Argonauta Drilling Services L.L.C.

Moving Forwards from Macondo

This document should be considered to be a "working document", subject to discussion and amendment . Questions are welcomed, including those to clarify the content or intent of the document , which is recognized may not have been perfectly articulated.

Objectives of Approach

Minimize the possibility of any future incident……not possible to say it will not happen again

Minimize the consequences of any such incident

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Reflection on Macondo and Montara

Montara – West Atlas Jack-up

- **No fatalities**
- **Well blew out for 2 months**
- **Rig caught fire when kill mud pumped**

Macondo – Horizon Semi-sub

- **11 fatalities**
- **Well blew out for 86 days**
- **Rig caught fire when hydrocarbon 1st reached surface**
- **Oil reached shore**

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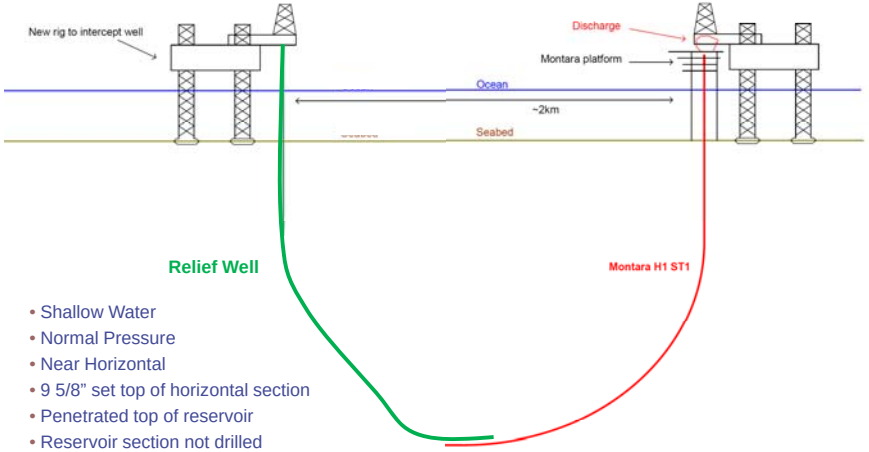
Montara Well – Australia (1)



- Shallow Water
- Normal Pressure
- Near Horizontal
- 9 5/8" set top of horizontal section
- Penetrated top of reservoir
- Reservoir section not drilled

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Montara Well (2)

- 9 5/8" casing run and cemented April 2009
- Float shoe failed to hold – cement flowed back
- Pumped cement back down casing
- Potentially ruined shoe track
- 9 5/8" pressure containing corrosion cap (PCCC) installed
- No other internal barrier installed

- Aug 21st 2009: Came back to work on well (Rig on other slot)
- Removed PCCC
- Other operations – perhaps slightly reduced hydrostatic
- Well blew out – Rig evacuated – No fatalities – Well did not catch fire until 2 months later

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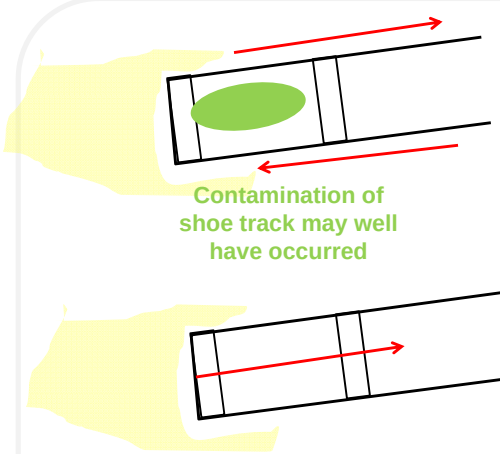
Montara Well (3)



Montara Inquiry – Mar/Early April 2010 – Transcripts and submissions cover all of above. Report issued 11/24/2010.

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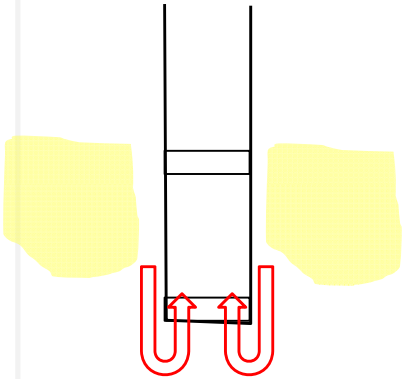
Macondo

