometry:
  - Number of relief wells
  - Blowing well geometry
  - Inflow and outflow of kill fluid



Deep Water Blowouts



Surface Boil Due to Well Broaching

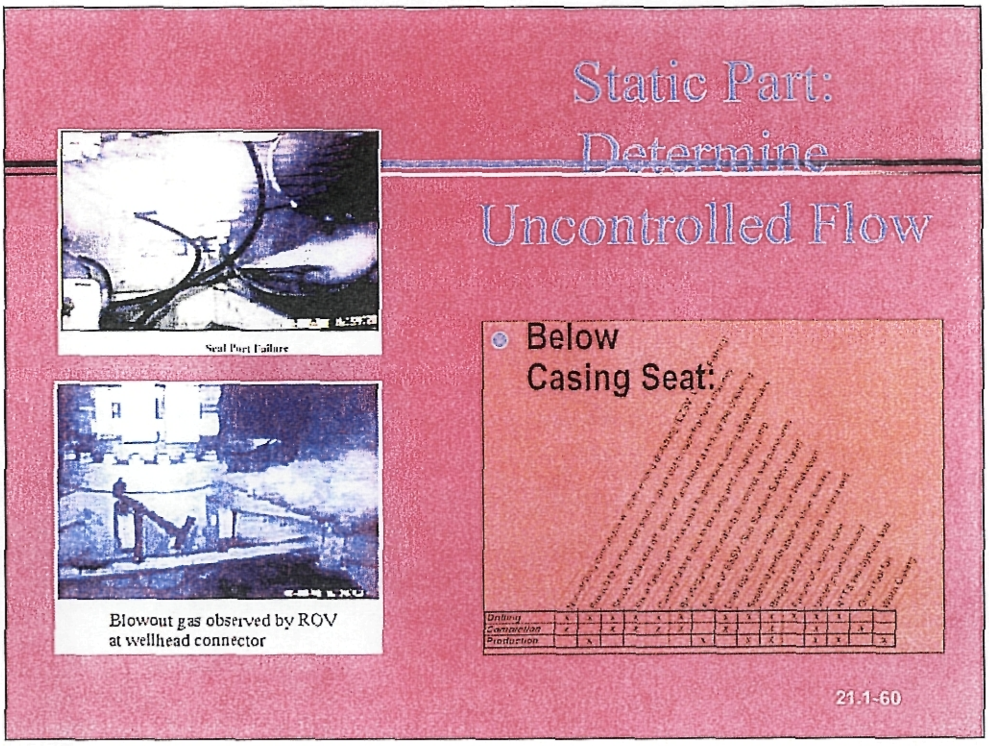
- 4 deepwater sustained underground blowouts controlled by Boots & Coots
- 3 broached mud line gas flows (20" casing set BOPs installed)
- 1 BOP Failure Gas Blowout
- No oil blowout has reported to date

FOR MORE INFO...

Flak L.: "Control of Well Issues", "Marine Insurance – Facing the Changed World", International Union of Marine Insurance NEW YORK – 2002, on-line http://www.iumi-newyork. -2002.org/Flak.htm

21.1-59

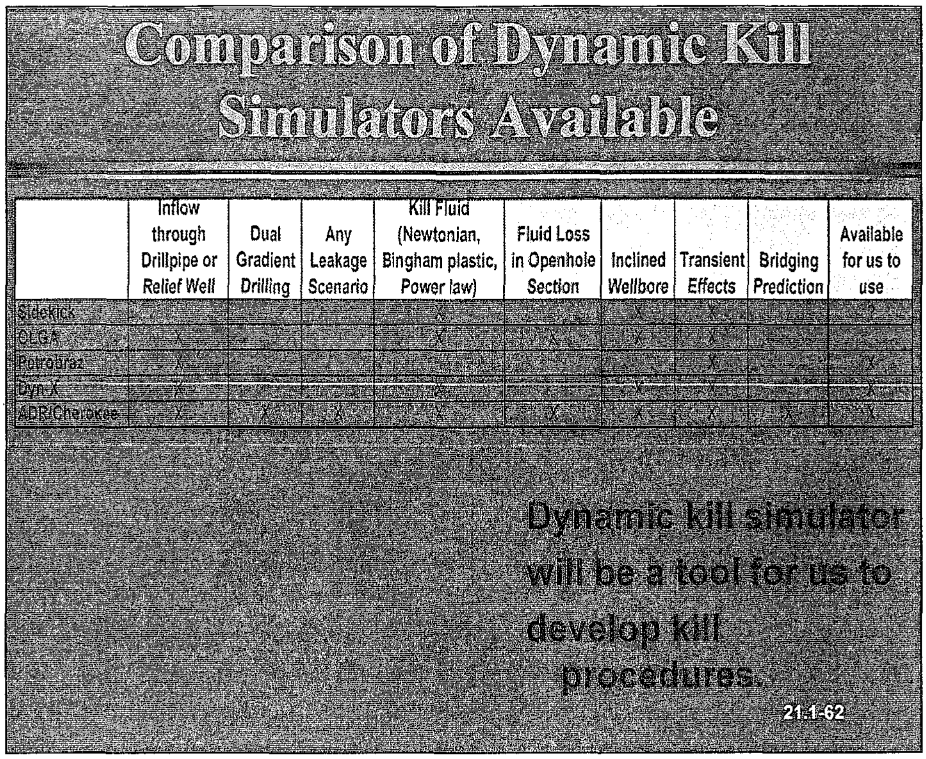
The dynamic kill simulator should be applicable to any type of uncontrolled flow.


