Effects of Water Depth on Offshore Equipment and Operations
Topic #5: Post-incident Containment and Well Control

GENERAL PURPOSE

This white paper on "Post-incident Containment and Well Control" is one of six papers that will be used as starting points for discussions in breakout sessions at the November 2-3, 2011 BSEE/ANL/Industry workshop on the *Effects of Water Depth on Offshore Equipment and Operations*. This white paper is meant to provide a brief background of the topic and identify current trends and challenges in this area. This paper addresses:

- Current technologies and challenges with implementing those technologies.
- Trends and/or notable technologies envisioned for the near and long-term
- Coordination and communication to help align the efforts of industry and regulatory agencies
- Human Factors in safety (e.g. training, procedures)

Note: For the purpose of this document, deepwater well operations will be defined as: *"drilling and/or completion operations that are performed from a floating vessel or structure*."

SCOPE

Topic #5 is substantially about the design, implementation, and deployment of deepwater subsea containment systems. These systems would be deployed on "blowout" wells that are being drilled or completed from floating vessels or a floating production structure (including wells utilizing subsea wellhead/Blowout Preventer (BOP) systems and those wells utilizing surface wellheads/BOPs that are drilled and completed from floating facilities such as spars or TLPs). The subsea containment systems would in all cases be deployed on the seafloor. The systems would be used to achieve one or more of the following:

- Full shut-in and containment of the well via well capping.
- Shut-in of the well with subsurface pressure relief that will not broach the seafloor.
- Containment of the well within a system that allows flow to the surface until a relief well can be drilled.
- Provide for well kill operations such as top kill, bull heading, volumetric kill, and/or secondary intervention by another vessel or rig.

This paper begins with an overview of the causes of a well blowout, typical methods of regaining control, current and near-term challenges, and the new subsea well containment systems. From this foundation, the document identifies and discusses existing technical, operational and regulatory challenges associated with the design, construction, implementation, & deployment of deepwater subsea containment systems and regaining well control. Additionally, consideration is given for the challenges associated with the progression of subsea containment into deeper water depths.

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INTRODUCTION

Primary well control is achieved by a combination of the density of the circulating well fluid system (mud), the mechanical integrity of the well itself (tubulars, cement, and tubular hanging & sealing system), and the integrity of the rock in the open wellbore. The fundamentals of well design to achieve primary well control are the following:

- Predict/determine formation/pore pressure versus well depth and formation fracture resistance/strength versus well depth.
- Determine mud densities necessary to manage the pore pressure versus depth.
- Determine points at which the hydraulic pressure of the required mud density closely approaches the formation fracture resistance.
- Set and cement concentric strings of well tubulars at these points to protect the shallower formations.

During a drilling operation, the well is continuously monitored to ensure the density of the static fluid system delivers a hydraulic pressure that exceeds the pore pressure in the permeable formations penetrated. If the hydraulic pressure is insufficient, the formations penetrated in the open hole may begin to flow into the well (this could be either or both saltwater and hydrocarbons flowing). This event is referred to as a “kick”. A fundamental task in drilling besides maintaining proper mud density is the recognition and early detection of kicks. Although the well is planned for to avoid “kicks”, it is not uncommon, especially in exploration wells for kicks to occur where detailed information about formation pressure is less understood. Kicks can be routinely handled if the kick is detected and dealt with early. They are controlled by shutting in one of the components of the BOP system and circulating out the small inflow in a specifically designed and controlled way while raising the mud weight to eliminate further influxes. Training in these methods is widely required in the industry for well site personnel. A common use of the BOP system is in circulating out kicks – infinitely more common than dealing with a “blowout” situation.

How do blowouts occur?

- Small influxes into the well are not detected, become very large, and cannot be dealt with by normal shut-in and circulation techniques.
- Normal shut-in and circulation fails because of equipment failures.
- Emergency shut-in via the blind shear rams fails for mechanical or other reasons
- Normal or Emergency shut-in by the BOP’s is effective but well blowout downhole in the open-hole section or from casing or shoe failure. This is known as an underground blowout.

BOP devices were first designed to allow shutting in a well that had drilled into and discovered a hydrocarbon zone. In the early days of drilling, the well was simply drilled until it flowed resulting in a “gusher” or what we now call a blowout. Well control and containment procedures and equipment have been in existence for more than a century and have been available and used since the early days of well drilling. The first commercial blowout prevention and well containment equipment were developed and used in the early 1900’s. The ram BOP was invented by James Smither Abercrombie and Harry S. Cameron in 1922, and was brought to market in 1924 by Cameron Iron Works.[1]

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[1] “First Ram-Type Blowout Preventer (Engineering Landmark)". *ASME.org*. http://www.asme.org/Communities/History/Landmarks/First_RamType_Blowout.cfm

Modern BOP systems serve many functions and are used in common well drilling operations including:

- Various tests of the well and its mechanical systems
- Shutting in the well on various size tubulars including an open wellbore
- Circulating out and controlling small influxes (kicks)

The industry has extensive and continuing experience using surface BOP's for oil and gas well containment. These can be on the surface of the ground or above the water on a jack-up rig or production & drilling facility. As the industry progressed into deeper water specialized subsea BOP's for the ocean floor were developed. These are the BOP's normally used by floating drilling rigs. This began in the early 1960's. [2] Subsea BOPs are positioned on the seafloor and not on the rig and are connected to the rig via a riser from the subsea BOP to the rig (for most operations). This approach to well control in deepwater fundamentally differs from land or shallow water equipment in that the point of pressure containment (well shut-in) is shifted from the surface at the rig to the seabed where the subsea BOP must be remotely controlled and monitored by a direct hydraulic (relatively shallow water) or electro/hydraulic control system with several layers of redundancy to improve reliability for deeper water. The BOP must be retrieved to the surface for maintenance and repair which is a lengthy activity on a deepwater rig. In some cases remotely operated vehicles (ROV's) are used in positioning and conducting some tests on the subsea BOP. In emergencies these ROV's can monitor and operate the BOP system.

Subsea BOP's have been available for nearly 50 years. The progression of subsea BOPs into ever deeper water has led to a changes and advances. One of these changes includes standardization of subsea wellhead and BOP sizes to an 18 3/4" bore for most subsea well drilling. Standardization always benefits the industry. The subsea BOP is latched to the top of the wellhead housing. There are minor variations in wellhead housing and functionality, but nearly all these utilize a 'stacked' casing hanger design in which the sequential running of smaller, higher pressure rated casings have their casing hanger landed and nested inside the single high pressure (10 or 15ksi rated) wellhead housing. This design of these wellhead systems allows the subsea well to be drilled to total depth (TD) without having to remove or change out the critical well control BOP to accommodate different size or pressure rating casing.

The use of tension loads from the riser of dynamically positioned Mobile Offshore Drilling Units (MODUs) in deepwater combined with increased subsea BOP weight (from increased functionality) have combined to require wellhead housing systems with higher bending load capacity and more structural foundation capacity at the mudline. Anchored MODUs place similar loads on the subsea system but to a lesser extent.

Deepwater subsea BOP stacks have been designed with two connected sections. A lower (BOP) section with a hydraulically operated wellhead connector on the bottom and the assembly that contains the primary well control BOP rams (including blind/shear rams) and the fluid displacement choke/kill valves. Attached above this using and additional hydraulic connector is a Lower Marine Riser Package (LMRP) section which may include annular preventer(s), some of the control system components for the BOP, and the riser flex joint (which allows the rig and drilling riser system to be offset from the well by some angle without damaging the equipment. The flex joint reduces the loads put on the subsea BOP and the wellhead housing and foundation.

As part of modern BOP controls, an automatic and emergency disconnect function is programmed into the BOP control system to allow the well to be secured and drilling riser and LMRP to be disconnected within 45 to 60 seconds of an emergency well control event. This is

[2] "Blowout Preventers – History Performance and Advances". PetroMin July/Aug 2011 (**www.safan.com**)

done through a pre-programmed series of commands that close critical BOP functions and disconnect the LMRP and drilling riser from the subsea well. These systems are known as EDS or Emergency Disconnect Sequence. In the event that EDS operations are impaired or cannot be activated in time, many deepwater BOP stacks are now designed with Auto-shear and Deadman capabilities to activate closure of the primary BOP rams when hydraulic power and electrical signals are cut-off to the BOP. Lastly, intervention panels are provided on the lower BOP section to ensure that remote operation of critical functions can be carried out by ROV's that can be launched & recovered from a multi-purpose construction (ISV/DSV) vessels or other support vessel responding to the offshore incident.

If well control is lost and/or the rig cannot hold station, the blind-shear rams on the BOP can be activated and shut to prevent a blowout as part of the emergency sequence; this requires that the string of drilling pipe in the well be positioned such that the pipe body is opposite the shear rams and that the pipe is centered via use of the annulars and pipe rams. After drill pipe positioning, the blind-shear rams are activated resulting in cutting of the drilling string and full shut-in and closure of the well by the blind part of the blind-shear rams. Following activation of the blind-shear rams and as part of the automatic sequencing noted above, the upper part of the BOP system called the LMRP disconnects releasing the riser and rig from the BOP.

If the blind-shear part of the BOP system fails to activate or close and seal when needed, there is an uncontrolled blowout at the seafloor. In this case, the response is to regain well control via a subsea capping stack with support equipment.

The majority of necessary equipment and techniques to do subsea containment in deepwater has been known to the industry. However, pre-designed, pre-assembled, and tested systems were not available in the industry prior to Macondo. The Macondo MC-252 incident dramatically demonstrated the importance of pre-staging, and pre-planning of this equipment as well as the importance of planning, practice drills, management of change, simultaneous operations management, logistics, and resourcing to address the requirements of a deepwater subsea containment response. The industry did not have equipment ready to cap and flow a deepwater subsea well that was blowing out. There was a demonstrated need to enhance response capability. Now, the industry has equipment resourced and a pre-defined plan in the event of a deepwater well control incident.

This paper addresses the capabilities of the currently available subsea containment systems. It also discussing any technical challenges that such systems might face in the future as well types and water depths change.