7" x 9 7/8" casing



Apparent failure of shoe track

No additional barrier installed, even given the problems with the cementing job

Negative pressure test mis-interpreted

Flow (apparently) thru' shoe track & inside casing

Many other issues – see Commission hearing on Nov. 8th/9th

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Summarization of These 2 Incidents (1)

- Lack of Barriers was key in both cases
- Human Factors were key in both cases
- In one case equipment (BOP) may have failed (but was only activated at the time of the explosion) – In the other case, equipment was simply not installed
- Fire may break out at any time – Luck is essential
- Deepwater may allow for easier intervention

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Summarization of These 2 Incidents (2)

The failures were in the "process" and the "systems design" – a lot of "human factor" is involved

Multiple process failures

- Failure of the float collar
- Failure to ensure the crew measured pit gain
- Failure to ensure appropriate use of a riser gas handler?
- Failure of the BOP to close following the explosion

Systems design failure

Underlying well design

Long string – Macondo

Near horizontal well - Montara

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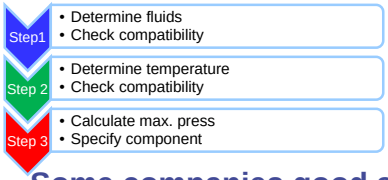
Systems and Processes

Systems Design (shown for yacht)

Iterative – hard to describe what to do!

- It is almost impossible to describe how to perform a systems design or indeed how one was performed even after the event.
- It is readily possible to assess the effectiveness of a design once the design is finished.
- Changes to any part of the system can inflict a critical flaw in the system – any changes must be subjected to a comprehensive MOC program



Process Generation

- Linear – Can (& will) have guidelines/ procedures for completing these tasks
- Provides disciplined checklist(s) for components of the system (for example: detailed casing specifications)

Some companies good at one but not other – obviously they have to be good at both

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Moving Forwards

Understanding of what happened on Macondo
(& Montara)

It won't be the same next time (?????)

We must assure ourselves that the same thing won't happen

We must be able to identify what else could happen and take steps to avoid or mitigate – realistic modeling is a key activity

It may be impossible to put together a "how to" that covers all cases – it is more practical to review each well and adjust designs and procedures using "underlying rules/practices/ experiences/engineering analysis"

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Objectives of an Effective Program

Prevent Injury and/or Loss of Life (immediate time frame)

- Focus on well control prevention
  - Well design to allow safe operations
  - Assessment/Replacement of barriers
  - Influx/Kick detection
  - Solid procedures – Reliable Equipment
  - Training

Minimize Pollution (following failure to prevent initial incident)

- Focus on well control prevention (as above)
- Well design to allow for intervention and minimization of blow-out flow period

Ability to Recover from event

Ability to Progress work- after Loss of Life/Pollution/Recovery assured

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Well Design – Easier Normal Operations

A "Systems" Design is required

- Well geometry
  - Long string vs liner
- Drill string Geometry
- Mud properties
- Rig equipment

Key is to look at the well as a system and identify what can happen and if a different geometry will help to resolve the issues. It is an iterative process – difficult, if not impossible to use a "linear" approach

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Well Design – Industry Approach

Once you have a well geometry

- Specify Load Cases
- Run Analysis using Triaxial Analysis Program (e.g. Wellcat/Stress Check)
- Iterate to satisfy Safety Factor requirements

This is essentially a FMEA

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Well Design – Formalization

A failure modes and effects analysis (FMEA), is a procedure for analysis of potential failure modes within a system for classification by the severity and likelihood of the failures.

Essentially, it is identifying all of the "load cases" that can occur and then analyzing each situation to determine the result.

The difficulty is in identifying all of the "load cases" – this is made worse if the well geometry is complex…effect of trapped annuli etc..

How did this work for the 16" string on Macondo? This casing string was exposed when drilling into the reservoir.

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Well Design – Macondo 16"

- **Given the burst rating of the 16" (with burst discs installed), and given the distinct possibility that the flow was between the 16" and 9 7/8" x 7", there was a reluctance to move more quickly, install a 2nd BOP and shut the well in – this took 86 days on Macondo**
- **<u>Maybe the well should have been designed to accommodate an oil gradient back to the wellhead</u>**
- **Suggest that for hole sections that penetrate the reservoir, casing is in place whereby the well can be shut-in should a blow-out occur. This will not reduce the chance of a blow-out, but will significantly reduce the period of the blow-out in many cases. Might consider an oil gradient.**
- **At the least, the load cases that can be handled and those that cannot must be readily transparent to the whole well team and to any individuals/bodies that review/approve**

