Science (and Technology) to Tame a Wild Deep-sea Oil Well

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Thousands of oil and gas wells have been drilled in the ocean floor ranging from the North Sea to the South Atlantic and beyond. Of most of these you never hear, as they contribute to the gas and oil supply of world commerce. Many more are being drilled for exploration and production.

Slide 1 is a schematic of a Kuwait oil well, from my paper[1] with Henry Kendall of November 1991, reporting on the world's success in stopping the flow of 640 wells that had been destroyed and set aflame in March 1991 by explosives by Saddam Hussein's military engineers.

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[1] "Quenching the wild wells of Kuwait," by R.L. Garwin and H.W. Kendall in *Nature* Vol. 354, No. 6348 (pp. 11-14), Nov. 7, 1991 (with brief comment by Peter Aldhous, p. 5). http://preview.tinyurl.com/2fv6ko4

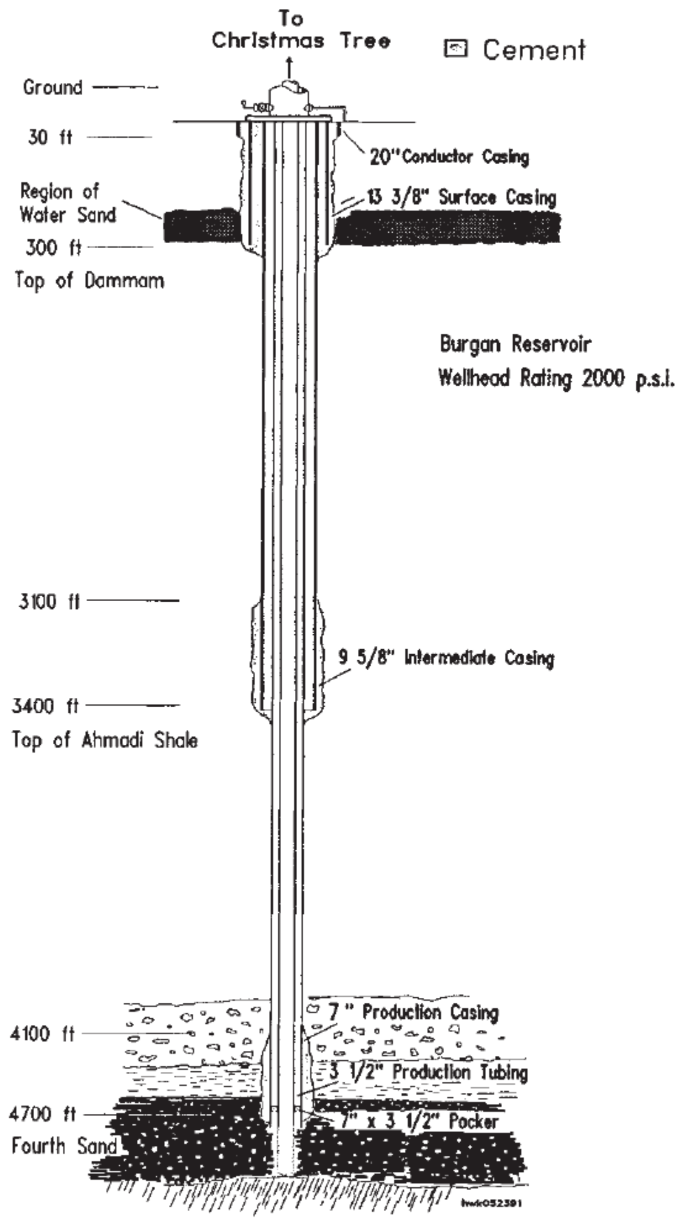


FIG. 1 A typical oil well in the greater Burgan field, south of Kuwait city, not to scale.