ANALYSIS

A) Technologies & Challenges Implementing those Technologies

Current Technology – Marine Well Containment Company

The Marine Well Containment System and Marine Well Containment Company (MWCC) have been established to enhance industry subsea containment capabilities. The MWCC is a not-for-profit; independent organization committed to being continuously ready to respond to a well control incident in the Gulf, and is committed to advancing its capabilities to keep pace with its members' needs. Membership is open to all companies operating in the U.S. Gulf of Mexico. Members have access to the current interim containment system, as well as the expanded system, upon completion of its construction. Non-members will also have access to the systems through a service agreement and per-well fee. Current members include: ExxonMobil, Chevron, ConocoPhillips, Shell, Anadarko, Apache, BHP Billiton, BP, Hess and Statoil.

The containment systems provide pre-engineered, constructed, and tested containment technology and equipment to be mobilized immediately upon being notified of an incident. Preparation and deployment of equipment will begin promptly upon activation of the MWCC team under the direction of the responsible party and Unified Incident Command. It represents an initial commitment of over $1 billion with substantial continuing commitments for operational and technical enhancements and development costs.

The currently available interim containment system consists of equipment owned and maintained by MWCC along with mutual aid vessels. The system meets the Bureau of Ocean Energy Management Regulation and Enforcement (BOEMRE) (Now Bureau of Safety Environment and Enforcement, BSEE) requirements for a subsea well containment system that can respond to an underwater well control incident in the U.S. Gulf of Mexico, as outlined in NTL No. 2010-N10.

The interim containment system can handle pressure up to 15,000 pounds per square inch (psi) and is engineered to cap or contain a well in deepwater depths up to 8,000 feet. The capping stack itself can be used to cap a well in up to 10,000 feet of water. The system has capacity to contain up to 60,000 barrels of liquid a day (and handle up to 120 million standard cubic feet per day of gas). It includes the 15 ksi capping stack and dispersant injection system. Through mutual aid provided by members, the interim system includes capture vessels for surface processing and storage.

The centerpiece of the system, the capping stack, is about 30 feet tall, 14 feet wide and weighs 100 tons. The capping stack provides a dual barrier for containment - a blowout preventer ram, plus a containment cap. The subsea valves on the capping stack can be closed to cap the spill, or if necessary, the oil flow can be redirected to surface vessels through flexible pipes and risers.

In the event of an incident MWCC will provide the operator of the well with subsea equipment, including risers, dispersant and hydraulic manifolds, as well as the capping stack. Preparation and deployment of equipment will begin promptly upon activation of the MWCC team under the direction of the Responsible Party and Unified Incident Command. MWCC continues to maintain the list of mutual aid equipment inventory, which will be accessible to the member company in the event of an incident.

The Responsible Party would be responsible for well intervention, relief well drilling, debris removal, and deploying operating equipment. The company is also responsible for securing vessels and surface cleanup. The expanded containment system will have dedicated on-call capture vessels.

While the interim system is available now, an expanded containment system is being engineered and constructed for deepwater depths up to 10,000 feet. It has the capacity to contain up to 100,000 barrels of liquid per day (and handle up to 200 million standard cubic feet per day of gas). The expanded containment system will include a 15 kpsi subsea containment assembly, dedicated capture vessels, and a dispersant injection system.

Contracts are in place and construction is underway on subsea containment assembly, process modules, risers, flow lines and umbilicals. The capability of the interim containment system will continue to build as components of this expanded system are completed and delivered beginning in 2012.

Surface Components
The expanded containment system design includes use of capture vessels (modified Aframax tankers) with up to 700,000 barrels of liquid storage capacity, which can process, via processing modules, store and offload to lighter vessels if the capture vessels are needed.

Modular, adaptable process equipment will be installed on the capture vessels and will connect to the riser assembly that directs the oil from the subsea components. The process equipment will separate the oil from gas, safely store the oil and flare the gas. Then the oil will be offloaded to shuttle tankers which will transport the oil to shore for future processing.

During hurricanes, capture vessels will disconnect and move away from the storm for the safety of the operating personnel, equipment and the environment. Once the storm passes and safety has been ensured, the vessels will return and be reconnected to the free standing risers that remain in place.

Subsea Components
A newly-fabricated subsea containment assembly (SCA) (which is the well cap) will create a permanent connection to the well and seal to prevent oil from escaping into the ocean. The assembly will be equipped with a suite of adapters and connectors to interact with various interface points, including a variety of well designs and equipment used by oil and gas operators in the U.S. Gulf of Mexico. Also, mechanical connectors will be available to connect to pipe if one of the planned connection points is not available.

If the well integrity will allow, the SCA (well cap) will shut in the well and stop the flow of oil, without additional system equipment. If there are well conditions that require that the oil continue to flow, the risers will attach to the SCA and other containment equipment via seafloor flexible flowlines to direct the oil to the capture vessels for storage.

The oil captured by the SCA will flow through flexible pipes to riser assemblies, configured to connect to the capture vessels at the ocean surface. An additional component will be available to inject dispersant into the subsea system during a hurricane when surface vessels must disconnect.

In designing the system, MWCC worked with BOEMRE regulators to ensure all expectations were met. MWCC has continued to stay in regular communication with BOEMRE/BSEE, including onsite reviews and witness testing of the capping stack, as well as a review of the interim containment system equipment. The BOEMRE/BSEE has also participated in a responsible party checklist workshop for new member companies, as well as TLP/SPAR checklist development workshops.

A plan to contain a well under a floating structure, so-called TLP or SPAR, has also been put into place. Capping a well in this case requires a plan to move the structure out of the way to allow access to install the capping stack or a plan to lower the capping stack underneath the structure. All of this activity has been defined and is pre-planned before a well is drilled from a floating structure.

MWCC is committed to continually improve the system to meet future member needs, especially as new technologies emerge.
(Illustrations Attached)

<u>Current Technology – Helix Well Containment Group (HWCG)</u>

Twenty-four deepwater energy companies have joined to form the Helix Well Containment Group (HWCG) to develop a comprehensive and rapid deepwater containment response system. The HWCG has invested in technology & engineering and applied lessons learned from the past, to create a comprehensive well-containment response system made up of equipment, procedures and processes ready to be activated immediately in the event of a subsea well blowout. The

HWCG is organized under Clean Gulf Associates, who provides administrative and member services.

Procedures and Processes
The HWCG created a Deepwater Intervention Technical Committee (DITC), comprised of more than 30 technical industry experts, to establish processes and procedures that could be implemented in the event of a deepwater incident. With guidance from BOEMRE the HWCG DITC developed the HWCG Well Containment Plan, a comprehensive and detailed technical plan clearly identifying response protocols for foreseeable deepwater containment scenarios.

Each HWCG member company has committed to a mutual aid agreement, allowing any member to draw upon the collective technical expertise, assets and resources of the group in the event of an incident. Members of the HWCG are conducting a series of crisis exercises and drills to increase coordination and preparedness, striving for continuous improvement.

Equipment
Building upon Helix-owned equipment effectively used in the Macondo response, the system is currently capable of facilitating control and containment of spills in water depths up to 10,000 feet and capture and processing capabilities of 55,000 barrels of oil per day and 95 million cubic feet of gas per day. The HWCG has two capping stacks -- a 15,000 psig capping stack and a 10,000 psig capping stack. The capping stacks are designed to handle deep, higher-pressure wells and would be used in the event a blowout preventer is ineffective. The HWCG has agreements in place with more than 30 service providers who will provide additional services, products and personnel, if needed.

Building upon the foundation of the proven Q4000 intervention vessel, the existing containment system capabilities include:

- The ability to fully operate in up to 10,000 feet of water
- A 15,000 psig capping stack and a 10,000 psig capping stack
- Intervention equipment to cap and contain a well with the mechanical and structural integrity to be shut in
- The ability to capture and process 55,000 barrels of oil per day and 95 million cubic feet of gas per day

(Illustrations Attached)

Explanatory Note – MWCC & Helix
There are many technical and operational differences between the Helix and MWCC systems. However the fundamental differences are flow handling capacity and location of the production risers. The MWCC system uses remote risers while the current Helix system uses a single direct riser vertically above the well.

<u>Current Technology – Other Containment Resources</u>

Many other companies have or are in the process of creating subsea containment capabilities. Most of these are centered on capping stacks. Notable is the Wild Well Control system. These other companies providing discrete subsea containment services do not provide the capability to flow a well to the surface.

Subsea Containment Response Sequence
After a blowout the response sequence for subsea containment is the same for all existing and near term technology. The sequence is:

1 – Attempt to intervene and gain well control via the BOP stack using ROV intervention. Gather data with ROVs and other devices and instrumentation.

2 – Deploy debris field clean-up resources if there is debris and begin removal. This would include multiple ROV manipulated cutting & handling devices along with ROV hydraulic power units for large scale work. It could also include DW hoisting equipment as well as equipment to straighten a bent wellhead.

3 – Immediately deploy the capping stack, subsea dispersant injection system, methanol injection, and open water capture device. Begin subsea dispersant injection and capture with the open water device.

Note: A special case here is if responding to an event that involves a drilling rig on a floating production structure. In this case there are multiple wells and well risers in close proximity as well as the structure itself potentially blocking capping stack access to the well for intervention. This is a complex scenario that could involve modifying the mooring/tendon system of the structure in order to displace it from over top of the blowing well, which has been developed.

4- Install the capping stack. Provide hydrate mitigation as required.

Several different means exist for transporting and handling the capping stack. These can be limited by the size and weight of the capping stack.

It is important to note that current containment systems are designed to make a hard sealing connect to the well. BOP systems are designed to release the LMRP in an emergency sequence. This is the most desirable connection point for a capping stack. It is thus important for this disconnect to be reliable and effective. Other connection points can include the wellhead housing with the entire BOP removed or at the riser connection point. However simple disconnects at the riser connection point are not currently available. If there is a damaged connector or only a well stub/riser stub, containment projects are developing connectors for this purpose.

Full rated pressure connections are generally available for capping stacks to attach to the LMRP disconnect point. There are some BOP's where the pressure is limited at this point by the fact that one of the two annulars is part of the BOP frame and not part of the LMRP. Since the annular has a lower pressure rating than the BOP rams this reduces the rated pressure at this point. This is not a limit for the capping stack because the body test on the annular is often equivalent to the rated pressure of the capping stack. There is always a fully pressure connection point at the subsea housing. If necessary the full BOP could be removed and the well cap installed at this point. The desired sequence is to attach at the LMRP point first and the wellhead housing second.