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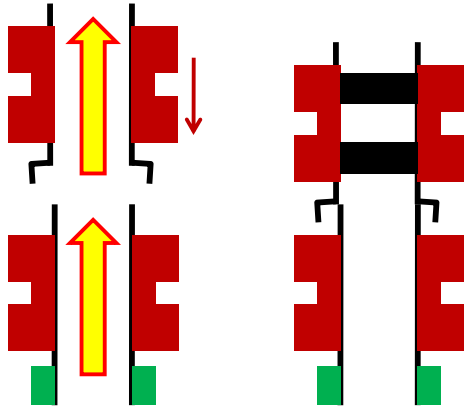
Well Design – Intervention

Deepwater is good! We can move a replacement or additional BOP on top of a wellhead even though the well might be flowing at 50-60,000 BOPD

Fluid velocity is not greatly accelerated – "little" gas expansion at water depth



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Well Design – Intervention

If you can access the well and install a replacement or second BOP you can dramatically reduce the time period of the well blowing out!.....weeks to days….it should be possible to have an emergency BOP/Shut-off on standby!

However, the well must have the integrity to allow this shut-in.

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Barriers – A (if not The) Key Element

2 Barriers plus Cement

Qualification of Barriers

Assessment of Barriers

Ongoing Reporting of Barrier Condition

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Barriers Characterization

Category	Principle
Red	One barrier failure and the other is degraded/not verified, or leak to surface
Orange	One barrier failure and the other is intact, or a single failure may lead to leak to surface
Yellow	One barrier degraded, the other is intact
Green	Healthy well - no or minor issue

Table 0-1: Overview of category principles

Recommended guidelines for Well Integrity

Further detail from Well Integrity Forum (Norway)

"Typically a well categorized as Red will be outside the regulations. Repairs and/or mitigations will be required before the well can be put into normal operation and there will usually be an immediate and urgent need for action."

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Establishing What is Normal (1)

Setting out a "Baseline" such that the drilling crews know what is "normal" and in particular "what is not normal". They need to know what to look for!

- Well & rig specific (focuses in on what is relevant – allows crew to discount what will not happen on their operation)
- (Simple) Procedures based on well drilled and equipment installed
- Communication with all members of the rig crew – it is important that the pit hand knows when to call the Driller!

Modeling Using "Dynamic Drilling Simulator" (Drillbench/ OLGA) or similar…..well control events are like airplane emergencies…..very infrequent…..we must train our crews on realistic rig/well specific simulators such that they know what to do.....training pilots on Microsoft Flight Simulator simply won't work!!

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Establishing What is Normal (2)

The focus is on "eliminating the human factor"

- Misplaced optimism
  - "we should be seeing a gain…must be gas expansion"
- Herd mentality
  - "The toolpusher thinks it is no problem"

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Establishing What is Normal (3)

1. Must use a very high level of analysis to provide the required understanding (of events in the annulus) to remain between the pore pressure/frac gradient window and know what an influx looks like (undetected and detected/ dealt with)……especially as SOBM is involved. Must use modeling tools such as Drillbench/OLGA which give transient/realistic results.
2. For "simple" events (for example) negative pressure tests
   a) Must map out up front what should be observed
   b) Must keep fluids system simple enough such that there can be no confusion about the results
3. Must "translate" what is likely to be seen into specific observations that the rig crew can make and verify that the rig equipment is capable of and is laid out such that these observations can be made.

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How to have the Rig Crew Understand

Training different to IADC WellCap

- Rig and well specific
- Model up front what is normal…be able to graphically show how the "system" reacts and can be operated
- Detail "What" must be done
- Detail "Why" the procedures are in place
- Include all of the rig crew
- Much greater focus on the annulus!

Use of the Realistic/Graphical model allows this to be successful – Roughnecks do not have to understand simple(misleading) physics

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Reflection on Simpler Wells

Simpler wells:

- Higher window between pore press & frac gradient
  - Can overbalance without fear of losing returns
  - Do not have to pay so much attention to calculation – simple drill pipe well control methods work
- Access to annuli
  - Can bleed off any trapped pressure
  - Can monitor trapped pressure
- Typically wells capable of much lower flow – Consequences will be MUCH LESS
- Barriers still essential (see Montara Example)

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Reflection on Simpler Wells

Barriers still most important

Montara showed that a lack of barriers can lead to disaster

"Simpler" well design (no APB) and well control approach is appropriate

Tighten up on BOPE specification & maintenance….essential, given that it may be more difficult to install equipment if the well does blow out

IADC/WellCap well control is probably sufficient – but must pay attention to horizontal wells, SOBM etc.