A seafloor well is drilled by a long string of drill pipe hanging as much as 3000 meters below a drill ship or drilling platform. In the case of the Deepwater Horizon (DH) well owned by BP in the Gulf of Mexico, the seafloor is at 5000 ft (1500 meters) and the well was completed for exploration with a blow-out preventer (BOP) and on top of that a Lower Marine Riser Package (LMRP) to connect to the mile-long 21-inch diameter steel tube (riser) that extended to the surface. The riser is buoyant, in order that it need not support the dead weight of a mile of pipe. Inside the riser is run the drill pipe, of various diameters, including that for drilling the hole for the 18-in casing. The riser allows control of the well environment, the circulation of drilling mud from tanks on ships or platforms at the sea surface, etc.

Deep wells on land or undersea must be built to contain much higher pressures than wells of shallow depth, and the pressure varies greatly with the nature of the fluid contained in the well bore, and even with the location of that fluid. A well 18,000 ft deep could have a surface pressure of more than 6000 psi if it contacted a gas reservoir that was normally “hydropressured,” considerable more for a “geopressured” reservoir, in view of rock density that may be 2.5 g/cc.

The Figure shows the particular BOP and LMRP used for the Macondo 252 well. Many of the components were specified and tested to withstand 15,000 psi, accounting for the massive steel structure.