In the case of Macondo, the cap was actually attached at the riser stress joint connection. This is the least desirable connection point. First it is usually a flanged and bolted connection and not a hydraulic connector. Second the riser is only is only needed for mud return circulation and has a much lower pressure rating than any of the BOP/LMRP components. However, a connection can be made here with difficulty as noted at Macondo. Also reasonably high pressures can be contained making full use of minimal safety factors and test pressures.

5 – Shut the Capping Stack & Shut-in and Fully Contain the Well

If there is minimal debris and there is a clean connect point where the LMRP has released, this is a straight forward operation to install the capping stack. The well is then fully contained and the event is fully controlled. No other containment equipment is required. Achieving this operation successfully is the prime goal of all containment work. If there is another containment event, the likelihood is it can be dealt with in this manner. Thus in many areas now – capping stacks are being made locally available or quickly air transportable as the prime response.

Using the capping stack to gain full shut-in and containment requires that the well have full integrity and can accommodate the pressure from the shut-in. If the well does not have this integrity, a capping stack with a flow system to the surface is required. This lack of full integrity could be a mechanical aspect of the well casing design or it could be due to the fracture pressures of exposed formations in the well. In some special cases, it may be desirable to flow the well with the cap on to mitigate risks from subsurface pressure relief.

6 – If the capping stack alone does not achieve the desired shut-in and containment, deploy the flow system.

The flow system involves the manifolds, risers, interconnecting piping, control systems, and surface facilities to flow hydrocarbons to the surface from the capping stack. On the surface the hydrocarbons are captured and the gas is flared and the oil and water are transported to shore by shuttle tankers. Flow would continue until the well was killed and controlled. The well would most likely be ultimately controlled by a relief well. Some operations such as bullhead killing and volumetric kills may be possible at the well itself.

Challenges Implementing Current Technologies

- **What is the impact of water depth on each of the functions or operations?**

The process and equipment components for subsea containment and well capping are the same regardless of water depth in DW. However the capacity and capability of the equipment has to be matched to the water depth. This includes:

- Hydrate prevention is more difficult as water gets deeper and colder. When hydrocarbon gas is being released near the mudline in these conditions hydrate formation is quite likely. Formation and mitigation of hydrates in this environment must be well understood, evaluated and addressed in the design of well control and containment equipment.
- Intervention vessels and equipment must have adequate ratings for the depths being worked. This rating includes the load capacity of equipment at the surface, the length of coil tubing, hoses, umbilicals, tethers, flexible flowlines, etc. and the ability of the equipment on the seafloor to accommodate the increased pressure and current from increased water depth. Equipment is available in ratings to 10,000 feet. It must be simply qualified and chosen correctly.
- Pressurized hydraulic fluids are often used to provide the motive force for containment equipment. It is more challenging to overcome the effects of the hydrostatic pressure of the DW and to provide a sufficient amount of stored accumulator volume and pressures to quickly activate hydraulic functions in the deep ocean environment, such as BOP rams, subsea tooling packages, debris removal equipment, etc.

It should be noted that capping stacks are available and rated for 10,000 feet of water. The full MWCC expanded system will be capable of working in 10,000 feet of water. The limit of the current MWCC interim system is primarily the risers which are risers extended to their maximum length from Macondo. It is not a technical limitation. The 10,000 foot risers can and will be easily constructed. The maximum depth in the GOM is between 12 and 14,000 feet. Current exploration and production is not occurring in more than 10,000 feet of water. Thus containment system do not have a water depth limitation or technical limitation related to water depth in the GOM.

There are benefits to the water depth in DW which include:

- The increased hydrostatic head of the seawater (approximately 0.45 psi/ft or 1 Atm for every 33' feet of depth) has a positive benefit in that this pressure acts on the well bore and actually reduces the flow rate and maximum flowing potential of a subsea well. It also reduces the differential pressure on pressure containing equipment.
- Although questions remain, dispersants are thought to be more effective in deeper water due to the amount of time mixing and dispersion can occur within the water column.

There are limitations in utilizing DW containment equipment in shallow water. The challenges in shallow water include:

- The visibility of shallow water well sites may be affected or obscured due to hydrocarbon or gas releases at the mudline.
- Significantly large hydrocarbon releases in shallow water may render direct vertical intervention on the well almost impossible, because of disruption of the water column in the nearby vicinity of the well site and the potential for high concentration of hydrocarbons directly above the well because of the short vertical water path to the sea surface. It is possible to "fly in" capping stacks latterly in this circumstance but that is not the design purpose of current containment systems.
- The 'watch circle' or operating envelope of dynamically positioned vessels will be reduced in swallow water, especially if these vessels are deploying equipment packages that will be connected to the seabed and vessel (such as riser systems) or are required to maintain station keeping for extended periods of time.

Availability of Relief Wells for Floating Production Systems:

Plans for relief well drilling if required have always been part of an operators planning and portions of this planning are submitted in the permitting process. The information submitted today is more than had previously been required. There are not limitations to drilling relief wells from MODU's in DW. This includes the possibility of drilling a relief well from a MODU to intersect a well drilled from a TLP or Spar that was blowing out. This can readily be done with current directionally drilling and "homing in" in technology. Because of the high rig count in the GOM, availability of MODU rigs for relief well drilling is always assured.

- **What are the most challenging functions and operations?**

The most challenging operation in DW subsea containment response is removal of any debris from the well site. A special case of this is intervention on a drilling well event from a floating production system. This could involve moving the structure in addition to addressing debris. Although debris is not a given in all responses, if it does occur it can be a variety of sizes and weights including the BOP LMRP, a drilling riser, drill pipe, drilling tubulars, or even the entire drilling rig. Much of the debris removal would have to be done with ROVs and crane vessels. Power is limited in deepwater because of the length through which the power (like hydraulics) must be transmitted. Thus hydraulic power units that accumulate power must be deployed on the sea floor. Availability of sufficient DW hydraulic power units must be assured. Lastly this is a non-standard operation that is seldom encountered during normal operations. The volume of ROVs and equipment operating this close together will also result in risk of collision and damage of the recovery equipment itself. This was managed at Macondo but this will always be a key simultaneous operation challenge that can be addressed via good management and planning. Lastly, there could be debris such as a drilling rig that is simply too heavy to be lifted from these depths.

Another challenge in DW containment is conducting the drills, performance tests, and verification tests for containment equipment and system. Such testing if done with full deployment on the seafloor is complex and has some risk of damaging the equipment that you need in a state of readiness. Also deploying a full system may require a large mutual aid effort from several companies, including, in some cases, halting drilling and moving the drilling rig to be part of the response test. How drills are done to be effective but to take into consideration these challenges is important. Subsea production systems are routinely deployed and operated after only performing surface based testing of the systems and hyperbaric testing of some components to prove their capabilities. Containment companies have been formed to ensure continuous readiness to respond. Sufficient drills have been completed to ensure readiness.

An additional major challenge is simultaneous operations (SIMOPS). A subsea containment response requires many vessels in various sizes including shuttle tankers, aircraft, and numerous ROVs. It is a significant challenge to manage all this equipment and its operation. This is further complicated by the small operating area and the risk of collision. There is also the fact that all the SIMOPS have to be done with all equipment in close proximity to volatile hydrocarbons.

There is the impact of adverse weather and its impact on offshore operations. Adverse weather conditions such as strong surface currents in the U.S. Gulf of Mexico (known as ‘loop’ currents) or elevated weather conditions including high wind or sea states and winter storms may hamper or impede the well control and containment operations by impacting the ability of support vessel to carry out routine operations including material handling, crew transfers and crane operations. There is also the risk that all vessels must disconnect and leave for a hurricane, during hurricane season.

There are also minor challenges. The first of these is the lack of training and experience regarding testing and remote intervention on the BOP stack by ROVs. Related to this is the lack of data and instrumentation on current BOPs. This lack of data including condition, well flow-rate, pressures, and ram position makes it difficult to do intervention on a disabled BOP. Lastly, it is the logistics and handling to effectively and quickly deploy capping stacks. Many capping stacks with “flow to the surface” capability are very large and heavy. Some of these cannot be handled or deployed with conventional BOP lifting, handling, and transporting techniques. Containment companies are doing the planning and logistics work to have appropriate lifting, transporting, and handling equipment and techniques available for these large capping stacks. This type of planning and design must continue to be an important part of a containment companies planning and logistics.

There are a number of potential technical challenges and limitations that might manifest them in a full subsea containment response that involves flowing to the surface. These have been designed and planned for in the current containment systems. But they need to be carefully monitored in an actual deployment situation. They may result in system limits if they do in fact become problems. One of these is the flaring of large volumes of hydrocarbons. High volume flaring is difficult and the heat loads on the capture vessel would be very large. These systems depend on water spray cooling. Heat loads may have to be managed which would limit well flow rates. If the containment response requires lengthy flowback times with high rates and pressures, this is a significant load on the containment system equipment including chokes, manifolds, flowlines, etc. Since all this equipment is subject to flow erosion, it could limit the system operation.

Lastly vessel station-keeping and quick disconnect capabilities during hurricanes and other weather/current events could be limiting. The current plan is for the containment systems to disconnect and leave for hurricanes.

Summary Comments – Mitigators to the Most Challenging Functions & Operations:

- Debris removal operations are made significantly easier if the BOP EDS system has been activated and the Drilling Riser and upper BOP (LMRP) package has been unlocked and released from the subsea well. The timely activation of the EDS system is also necessary to protect the personnel working on the vessel and allows the MODU to disconnect and move (or be towed) away from the well site during the blowout.
- The gaps and deficiencies identified in offshore training, equipment and the performance of subsea tooling packages can be addressed by strengthening expectations and performance requirements in these areas.
- Availability of vessels to transport or perform offshore work should be addressed by the well intervention plans and containment procedures being developed by the offshore Industry.

B) Trends and/or notable technologies envisioned for the near & long-term

Containment equipment must be modified or changed to address generally increasing trend in well pressures and temperatures in DW as they this is anticipated. This will likely include increasing temperature ratings to +/- 350 degrees F and pressure ratings to 20,000 psi and potentially even higher.

Technical advancements that reduce weight, improve ease of handling and installation, and speed of deployment and installation should also be evaluated and considered.