May consider well/rig specific modeling/training to identify "what is normal" – probably essential on horizontal and certain other well types

May consider "Pre-Installing" independently operated Super-Shear Sealing Rams on any "high consequence" well

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BOP Equipment

For most wells we should be able to drill and complete a well without using a BOP

Implies maintaining hydrostatic control with mud and or completion fluid

A BOP is needed when:

- The formation pressure is different than expected
- A "less than perfect" operation is conducted
- A different piece of (downhole) equipment fails

How can we Ensure that the BOP will work when we (very infrequently) need it?

API RP 53 is a start!! But!!!!...enhancements such as OTC 20059 are suggested

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BOP Equipment

Perhaps a 2-tier approach?

New (Deepwater) Rigs……focus on OEM equipment…… somewhat like taking your Cadillac back to the dealer

Shallow water (simpler systems)…..equipment may be replaced/substituted…..somewhat like taking your Ford Focus to the local garage

Perhaps the approach is summed up:

1. Verify condition & functioning of mechanical parts of system
2. Simplify the control system
3. Feedback detail of equipment operation to verify functioning and deterioration (if any) of BOP and control system

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Final Thoughts (1) – Questions to Ask

Which barriers are in place & what incidents can they withstand?

If the well were to blow-out, could it be shut-in?

What steps have you taken to ensure that the rig crews will recognize what is going on and take appropriate actions?

What processes are in place within the operator (well) and contractors (rig & services) to ensure that the required level of attention has been taken?

For the BOP and other equipment, more work is still to be carried out, but have you determined the flows and pressures that it might see & do the operational procedures reflect this understanding?

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Final Thoughts (2) – What is Missing?

What is missing from the proposed final rule?

If the well were to blow-out, could it be shut-in?

- Slides #12- #18 sum up this area
- Work must be carried out to better identify load cases. Realistic modeling will be a key activity.
- For shallow water wells, additional focus on the BOP and independent control of it are appropriate

What processes are in place within the operator (well) and contractors (rig & services) to ensure that the required level of attention has been taken? Further reflection is required to best work out how to assess this area

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Specific Comment on Proposed Final Rule

Citation and Requirement	Recommendation	Applies to
§ 250.198(a)(3) All documents incorporated by reference "should" and "shall" mean "must"	Based on NTL No. 2010 N05.	All operators
§ 250.198(h)(79) Incorporation by Reference of API RP 65 – Part 2 Isolating Potential Flow Zones During Well Construction	Safety Measures Report: II.B.3.7: Enforce Tighter Primary Cementing Practices	All applications for permit to drill (APDs).**
§ 250.415(f) Written description of how the operator evaluated the best practices included in API RP 65- Part 2. The description must identify mechanical barriers and cementing practices to be used for each casing string.	Safety Measures Report: II.B.3.7: Enforce Tighter Primary Cementing Practices	Submitted with APD. Applies to all APDs.

Some caution required with this statement….It would be appropriate to require that the "intent" of the related API and other cited documents is followed. It is not appropriate to require that the letter of these documents is followed because there are discussions of alternatives within the documents and some instances where following the suggestion within a document will lead to a poor design given the other characteristics of the system This is the issue of the "Systems Design" as shown in Slide #10 above.

API RP 65 provides some guidance as far as isolation of potential flow zones as does Norsok D-010. It is complex trying to work out what is required and will be effective during the design stage. However, it is much easier to assess the barriers at the design stage and then to re-assess on an ongoing basis as operations progress and as the underlying well characteristics are better understood.

This type of assessment has been captured by the Well Integrity Forum in the form of a colored (Green/Yellow/Orange/Red) assessment of the state of the well barriers. It is suggested that a system such as this and which is noted in Slide #20 above is incorporated.