Static Part:
Determine
Uncontrolled Flow
Seal Port Failure
Blowout gas observed by ROV
at wellhead connector
Below
Casing Seat:
Drilling
Completion
Production
21.1-60

Deliverables for Dynamic Kill Simulator

- Fully Three Phase Transient Multiphase Flow Model
- Any Possible Well Configuration
- All Possible Leakage Points
- Dual Gradient Drilling Option
- Multiple Influx Zones
- Lost Circulation at Weak Zones
- Newtonian and Non-Newtonian Kill Fluid
- Bridging Prediction
- Simulator Written in Java Code

What we need....



Comparison of Dynamic Kill Simulators Available

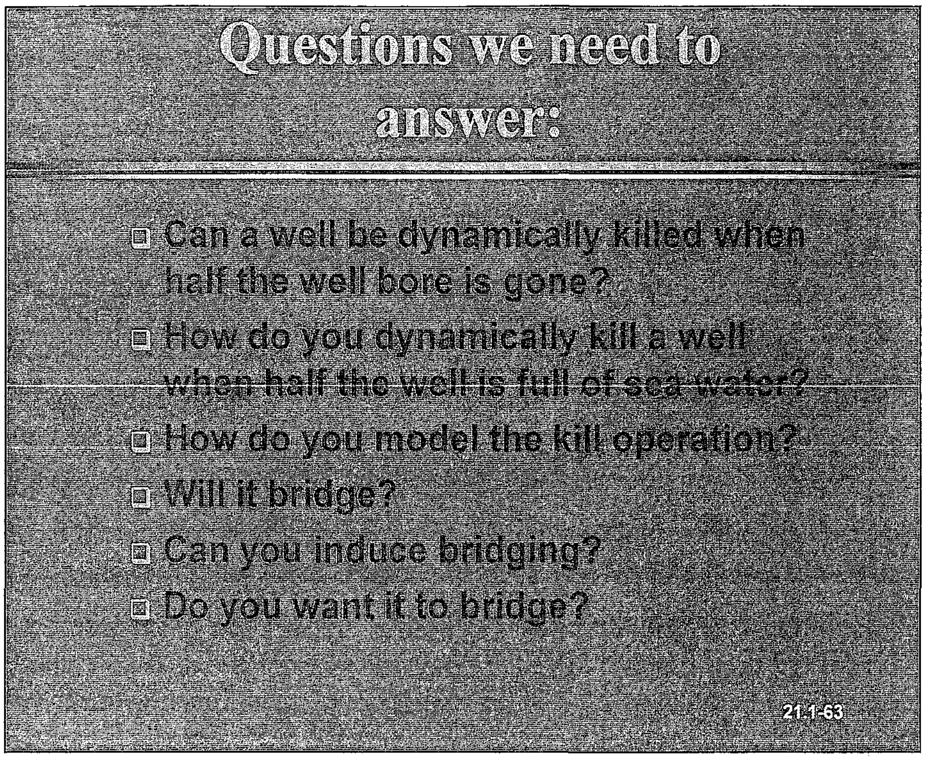
	Inflow through Drillpipe or Relief Well	Dual Gradient Drilling	Any Leakage Scenario	Kill Fluid (Newtonian, Bingham plastic, Power law)	Fluid Loss in Openhole Section	Inclined Wellbore	Transient Effects	Bridging Prediction	Available for us to use
Sidekick				X		X	X		?
OLGA	X			X	X	X	X		
Petrobras	X						X		X
Dyn-X	X			X		X	X		X
ADR/Cherokee	X	X	X	X	X	X	X	X	X

Dynamic kill simulator will be a tool for us to develop kill procedures.