Although it is possible to deploy current subsea capping stacks beneath a Spar or TLP, the capability of the equipment and system needs to be further optimized. In particular, specialized smaller well caps would be beneficial in enhancing install-ability.

The value of a project to develop a hydraulic disconnect at the bottom of the riser and above the LMRP should be evaluated. This rapid release of the riser could be beneficial in some situations. Also such a disconnect could include a high pressure hydraulic connection point thus making the top of the LMRP a more useful connection point for a cap. However, the prime effort should be in ensuring that the LMRP always disconnects with no connector damage.

Lastly, there are projects on better instrumented BOPs, new devices that can supplement the cutting capability of mechanical shear devices, and secondary well shut-in devices that can be pre-run on drilling tubulars. They can be activated if needed to close in the casing deep in the well.

C) Coordination & Communication to Align the Efforts of Industry & Regulatory Agencies

1) Current Alignment Mechanisms

To achieve safety and performance objectives, is imperative to establish and maintain an ongoing dialog between operators, equipment and service suppliers, and regulators.

Historically the regulatory agencies have relied upon the technical arm of the API for development of industry standards and recommended best practices. Many of these documents are cited in the **Code of Federal Regulations.** The recent development of the Center for Offshore Safety (COS) within the API is a positive development that will help ensure increased safety.

Industry Standards work is a good way to improve relationships. This is a collaborative consensus process. There are many work groups established in API to create and deliver standards. This work is open to all operators, contractors, suppliers, consultants and the government. This working together and opportunity to communicate openly is extremely valuable to deliver quality standards and relationships. The newly established Federal Advisory Committee (Ocean Energy Safety Advisory Committee) also brings together all segments of the industry including the regulators and government to work cooperatively to develop solutions to these challenges. The recently established containment companies and mutual aid resources regarding emergency response are an entirely new and unprecedented forum for cooperation and collaboration. They are also having active dialogues with the regulators. Lastly there are Industry Conferences, Forums and Workshops as well as Industry Trade Associations that have always played a key collaborative role. In particular industry events are opportunities for open communication. Lastly, there are two other organizations to deliver coordination and communication:

a) Offshore Operators Committee (OOC)

The Offshore Operators Committee is the recommended organizational point of contact to provide an ongoing interface between offshore operating companies, suppliers and regulators. It would be beneficial to further develop this relationship to address cultural issues in support of enhanced offshore safety.

b) Petroleum Equipment Suppliers Association (PESA)

The Petroleum Equipment Suppliers Association is the recommended organizational point of contact to provide an ongoing interface between suppliers of offshore oilfield equipment and services and regulators.

2) Improved Relationships

Are there opportunities for improvement in the relationship between operators, drilling contractors, third party suppliers, manufacturers and regulatory bodies?

Coordination and collaboration between all parties performing work in deepwater operations is the responsibility of the operator or drilling contractor, depending on contractual relationship. Ultimately, the safety management system of the operator must provide assurance that all parties are able to work in a well coordinated fashion and in a safe and environmentally responsible manner.

There are other areas for improvement. Perhaps most importantly is enhanced clarity and certainty in the regulatory process including always having appropriate industry comments (e.g. APA process) into the process. A companion to this is simply more and better dialogue and understanding between industry and regulators in general. A good way to create more dialogue is to have increased regulatory participation in the development and review of industry standards. This occurred more in the past but seems to have significantly reduced in the last few years. Another new vehicle for collaboration is the mutual aid resources and well containment organizations striving to be 'best practice' industry sharing groups. Lastly there needs to be a functioning Center for Offshore Safety to share safety management system best practices while removing barriers to sharing of industry issues regarding safety.

D) Gaps and Issues - Regulations, Standards, Practices, Collaboration, & Technologies

a) Advanced Notification of Proposed Regulation

Operators would like to encourage regulators to provide advanced notice of proposed regulations. This practice has worked well in the past and provided operators with a chance to provide input beneficial to both themselves and the regulatory body. This approach would help to identify issues to be worked and resolved prior to the issuance of regulations.

b) Use of Dispersant

Industry needs clear and concise regulatory guidance on the use of dispersants during incident response. Dispersants ameliorate volatile organic compounds during incident response and their use allows vessels to operate with reduced volatile organic compounds effects. The Macondo response clearly showed that the use of dispersants enhanced the ability of vessels and crews to operate at site and respond to the incident. Industry should improve the efficiency and effectiveness of dispersants during a response. This work should consider use rates, dispersants specifically formulated for subsea use and enhanced mixing and injection techniques including mechanical devices. The regulatory environment needs to support the use of dispersants in subsea containment responses.

c) Hydrogen Sulfide (H_2S)

Industry should consider the potential issues associated with response to a sour service (H_2S) incident. Plans should be developed for subsea containment intervention for sour service operations in the GoM if any are expected or planned.

d) Well Control Training

There is a need for updated and more advanced well control training (e.g. modern offshore MODU & subsea BOP systems) and more validation of competence for key personnel that operate these systems.

e) Risk Based Regulation

Analysis of risk and an assessment of where the industry and regulatory focus would best reduce risk and minimize the probability of hydrocarbon release to the environment should guide and prioritize regulation.

f) BOP Control Systems

A review of the MODU BOP and related well control safety systems (e.g. MODU Diverter control systems) should be done. The future state should be the addition of instrumentation and automatic safety systems to BOPs for the assurance of fail-safe operations. This review should include addressing tighter and more specific well suspension requirements and requirements regarding the removal of gas from mud handling systems.

h) Standards

There is currently no regulatory guidance or API or ISO standard for BOP capping stacks. There is no 'recommended practice' or API RP on well containment measures, techniques, and planning. However, task groups have been commissioned to create both documents. Also API should complete and issue new/updated API documents: RP 96, Std 53, Bul 97 which are in process.

i) NTL No. 2010-N10

There needs to be a mechanism to ensure that the growing guidance in support of NTL N10 is based on a collaborative dialogue that ensures that recommendations and decisions are focused on determining and addressing those areas that focus on the significant hazards and deliver best results in hazard mitigation.

j) Containment Company Cooperation

Collaboration between the various companies providing subsea well containment equipment and services should be considered.

k) Hydrate Prevention
Hydrate formation made using open water capture devices and capping stacks very difficult. There needs to be new and advanced technology to deliver enhanced hydrate prevention and control.

l) Open Water Capture Devices
Consideration should be given to technical and R&D projects that could lead to technical development and new concepts for open water capture devices. Improvements should include better oil capture rates, internal separation capability, hydrate prevention and resistance, and ease of deployment and operation.

m) Command Structure
Improved organizational structures, definition of responsibilities, and incident command functioning for a major subsea containment event should be developed. Current incident command mechanisms did not anticipate subsea containment events and their technical complexity. This improved 'command structure/ infrastructure' should include Government & Industry with pre-defined roles & responsibilities and include enhanced cooperation/collaboration between the USCG and the E&P industry.

- **In which of these areas is the Industry quickly advancing and adapting?**

Industry is moving both collaboratively and rapidly on subsea containment systems and equipment. This quick progress includes the development, availability and construction of BOP 'capping' stacks. Enhanced ROV capabilities generally including new seabed deployed hydraulic accumulator power packs which store additional hydraulic fluid at the seabed to close BOP functions or run specialized ROV tools is also moving quickly. Many more units are already available. There has also been extensive additional testing of subsea accumulators and BOP Control Systems, including remote operation of the EDS. Well designs to allow full cap and shut-in even with annular pressure build-up under worst case discharge (WCD) are being done and the wells constructed. Lastly, there has been a new spirit of sharing of capabilities & best practices between Operators that has been very effective. An excellent example is the formation of MWCC.

Technology and safety collaboration is usually seen as compromising competitive advantage. However, in areas of safety and subsea containment response technology can provide benefits in safety as well as performance. In those areas where subsea containment might be advanced, all should be encouraged to cooperate more fully in order to realize the benefits. Clearly, all parties share the benefit from the reduction in impacts of an event on the industry and the public.

E) Human Factors in Safety (e.g. training, procedures)

Industry is discussing ways in which organizations and personnel can develop from a culture of compliance to one of behavioral norms and motivations that focus on structure and control. At this time, a proactive regulator process of grading and counseling is recommended. Such an approach would deliver improved safety results when compared to the historic pass/fail approach to regulatory compliance.

From the Transportation Research Board of the National Academies: "One of the purposes of SEMS is to make a positive impact on the culture of safety of operators. SEMS elements have been identified as critical to, but not sufficient for, creating a culture of safety. For a culture of safety to exist, there must be a mind set of focusing on safety throughout the organization. The more the operator owns the process, the less the tendency for the operator to equate safety with compliance with prescriptive regulations." – Effectiveness of Safety and Environmental Management Systems for Outer Continental Shelf Oil and Gas Operations (Interim Report 2011).

Other ideas to improve training for containment responses include situational training and testing where staff is stressed under realistic situations and realistic situations to behave and make decisions in ways that support system and personnel safety. A potentially good model for this could be drawn from Nuclear Navy. They have had outstanding safety results with the current program even in the face of relatively high turn-over. A clear best practice in SEMS systems is an effective MOC processes with checks and balances. This includes the 'Stop Work' processes and protocols which - whenever activity or operation appears to be unsafe – allow anyone to take action to stop the work.

SEMS systems and bridging documents must have clear responsibility and decision making processes based on comprehensive and appropriate expert input. Once the component and tools are established, effective process safety & SEMS programs are based on effective implementation and leadership support.
Lastly there needs to be an effective feedback system to guide safety programs that uses the review of major incidents in the OCS and causation factors, including human factor response & decision making that can feedback into improving the system.

- **How are people trained to adequately meet these challenges?**

Containment Companies and Operators participate in table top drills, operational procedure reviews, oil spill and emergency response exercises, well control training classes, etc. Even though Offshore Well Control courses are mandatory for personnel directly involved in, and responsible for, well control and containment operations these courses need to be expanded to give a well systems understanding on how all aspects of the well can potentially impact containment responses. Training and knowledge of the critical MODU and subsea safety systems needs to include non-standard operations such various testing & verification methods and remote (ROV) activation of critical BOP functions. Lastly, 'On the job' training and experience gained from significant hurricane restoration work and response undertaken in the Gulf of Mexico over last 5 or so years has been beneficial as this work has many similarities to subsea containment response.