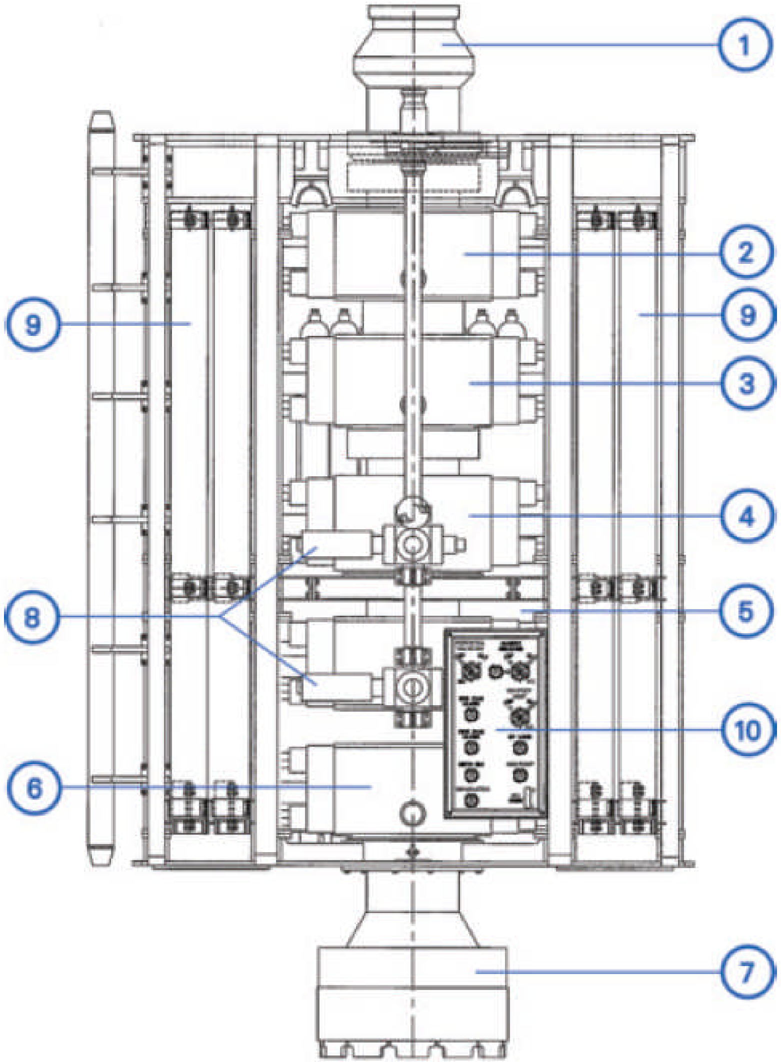
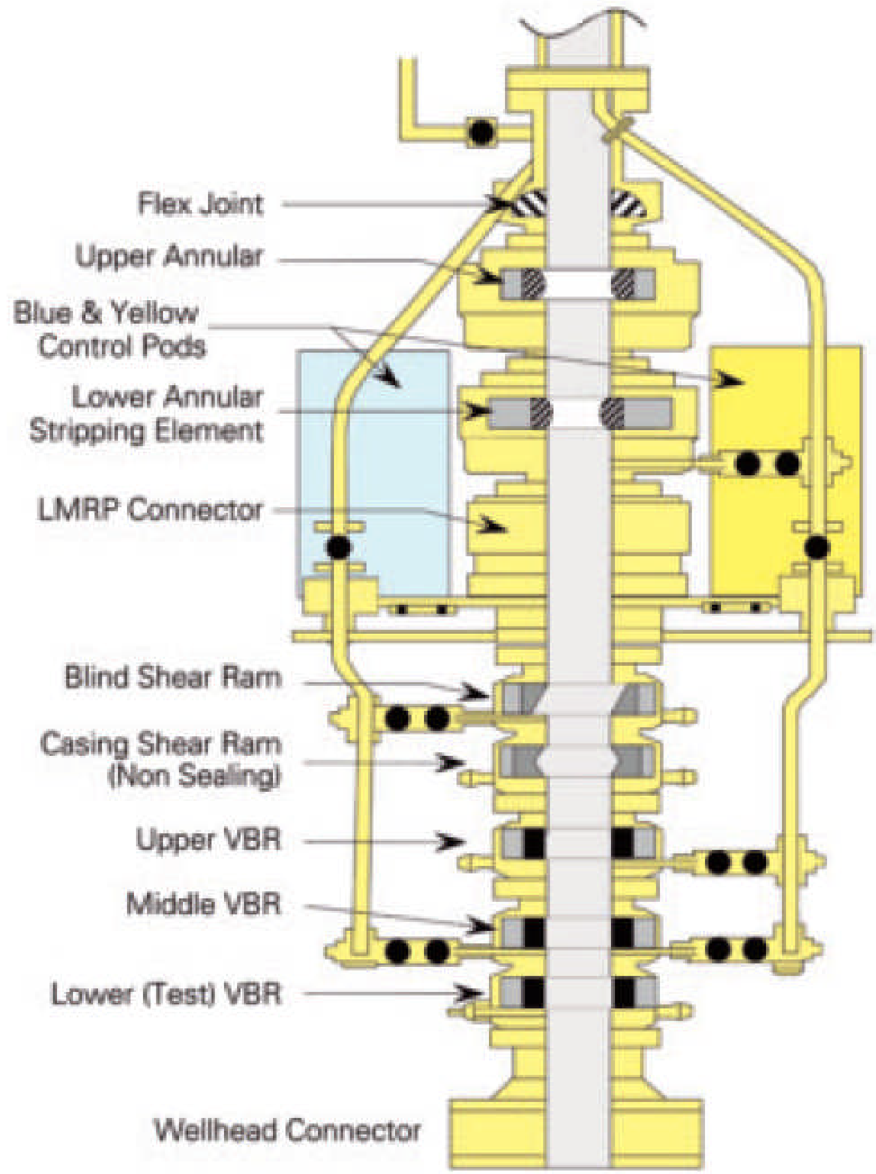


Figure 4. BOP Stack.