§ 250.416(d) Include schematics of all control systems and control pods.	Safety Measures Report: I.B.5: Secondary Control System Requirement and Guidelines	Submitted with APD. Applies to all APDs.	No comment – seems reasonable.
§ 250.416(e) Independent third party verification that the blind-shear rams installed are capable of shearing any drill pipe in the hole.	Safety Measures Report: I.C.7: Develop New Testing Requirements. Also in NTL No. N05.	Submitted with APD. Applies to all APDs.	There may be a conflict between the strength of casing required to assure capability to shut-in on a blow-out and the capability of a shear ram to effect shear….the possibility of a small window when running very high strength casing may need to be left available.
§ 250.416(f) Independent third party verification that subsea BOP is designed for specific equipment on rig and specific well design.	Safety Measures Report: I.B.2: Order BOP Equipment Compatibility Verification for Each Floating Vessel and for Each New Well. Also in NTL No.	Submitted with APD. All APDs for well with subsea BOP stack. Subsea BOP stacks are usually employed in deepwater.	No comment.- seems reasonable

Citation and Requirement	Recommendation	Applies to	
	N05.		
§ 250.416(g) Qualification for independent third parties.	Based on NTL No. 2010 N-05.	All APDs.	No comment.- seems reasonable
§ 250.420(a)(6) Certification by a professional engineer that there are two independent tested barriers and that the casing and cementing design are appropriate	Safety Measure Report: II.B.1.3: New Casing and Cement Design Requirements: Two Independent Barriers. This requirement was also addressed in NTL No. N05.	Submitted with APD. Applies to all APDs.	Liabilities that will be placed onto a "Professional Engineer" are an issue. The PE approach demands that the PE is intimately involved in all aspects of the design and also in primary communication as the well is drilled and small variations in the plan are made or happen. All liability for the well must remain with the operator without any "dilution" to a PE, although review by a PE or other "independent and reputable" 3rd party is totally appropriate.
§ 250.420(b)(2)	Safety Measure	Completed	

§ 250.420(b)(3) Installation of dual mechanical barriers in addition to cement for final casing string.	Safety Measure Report: II.B.1.3: New Casing and Cement Design Requirements: Two Independent Barriers. This requirement was also addressed in NTL No. N05.	Completed during the casing and cementing of the well. It applies to all wells drilled.	Given the Montara and Macondo incidents (see slides #6 and #7 above), this is required
§ 250.423(b) The operator must perform a pressure test on the casing seal assembly to ensure proper installation of casing or liner. The operator must ensure that the latching mechanisms or lock down mechanisms are engaged upon installation of each casing string or liner.	Safety Measure Report: II.B.2.5: New Casing Installation Procedures. This requirement was also addressed in NTL No. N05.	Complied with after the installation of each casing string or liner for all wells drilled with a subsea BOP stack. It is tested after the installation of the casing or liner.	Given the Montara and Macondo incidents (see slides #6 and #7 above), this is required. In addition (see Slides #21 - #24 above), it is imperative that the operator establish what is “normal” for this type of testing event, such that the rig crew is in no doubt as to what to look for and whether or not there is an event going on which is “not normal”.

Citation and Requirement	Recommendation	Applies to	
§ 250.423(c) The operator must perform a negative pressure test to ensure proper casing installation. This test must be performed for the intermediate and production casing strings.	Safety Measure Report: II.B.2.6: Develop Additional Requirements or Guidelines for Casing.	Tested after running the casing. All wells, involves all rigs with surface and subsurface BOPs in all water depths.	Given the Montara and Macondo incidents (see slides #6 and #7 above), this is required. In addition (see Slides #21 - #24 above), it is imperative that the operator establish what is "normal" for this type of testing event, such that the rig crew is in no doubt as to what to look for and whether or not there is an event going on which is "not normal".
§ 250.442(c) § 250.515(e) § 250.615(e) Have a subsea BOP stack equipped with remotely operated vehicle (ROV) intervention capability. At a minimum, the ROV must be capable of closing one set of pipe rams, closing one set of blind-shear rams, and unlatching the lower marine riser package.	Safety Measure Report: I.B.5: Secondary Control System Requirements and Guidelines. This requirement was also addressed in NTL No. N05.	Applies to all subsea BOP stacks.	No comment.- seems reasonable

§ 250.442(c) § 250.515(e) § 250.615(e) Maintain an ROV and have a trained ROV crew on each floating drilling rig on a continuous basis.	Safety Measure Report: I.B.6: New ROV Operating Capabilities; II.A.1: Establish Deepwater Well-Control Procedure Guidelines	Ongoing requirement. All subsea BOP stacks regardless of water depth.
§ 250.442(f) § 250.515(e) § 250.615(e) Provide autoshear and deadman systems for dynamically positioned (DP) rigs.	Safety Measure Report: I.B.5: Secondary Control System Requirements and Guidelines	Anytime drilling occurs with subsea BOP stacks on DP rigs.
§ 250.442(e) § 250.515(e) § 250.615(e) Establish minimum requirements for personnel authorized to operate critical BOP equipment.	Safety Measure Report: II.A.1: Establish Deepwater Well-Control Procedure Guidelines	Ongoing requirement. Applies to all personnel that operate subsea BOP stacks. Majority of drilling rigs

More work should be carried out in this area before final requirements are identified. In particular, the findings of the post-mortem on the Horizon BOP should be carefully looked at prior to a “final ruling”.