OTHER FINDINGS & RECOMMENDATIONS

- **Note areas that could benefit from discussion at the workshop**
    - Adoption of a Risk-based approach to offshore well control
    - Need for additional Industry and Regulator dialogue
    - Additional focus on well control, prevention and training: MODU safety systems, subsea drilling and well integrity, and additional BOP/LMRP testing.
    - The importance of early kick detection in subsea drilling operations
    - Greater awareness and understanding of what to do when a large volume of gas enters the riser, what to do about this, and when it is safe to use the MGS (Mud Gas Separator).

- **Include any preliminary recommendations to BSEE, also for workshop discussion**
    - *Someone who is qualified in well control & well suspension should review the current code requirements and 'Best practices' for proper suspension of a subsea well (including the regulatory requirements for an in-situ barrier philosophy) and the ensuing displacement of any 'temporary barriers' including drilling mud.*
    - Someone from Wild Well Control or Randy Smith should discuss the need and the methods for early kick detection in offshore wells, and reinforce that <u>preventative action</u>

must be taken before significant inflow from an uncontrolled well is allowed past the BOPs and up into the drilling riser.

Additional Notes and REFERENCE DOCUMENTATION

i. BOEMRE NTL No. 2010-N10 "Statement of Compliance with Applicable Regulations and Evaluation of Information Demonstrating Adequate Spill Response and Well Containment Resources"

ii. 30 CFR Part 250 Oil and Gas and Sulphur Operations in the Outer Continental Shelf—Increased Safety Measures for Energy Development on the Outer Continental Shelf; Final Rule

iii. BOEMRE well screening tool

iv. API Recommended Practice (RP) 53 is currently being revised and re-issued as API Standard 53.

v. There are currently no standards or pre-existing documents to define the functionality and the requirements for the dozen or so subsea capping & containment stacks that are currently being manufactured, however, an initiative is underway to provide an 'Industry Standard' to address this gap.

vi. The Bureau of Ocean Energy Management, Regulation and Enforcement – Report Regarding the Causes of the April 20th, 2010 Macondo Well Blowout.

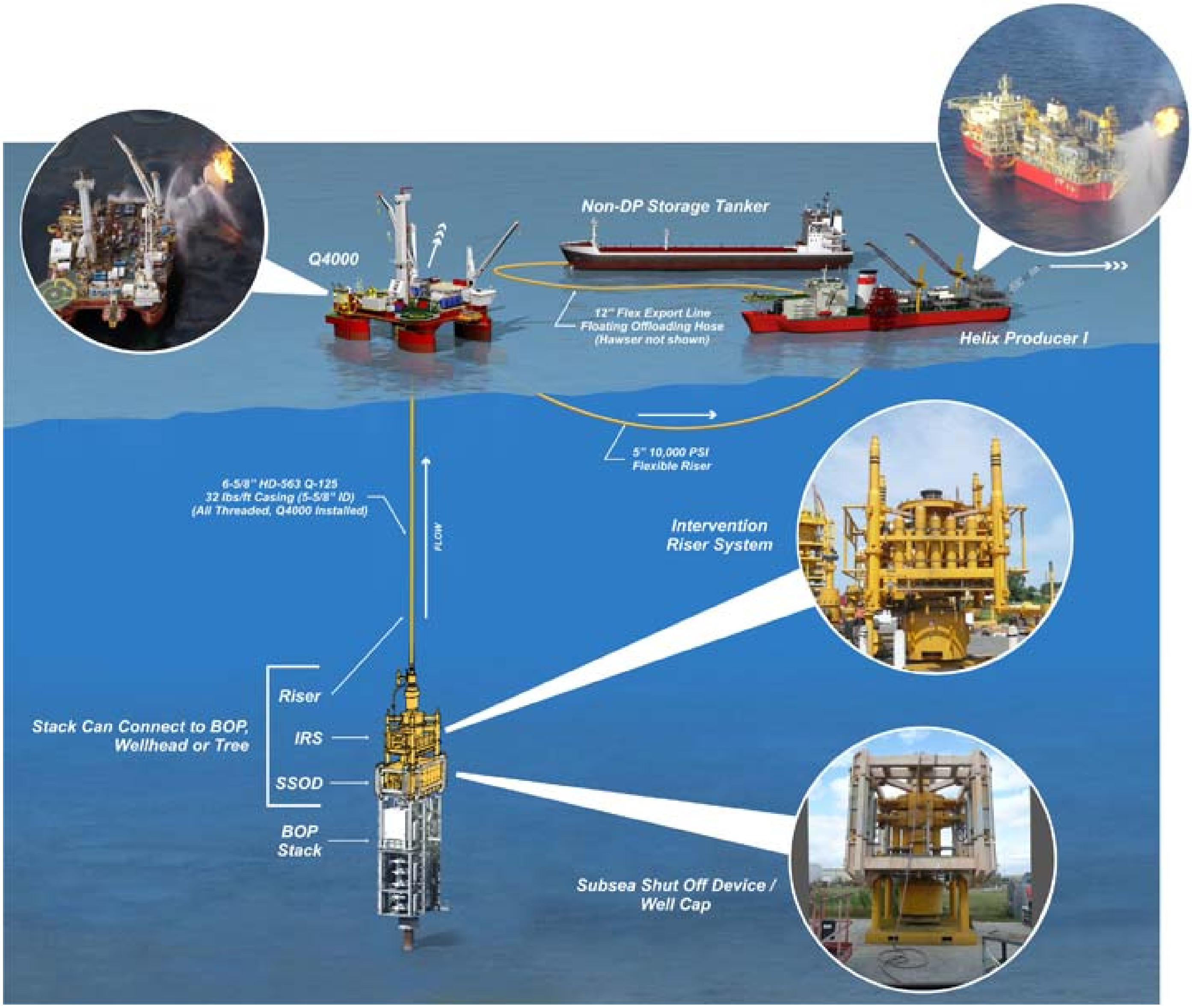
ATTACHMENTS or APPENDICES:

i. HELIX Deepwater Containment System

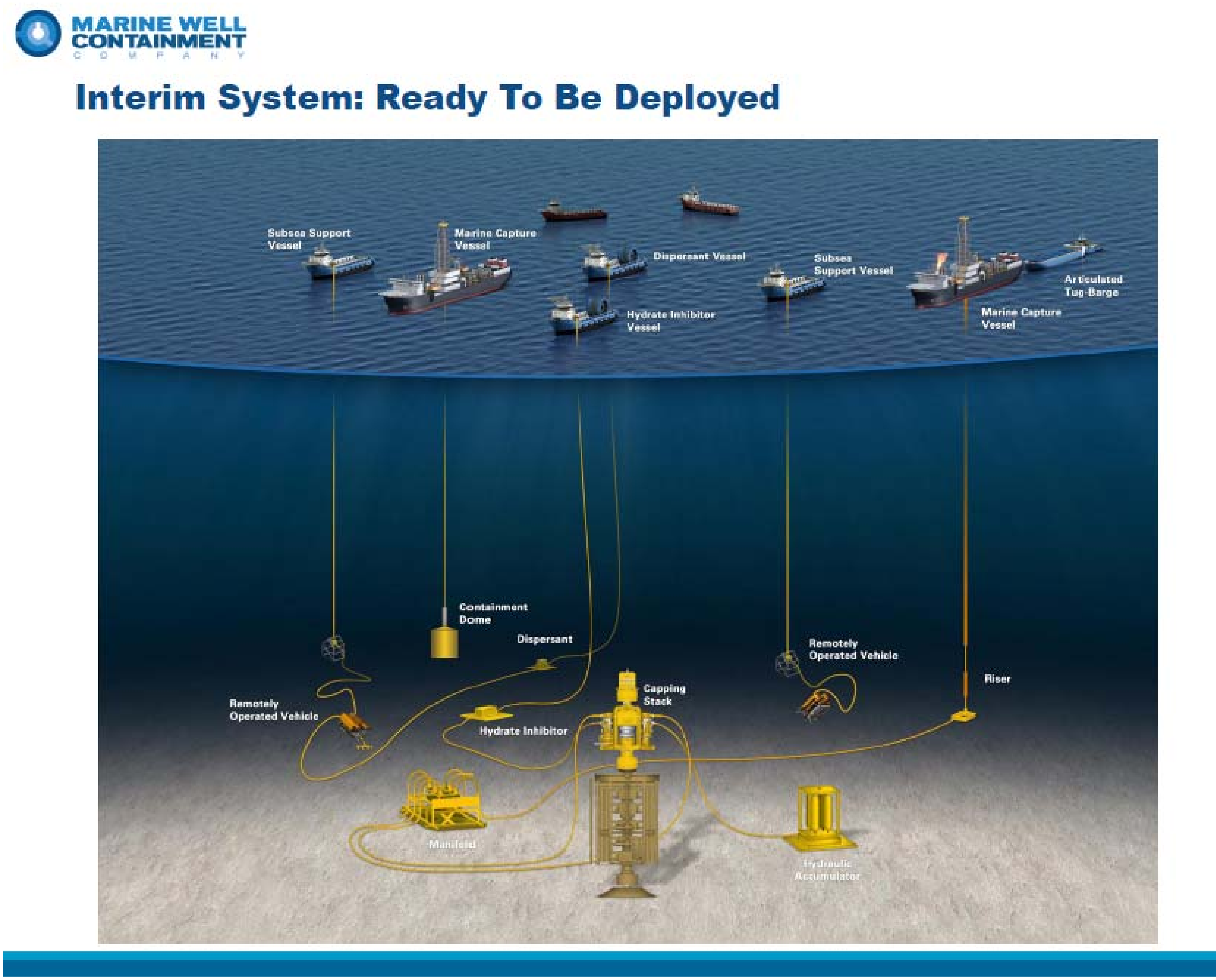
ii. Marine Well Containment Company System