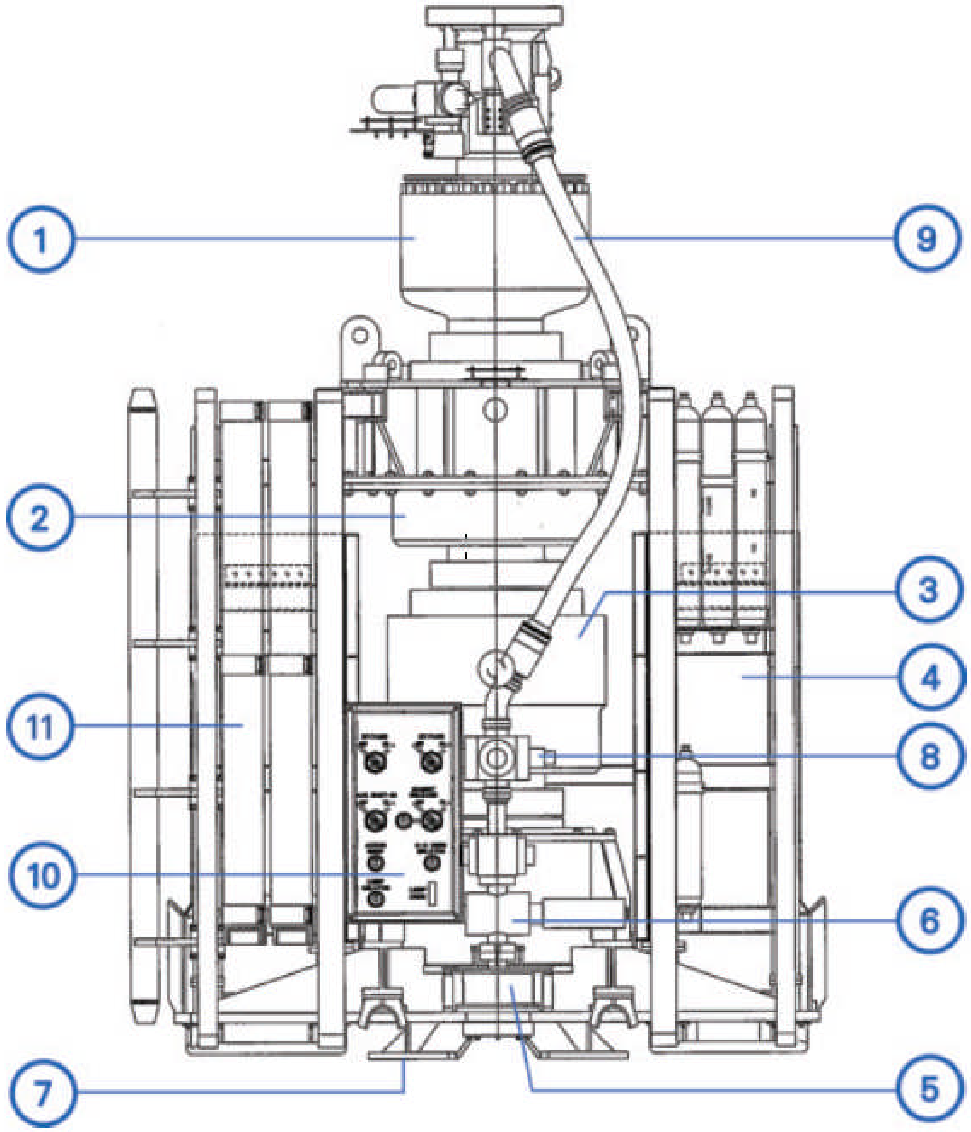


Figure 3. LMRP Assembly.