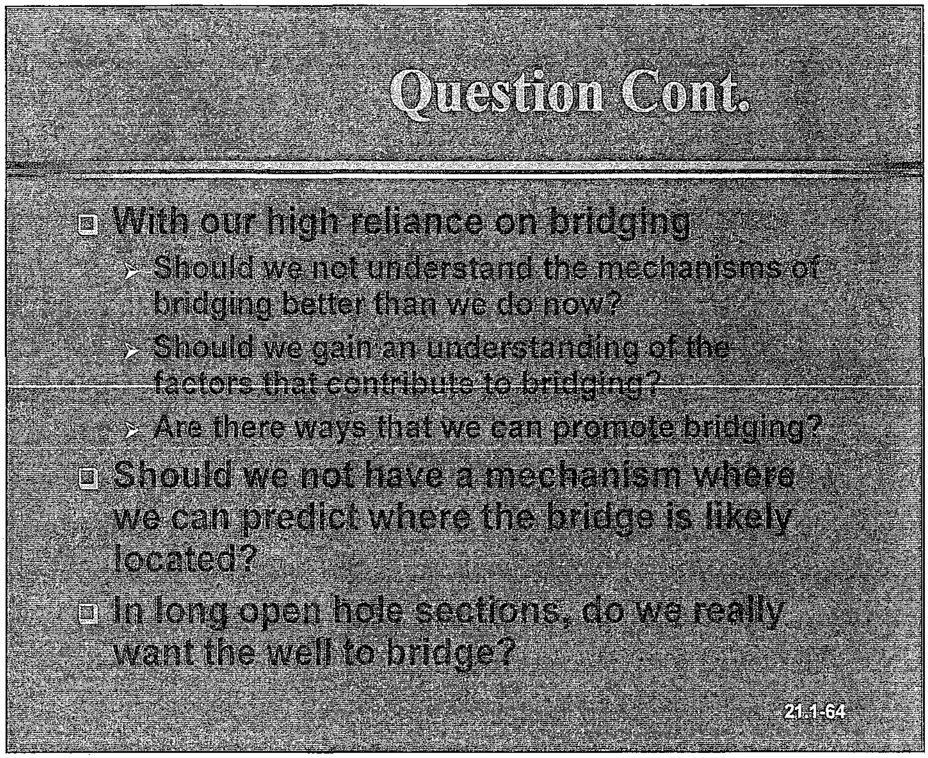
21.1-62

There are many dynamic kill simulators on the market. None of them fits our need. They are either lacking functionality and/or are not available for us to use.

It is important to note that our dynamic kill simulator is not meant to compete with simulators on the market.



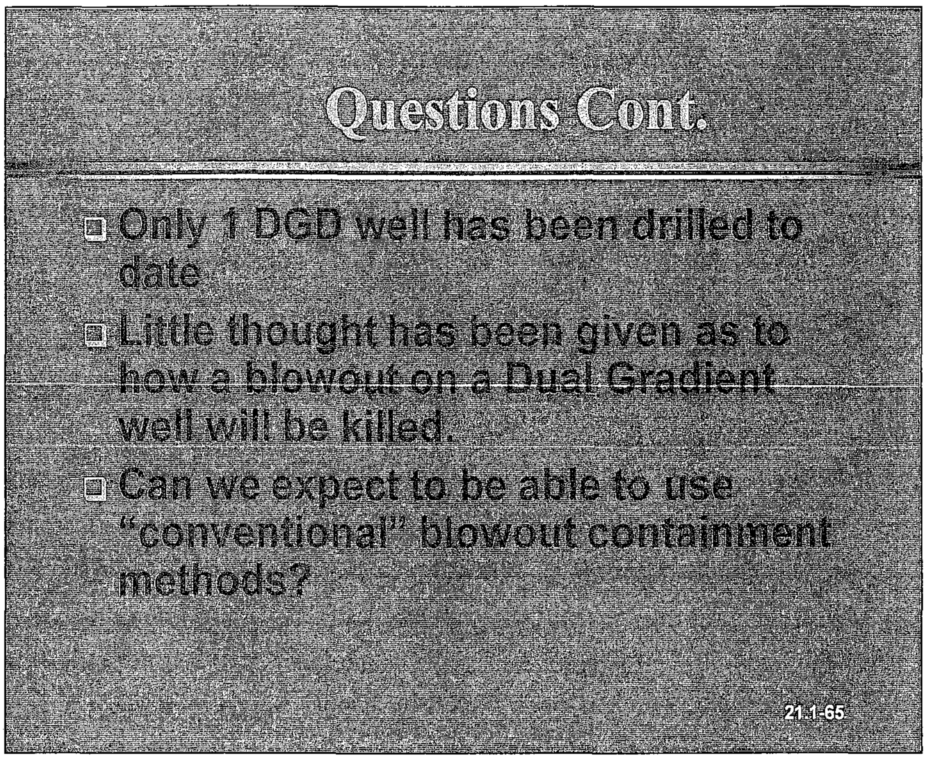
Conclusion….. these are the questions that needs to be answered in the future.



With our high reliance on bridging, should we not understand the mechanisms of bridging better than we do now?

Should we not gain a better understanding of the factores that contribute to bridging?

Are there ways that we can promote bridging?



Only 1 DGD well has been drilled to date and it was in less than 1000' of water.

No one has given any thought (and reported it) as to how a blowout on a Dual Gradient well will be killed.

Can we expect to be able to use "conventional" blowout containment methods?

Vertical intervention is not likely to work if the drillstring or BOP's are not intact.

It is likely that a relief well will have to be drilled with DGD technology.

Deliverables

- A best practice guide for blowout procedures.
- A study to determine the likelihood of of a well bridging.
- Ways to induce bridging.
- The consequences of undesirable bridging.
- A dynamic kill simulator for conventional and dual density wells
- Blowout control methods for dual density wells.
- Cost estimate for deepwater intervention.
- A final report in electronic format.

21.1-66

The objectives of this study will be……