iii. Joint Industry Task Force Report

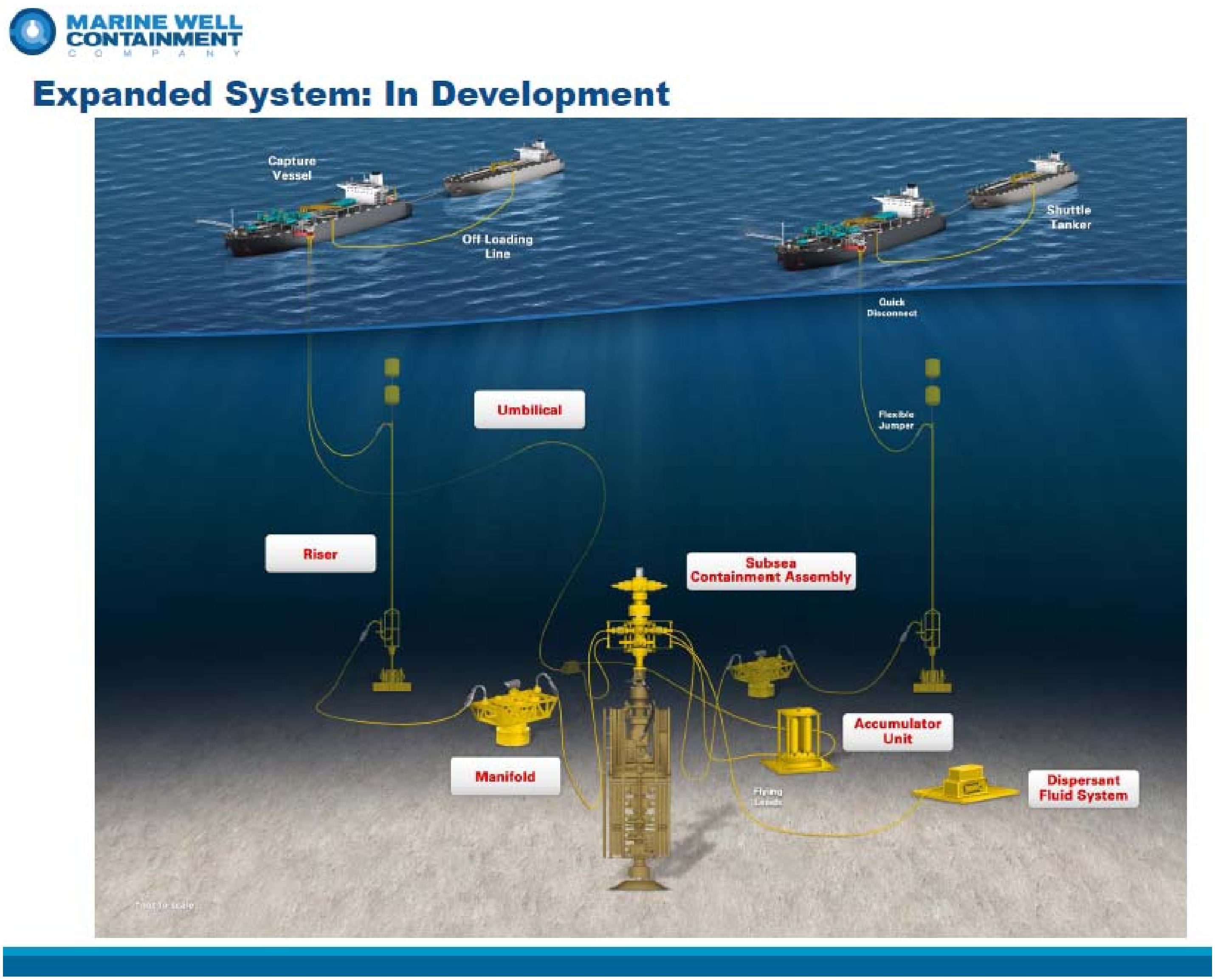
Helix Containment System



MWCC Interim System



MWCC Expanded System



JOINT INDUSTRY

SUBSEA WELL CONTROL AND CONTAINMENT TASK FORCE

DRAFT INDUSTRY RECOMMENDATIONS
SEPTEMBER 3, 2010

Subsea Well Control and Containment Joint Industry Task Force

In response to the Gulf of Mexico (GOM) incident, the oil and natural gas industry, with the assistance of the American Petroleum Institute (API), International Association of Drilling Contractors (IADC), Independent Petroleum Association of America (IPAA), National Ocean Industries Association (NOIA), and the US Oil and Gas Association (USOGA) has assembled a Joint Industry Task Force to Address Subsea Well Control and Containment (Task Force). Overall, the Task Force will review and evaluate current capacities, and develop and implement a strategy to address future needs and requirements in equipment, practices or industry standards to augment oil spill control and containment.

Wherever possible, information developed by the Task Force will be augmented with input from the Regulatory Agencies, oil spill response and well control specialists, investigation panels, and other public sector and other non-governmental organizations. Ultimately, materials produced through this effort will be delivered to Congress, the Administration, and the National Commission on the BP Deepwater Horizon (DH) Oil Spill and Offshore Drilling (Presidential Commission). It is important to note that recommendations will be formulated based on limited information, prior to agency rulemaking, and in advance of any investigative findings in relation to the current incident in the Gulf of Mexico. The contributing joint industry task force companies and trade associations express no views regarding the cause, fault or liability of the incident or regarding any mechanisms of prevention, nor should any recommendations be interpreted as a representation of any such views. The oil and natural gas industry remains committed to working with Congress, the Administration, the Regulatory Agencies, the Presidential Commission, and interested stakeholders as we work to enhance and augment oil spill control and containment.

Schedule and Work Plans

Short-term (Completed Tuesday, July 6)

- Review existing efforts and identify opportunities for augmenting capability, including examination of possible pre-staging of equipment, and research & development in the follow subcategories:
  1. Well Containment at the Seafloor
  2. Intervention and Containment Within the Subsea Well
  3. Subsea Collection and Surface Processing and Storage
- Review industry data associated with operation and testing of subsea well control and response methods, with the objective of identifying issues, areas of concern, etc.
- Identify potential for enhancing capability.
- Develop a strategy and action plan to complete Mid Term commitments.
- Develop subgroups to focus on specific issues.
- Communicate initial findings.

Mid Term (Completed September 3, 2010)

- Review existing testing and inspection requirements, regulations, protocols for subsea well control and containment. Based on industry experience, incident data, overlaying current regulations and requirements, etc., make recommendations to Presidential Commission and other appropriate government entities that can enhance subsea well control and response.
- Review Section II. C. (Wild-Well Intervention, Recommendations 9 & 10) of the DOI May 27 Safety Report, make recommendations regarding implementation of this section, including possible volunteers to the technical workgroup.
- Confirm current capability within the industry, including capability used successfully for containing the Macondo well.
- Make immediate recommendations that make available near term subsea containment solutions in support of enabling the resumption of industry drilling operations.
- Make long term recommendations on subsea containment solutions.

Long Term (by December 31, 2010)

- Develop a strategy and action plan to complete Long Term commitments.
- Review information available from recent Deepwater Horizon incident, specifically associated with subsea well control and response. (Junk Shot, LMRP Cap, Top Kill, etc.)
- Provide detailed report on progress and activities of the Task Force.
- Identify next steps/milestones to enhance subsea well control and containment capability.

Task Force Participants
AMPOL, Apache, API, Anadarko, ATP, Baker Hughes, BHP Billiton Petroleum, Chevron, Cobalt, ConocoPhillips, Delmar Systems, Diamond Offshore Drilling, Dorado Deep, ENI, ExxonMobil, FMC Technologies, GE Oil and Gas, Halliburton, Helix, IPAA, McMoRan Exploration, Newfield, NOV, Petrobras, Schlumberger, Shell, Statoil, USOGA, Wild Well Control

Executive Summary
The Joint Industry Task Force was formed to review current subsea well control preparedness and response options to determine their efficacy throughout all offshore operations. The review includes equipment designs, testing protocols, R&D, regulations, and documentation to determine if enhancements are needed. The Task Force will identify actions necessary to move standards to advance industry performance and identify enhancements. Where appropriate, enhanced capabilities and other information developed from the DH incident will be considered.

This task force will review intervention and containment at the seafloor along with processes for conveyance and processing to the ocean surface. The primary focus will be on single wells in deepwater and on operations that can occur after a BOP has failed and ROV shut-in attempts have failed or are not possible. The primary objective of subsea containment is to minimize the total time and volume of hydrocarbons discharged to the environment. Each incident needs to be assessed and the best available response and containment measures employed. Consideration will also be given to containment of open casing or casing leaks. Although some technical solutions can be applied to subsea producing wells and templates, these will be focused on in future work. The review will not include Blow Out Preventers (BOPs) and control systems such as Emergency Disconnect Systems (EDS), Autoshear Systems, and Deadman Systems all of which are covered in the Offshore Equipment task force. The task force will focus on well control and containment procedures including well shut in, kill methods, subsea capping, and collection & processing methods.

This task force has initially identified 5 key areas of focus for Gulf of Mexico deepwater operations, the Focus Areas: well containment at the seafloor; intervention and containment within the subsea well; subsea collection and surface processing and storage; continuing R&D; and relief wells, developed by the Task Force respond to the recommendations published by the Department of Interior on May 27, 2010 (no.s 9 and 10 respectively, excerpted and included as Appendix 1 in this document).

We make 29 specific recommendations within these areas of focus. Fifteen of these recommendations are for immediate action and we recommend begin immediately and plan to facilitate. Others will take a longer time and are focused on research and developing capability.

One of the most important "Immediate Action' items is to provide near term response capability until longer term projects and capability are available.

The near term capability must be made available to the industry via a collaborative Containment Company (like MWCC, Marine Well Containment Company). This can be accomplished via four action items: inventory equipment and capability that has been proven fit for purpose through use in response to the Macondo blowout and acquire all appropriate equipment into a Containment Company; reviewing the services and contractors that are advertising immediate containment capability and contract those best able to deliver near term response to the Containment Company; review available equipment for containment that is available "off the shelf" from manufacturers and acquire appropriate equipment; and review vessels and vessel contracts from the Macondo response and contract for those vessels necessary to provide near term containment response. Discussions and negotiations are already under-way to make the BP owned containment equipment available via Containment Company.

Well Containment and the Sea Floor

Our first set of recommendations are to address the goal of establishing a framework and capability for joint participation and cooperation in the industry in the area of subsea well control. We have the opportunity to enhance our capabilities through the acquisition of the equipment and technologies used in response to the Macondo event. Our immediate recommendations are to make the equipment and technologies used for the Macondo well available to all of industry through Containment Company, and to make use of best practices and learning from the Macondo response. The Containment Company will also do research into improved methods and equipment for subsea well control and containment. The Company will improve on designs used for Macondo and then procure, construct and test the needed equipment including over time drills, exercises and readiness reviews.