Citation and Requirement	Recommendation	Applies to
		that use subsea BOP stacks operate in deepwater.
§ 250.446(a) § 250.516(h) § 250.516(g) § 250.617 Require documentation of BOP inspections and maintenance according to API RP 53.	Safety Measure Report: I.B.5: Secondary Control System Requirements and Guidelines	Ongoing requirement. All BOP stacks. All water depths.

A reasonable start. Further suggestion is made on Slides #27 and #28. In particular the use of enhanced BOP function monitoring (OTC 20059) and the availability of a BOP "Black Box" (like and airplane black box) is very appropriate.

§ 250.449(j) § 250.516(d)(8) § 250.616(h)(1) Test all ROV intervention functions on the subsea BOP stack during the stump test. Test at least one set of rams during the initial test on the seafloor.	Safety Measure Report: I.B.5: Secondary Control System Requirements and Guidelines; I.C.7: Develop New Testing Requirements.	During the stump test and initial test on the seafloor. All subsea BOP stacks. All water depths.	No comment – seems reasonable
§ 250.449(k) § 250.516(d)(9) § 250.616(h)(2) Function test autoshear and deadman systems on the subsea BOP stack during the stump test. Test the deadman system during the initial test on the seafloor.	Safety Measure Report: I.B.5: Secondary Control System Requirements and Guidelines; I.C.7: Develop New Testing Requirements		
§ 250.451(i) If the blind-shear or casing shear rams are activated in a well control situation, the BOP must be retrieved and fully inspected and tested	Safety Measure Report: I.C.7: Develop New Testing Requirements. This requirement was also addressed in NTL No. N05.	Emergency activation of blind or casing shear rams.	
§ 250.456(j) Before displacing kill-weight drilling fluid from the wellbore, the operator must receive approval from the District	Safety Measure Report: II.A.2: New Fluid Displacement Procedures	Submit with APD or application for permit to modify (APM). All	This type of activity could be part of the re-assessment captured on an ongoing basis by the Well Integrity Forum in the form of a colored (Green/Yellow/Orange/Red) assessment of the state of the well barriers see Slide #20 above. The condition of the remaining barriers must be part of this assessment.

Citation and Requirement	Recommendation	Applies to
Manager. The operator must submit the reasons for displacing the kill-weight drilling fluid and provide detailed step-by-step procedures describing how the operator will safely displace these fluids.		wells where the operator wants to displace kill-weight fluids. This could occur on all rigs that use either a surface or subsurface BOP stack. Could occur with all water depths.
Subpart O, §§ 250.1500-250.1510 Requires that rig personnel are trained in deepwater well control and the specific duties, equipment, and techniques associated with deepwater drilling.	Safety Measure Report: II.A.1: Establish Deepwater Well-Control Procedure Guidelines	All wells drilled with subsea BOP stack.

Given the Montara and Macondo incidents (see slides #6 and #7 above), this is required.

In addition (see Slides #21 - #24 above), it is imperative that the operator establish what is "normal" for this type of testing event, such that the rig crew is in no doubt as to what to look for and whether or not there is an event going on which is "not normal".

See Slide #24 above. The effective way of doing this is to perform "well and rig" specific training, using the most realistic modeling tools available (for example SPT Group Drillbench/OLGA) to analyze up-front what will happen and then distill down to the rig crews what this means for them. The deliverable is training that provides "What to do", "How to confirm that the operation is going to plan" and "Why to follow procedures "or "When to change a pathway", given the observation at the rigsite.

The basic Wellcap well control training is simply not sufficient

§ 250.1712(g) § 250.1721(h) Certification by a professional engineer of the well abandonment design and procedures; that there will be at least two independent tested barriers, including one mechanical barrier, across each flow path during abandonment activities; and that the plug meets the requirements in the table in § 250.1715	Safety Measure Report: II.B.1.3: New Casing and Cement Design Requirements: Two Independent Tested Barriers	Submitted with APM. All abandonment operations regardless of BOP type or water depth.

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Liabilities that will be placed onto a "Professional Engineer" are an issue. The PE approach demands that the PE is intimately involved in all aspects of the design and also in primary communication as the well is drilled and small variations in the plan are made or happen.

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