Our next recommendations involve industry improvements and research regarding the lower marine riser package (LMRP) release. We specifically recommend ensuring the LMRP can be removed from the lower BOP using a surface intervention vessel and ROV to get access to the connection mandrel on top of the BOP. In the future we recommend further LMRP development: developing a method to release the LMRP without riser tension; developing methods for high angle LMRP release without damage and high angle reconnects; and developing a new quick release for risers at or above the flex joint.

Additionally in the well containment and the sea floor focus area, we recommend the ability for a vessel to remove a damaged or non-functioning BOP stack to allow installation of a new BOP on the wellhead housing or the subsea containment assembly, and second, be able to repair or replace a non-functioning control pod to be able to regain full functionality of the BOP stack.

We also recommend that there be an assured ability to connect the subsea containment assembly and other response equipment to all flanges and connecter profiles used in the industry. We recommend that the Containment Company acquire and maintain a full set of equipment and design and construct subsea connectors. We also recommend developing more effective methods of connecting to and controlling BOPs with ROVs.

Intervention and Containment within the Subsea Well

This section recommends that industry begin researching and developing capability in wellhead structural support, subsea stripping and snubbing technology, subsea coiled tubing, subsea freeze plug techniques and improvement and enhancement of Top Kill Methods.

This task force will work with the API RP 96 Deepwater Well Design workgroup to review well designs and assure designs that provide for full shut-in with containment devices.

Subsea Collection and Surface Processing and Storage
This set of recommendations is focused on having the Containment Company immediately develop the means to rapidly deploy production and processing equipment that will interface with containment equipment to convey wellbore fluids to surface for flare and transport. Further, this section makes recommendations specific to the Containment Company development of the capability to make a full containment connection to the seafloor that can be installed over the BOPs or a casing stub.

Continuing Research & Development
These recommendations focus on industry developing capability so that we can extend containment concepts to Subsea Producing Operations and putting a focus on researching new technology for subsea containment. We also recommend publishing the findings from the Task Force work as an educational background for the public, regulators, legislators and other stakeholders.

Relief Wells
We recommend for immediate action holding focused workshops to determine the most effective methods and information that should be included in well plans regarding relief well drilling planning. We also recommend reviewing technologies for relief wells –immediately by reviewing already published work - and in the future working with experts and vendors of specialized equipment that could potentially improve relief well capability.

Conclusion
This report is the reflection of the Task Force's identification of industry's current capability – including the capability used for containing the Macondo well – and the identification of longer term recommendations to enhance subsea well control and containment.

Focus Area	Description	Summary of Recommendations
Well Containment at the Seafloor	Establish framework and capability for joint participation and cooperation in the industry in the area of subsea well control and containment.	**1. Immediate Action:** Establish coordinated industry capability for owning and providing subsea well containment technology and capability. Immediate containment capability will exist via acquiring and refurbishing capability used by BP, contracting GOM contractors with immediate existing containment capability, and acquiring containment equipment available off the shelf from suppliers. This immediate containment capability will be provided via Containment Company. **2. Near Term Action:** Establish long term coordinated industry capability for owning and providing subsea well containment technology and capability. This recommendation and action can be addressed by the Marine Well Containment Company (MWCC) This will be a non-profit Company open to all industry with capability which will include the MWCS (Marine Well Containment System) constructed by the four company consortium. Or by other Containment Companies with suitable capabilities and support that are established in the GOM. All Containment Companies and systems will make use of best practices and learning from the Macondo response. **3. Well Containment Systems** should deliver a flexible, adaptable, and rapidly deployable tool kit of containment equipment. The equipment should be purpose designed and constructed for rapid deployment and successful subsea containment. It should fully contain the oil by full mechanical connection to the well or to the sea floor. The Containment

Focus Area	Description	Summary of Recommendations
Well Containment at the Seafloor	Establish framework and capability for joint participation and cooperation in the industry in the area of subsea well control and containment.	**3.** (continued) Company should procure, construct, and test the needed equipment. This includes testing effectiveness over time through drills and readiness reviews. The Containment Company should also do research into enhanced methods and equipment for subsea well control and containment. The MWCS will become part of the non-profit MWCC which will be open to all industry. It will be managed via boards similar to existing spill non-profits. It will issue reports appropriate to its mission.
	Remove LMRP in the event it is not released as part of the emergency disconnect sequence. Be able to use ROV and surface intervention vessel to unlatch and remove LMRP to get access to the connection mandrel on top of the lowermost BOP.	4. **Immediate Action:** Confirm LMRP can be removed from lower BOP using a surface intervention vessel and ROV. This should allow access to the mandrel on top of the BOP and the installation of subsea containment assembly. This assembly should have full shut-in capability in addition to choked flow from flow arms. If well flow is necessary it can be achieved by diverting flow to the capture vessels. The subsea containment assembly also allows vertical access to the well for intervention within the well if necessary. In almost all cases where there is confidence in the integrity of the well design, the well can be shut-in and top kill procedures executed. Well "capping" capability is available now through use of a second BOP stack or equipment used in the Macondo incident. Containment Companies should expand this capability.

Focus Area	Description	Summary of Recommendations
	Develop new methods to release LMRP without riser tension.	**5. Immediate Action:** Ensure effective methods to release LMRP's are included in BOP stack designs. This should include releases with no vertical tension is available as when rig is drifting without power. Releases should not damage the BOP or BOP connections. There are tools and techniques available now such as LMRP jacks but new methods should be considered.
	Develop methods for high angle LMRP release without damage and also high angle reconnects.	**6.** Research & Develop Capability – Ensure effective and non-damaging release of LMRP's. High angle release connectors exist now. This recommendation is to ensure they work in non-riser tension situations and that there is no need for additional development. Review connectors and develop new capability if necessary to reconnect to Bops and wellhead housings when they are non-vertical.
	Develop new quick release for risers at or above the flex joint/stress joint	**7.** Research & Develop Capability – Develop new quick release that can be installed in the lower riser sections to enable quick release and reconnect when the LMRP does not release in the emergency sequence.
	Remove damaged or non-functioning BOP stack. Be able to use ROV and surface intervention vessel to unlatch and remove BOP stack to get access to a subsea wellhead	**8. Immediate Action:** Remove damaged BOP stack to allow installation of a new BOP on the wellhead housing, or the subsea containment assembly. With a good integrity well design the well can be shut-in and normal kill procedures can be used. This capability is available now through use of a second BOP or equipment used in the Macondo incident. The Containment Company should expand this capability.

Focus Area	Description	Summary of Recommendations
	Regain full control of BOP stack. Be able to repair or replace non-functioning control pods to be able to regain full functionality of BOP stack (ROV intervention provides limited functionality)	**9. Immediate Action:** This can be done now with some hydraulically controlled stacks and on all rigs by pulling and repairing the LMRP/pods, and rerunning the LMRP. Research & Develop Capability: Research & develop ways to regain control over all important BOP functions in the case where the LMRP is damaged and cannot be removed and in cases where the LMRP is removed but cannot be repaired and re-run. This would be for cases where adequate control cannot be established with ROV intervention.
	Provide additional and more effective methods of connecting to and controlling BOP's with ROV's.	**10. Immediate Action:** The Containment Company should acquire and maintain a full set of crossover spools, connectors, and hub combinations. **11. Immediate Action:** The Containment Company should design and construct subsea connectors to fully seal, connect and contain on damaged connector profiles and casing stubs. Also consideration should be given to inside well connectors such as packers. **12. Immediate Action:** Coordinate with the Equipment Task Force to ensure methods and equipment are providing effectiveness and reliability in delivery of control fluids and control to BOP's and ROV's. Considerations should include: Evaluation of methods other than shuttle valves, for the ROV intervention plumbing.

Focus Area	Description	Summary of Recommendations
	Provide additional and more effective methods of connecting to and controlling BOP's with ROV's.	**13.** Research & Develop Capability – Review existing methods and number of connection points on existing BOP's. Determine if more outlets or different connections would enhance containment capability.
	Deepwater cutting, metal, and debris removal	**14.** Research & Develop Capability - Assess industry capability and conduct in-situ testing to determine what new technology and capability needs to be developed to remove a debris field and cut equipment like risers. Develop new equipment and capability as determined by testing.
Intervention and Containment within the Subsea Well	Assure necessary wellhead structural support via design & practices in the event of strong side forces from drifting connected rigs and riser collapse from rig sinking.	15. **Immediate Action:** Coordinate with API RP 96 and ensure deepwater well design includes a system evaluation of the design and material for subsea well head support (e.g.: templates, structural pipe etc.), and the release control methodology of the LMRP.
	Subsea Stripping and Snubbing Technology to allow intervention inside damaged wells	16. Research & Develop Capability - Survey industry for feasibility of developing subsea snubbing technology or consider proposal to Joint Industry Groups (RPSEA/Deep star etc) to develop preliminary designs for subsea snubbing equipment
	Subsea Coiled tubing to allow intervention inside damaged wells	**17.** Research & Develop Capability - Seek opportunities to accelerate development of subsea coil tubing deployment systems and make them available for subsea well intervention on damaged wells and BOP's. Consider all possibilities such as deepwater pipe-lay technologies for deploying pipe larger than conventional coil tubing.

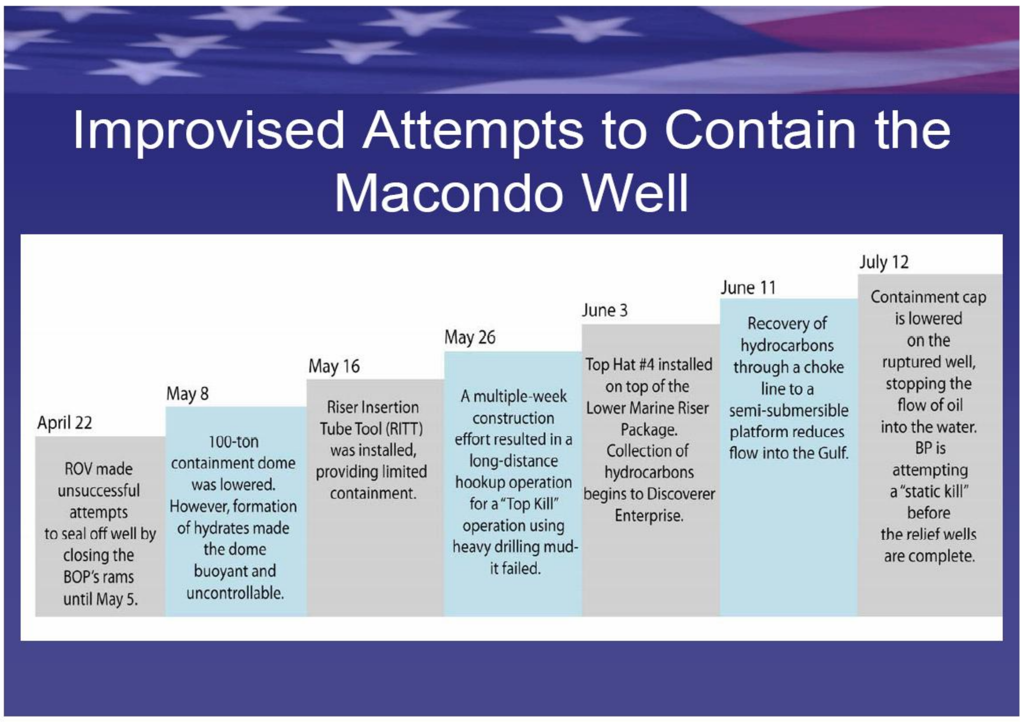
Focus Area	Description	Summary of Recommendations
	Subsea freeze plug techniques for subsea well containment	**18.** Research & Develop Capability - Survey industry experience, conduct research into basic science if necessary, and undertake field testing to develop industry capability for establishing and maintaining an „ice plug", to provide subsea well containment while avoiding detrimental affects to the BOP operation.
	Improvement & Enhancement of Top Kill Methods including evaluation of Reactant Pills and other Bridging Agents for subsea wells	**19.** Research & Develop Capability - The top kill method should be considered when the subsea well is contained by the subsea containment assembly or the BOP. This requires well integrity and containment integrity sufficient for the top kill. This effort should include a survey of capability, and development of supporting technologies for converting fluids into barriers in situ, augmenting bridging if desired, and pumping procedures and planning including hydrate management.
	Review well design criteria of RP 96	**20. Immediate Action:** The Task Force will coordinate with API RP 96 Deepwater Well Design team to ensure they understand the importance of full shut-in capability to the containment capabilities.
Subsea Collection and Surface Processing and Storage	Develop means to rapidly deploy production and processing equipment that will effectively interface with containment equipment to convey wellbore fluids to surface for flare and transport.	**21. Immediate Action:** The Containment Company will deliver a modular solution for capturing, processing, and transporting production from subsea wells that need to be produced until well control is complete. Such a system should be adaptable to DW met ocean and water depths up to 10,000 feet.

Focus Area	Description	Summary of Recommendations
Subsea Collection and Surface Processing and Storage	Develop means to rapidly deploy production and processing equipment that will effectively interface with containment equipment to convey wellbore fluids to surface for flare and transport.	**21. Immediate Action:** (continue) It should consider free standing production risers to move production to the surface away from the area of the well. It should have processing capability that can be rapidly deployed on vessels. All the equipment should be purpose designed, pre-constructed, and held on ready stand-by. Any concepts forwarded through BOEMRE Alternative Response Technologies Program should be evaluated and researched and included if they enhance capability.
	Develop capability to make a full containment connection to the seafloor that can be installed over the BOP's or a casing stub.	**22.** Research and Develop Capability – The Containment Company will develop, test, and have available technology to provide full containment via seafloor connection. This system should allow connection of a Subsea Containment Assembly so well production can flow to the production and processing system. Such systems should include chemical injection for hydrate mitigation. The sea floor connected containment system would be used for oil capture until a relief well was drilled.
Continuing R&D	Extend containment concepts to Subsea Producing Operations and equipment	**23.** Research & Develop Capability – As the next phase of the Task Force, evaluate extension of containment concepts, equipment, and capabilities to subsea production operations including production from templates. Make recommendations for enhancing current practices as necessary and appropriate.

Focus Area	Description	Summary of Recommendations
	Education	**24. Immediate Action:** Develop a historical context document of marine well control and containment that includes an extensive reference list. This could enhance Task Force work and will be a good base document for the industry.
	Evaluate new technology for subsea containment	**25.** Research and Develop Capability - Evaluate new and evolving ideas for subsea containment including open capture devices that would have separation capability. R&D should be a key part of the Containment Company in which all industry can participate. All the R&D programs will work collaboratively with appropriate organizations like RPSEA and Deep star to ensure maximum leverage in the R&D program.
Relief Wells	Relief well planning during well planning and permitting.	**26. Immediate Action:** Via focused workshops, determine and make a recommendation on the most effective methods and information that should be included in well plans regarding relief well drilling planning. Ensure full coordination and eliminate duplication with other groups‟ initiatives.
	Technologies for Relief Wells	**27. Immediate Action:** Undertake desk research to revisit published work on relief wells.

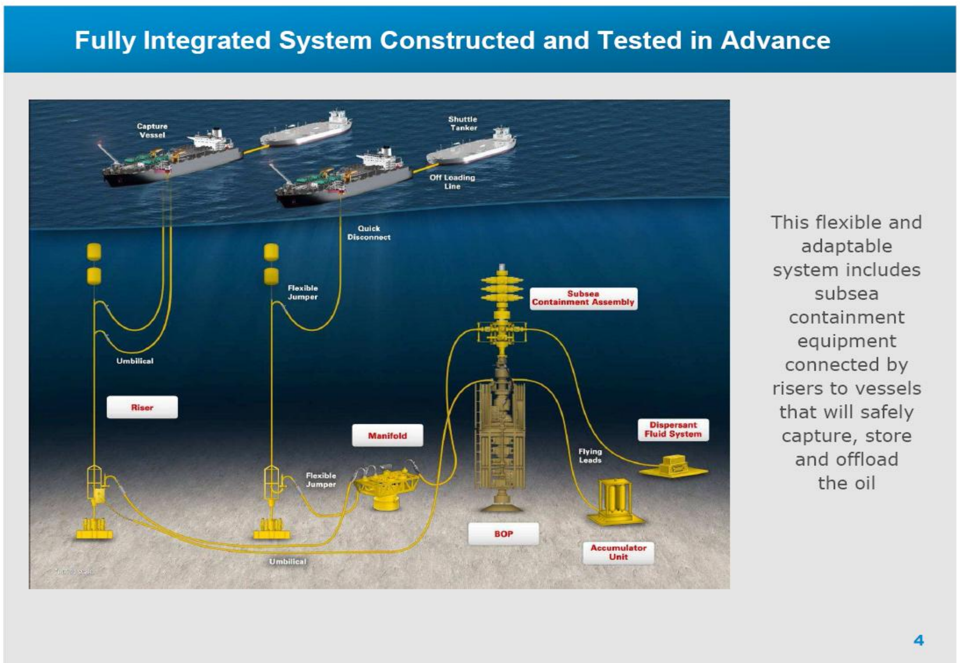
Focus Area	Description	Summary of Recommendations
	Technologies for Relief Wells (continued)	**28.** Research & Develop Capability – Conduct focused interviews with experts and vendors of specialized equipment (ranging tools, etc.) Understand and support, as necessary, plans for developing magnetic ranging tools that don't require tripping the drilling assembly and other equipment that should enhance relief well capability. **29. Immediate Action:** Write a white paper on relief wells that evaluates the feasibility and desirability of pre-drilling relief wells. This task is complete.

Figure 1: Excerpt from Michael Bromwich presentation at BOEMR Forum on August 4, 2010 1



The slide above illustrates, generally, the actions and decision process employed to contain effluent from the Macondo well. The Task Force intends to deliver more rapid response with full containment via Containment Company such as the MWCC.

Figure 2: Well Containment Systems [5]



The figure illustrates the initial design concept of the recently announced Marine Well Containment System. Other subsea containment system concepts are available for contractors in the GOM.

Appendix 1: Excerpt from DOI publication dated May 27, 2010 – Recommendations relating to Wild Well Intervention

C. Wild-Well Intervention

Recommendation 9 – Increase Federal Government Wild-Well Intervention Capabilities

Blown out, or —wild wells, involve the uncontrolled release of crude oil or natural gas from an oil well where pressure control systems have failed. The Federal Government must develop a plan to increase its capabilities for direct wild-well intervention to be better prepared for future emergencies, particularly in deepwater. Development of the plan should consider existing methods to stop a blowout and handle escaping wellbore fluids, including but not limited to coffer dams, highly-capable ROVs, portable hydraulic line hook-ups, and pressure-reading tools, as well as appropriate sources of funding for such capabilities.

Recommendation 10 – Study Innovative Wild-Well Intervention, Response Techniques, and Response Planning

The Department will investigate new methods to stop a blowout and handle escaping wellbore fluids. A technical workgroup will take a fresh look at how to deal with a deepwater blowout. In particular, the workgroup will evaluate new, faster ways of stopping blowouts in deepwater. The technical workgroup will also address operators' responsibility, on a regional or industry-wide basis, to develop and procure a response package for deepwater events, to include diagnostic and measurement equipment, pre-fabricated systems for deepwater oil capture, logistical and communications support, and plans and concepts of operations that can be deployed in the event of an unanticipated blowout, as well as assess and certify potential options (e.g., deepwater dispersant injection).

References

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3. Danenberger, E.P., *Submission to Commission of Inquiry, Montara Uncontrolled Hydrocarbon Release*. 2010.
4. Izon, D., Danenberger, E. P., Maynes, Melinda, *MMS study of OCS blowout incidents 1992-2006.* Drilling Contractor, 2007(July/August, 2007).
5. Sara Ortwein, ExxonMobil; Melody Meyer, Chevron Entergy Technology; Charlie Williams, Shell Oil; Steve Bross, Conoco Phillips, *Safe, Protective Drilling Practices in the Deepwater Gulf of Mexico*, in *BOEMR Forum*. 2010: New Orleans, Louisiana.