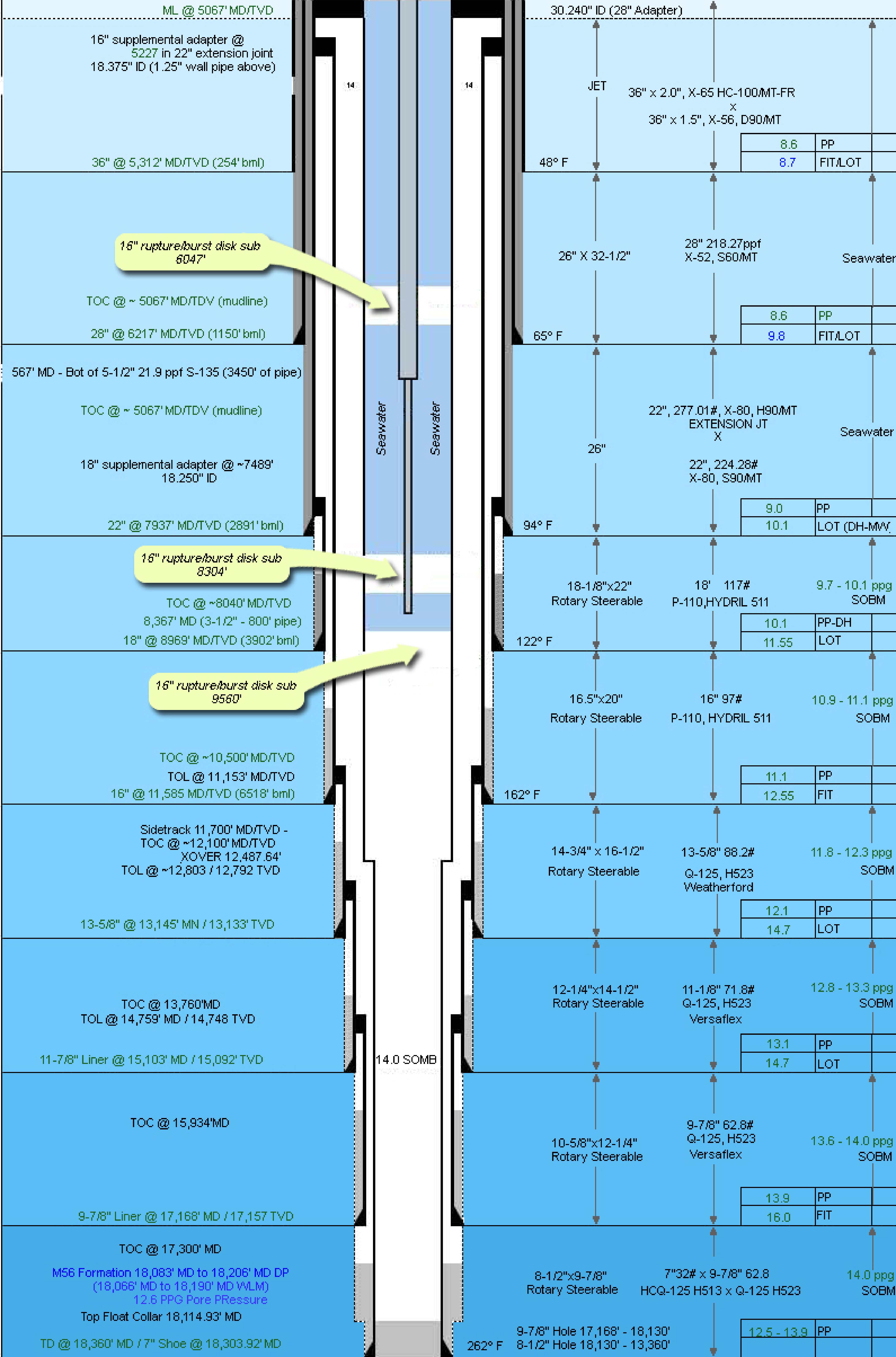
In reality, the ocean floor is drilled first with a "conductor casing," 36-inches diameter, and there are various cementing operations that go on as longer casings of smaller diameters are installed. Deepwater Horizon was drilled to a depth of 13,293 ft (4052 m) below the mud line (seafloor) or 18,360 ft (5596 m) below the sea surface.

DH was reportedly filled with a modest 50 bbl of cement at depth, and seawater in the 9-inch casing, instead of mud to keep it safe while the drill platform was to be moved away, and another sea surface platform was to come in to complete the well for production. In reality, the standard "negative pressure test" of cement integrity was failed, but none of the three corporations on the platform took any action as a consequence, and the well proceeded as if the test had been passed.

A WELL FULL OF MUD OR CEMENT OF DENSITY COMPARABLE WITH THE SURROUNDING ROCK IS SAFE BECAUSE FLUID FROM THE RESERVOIR AT ITS FOOT CANNOT ENTER THE WELL.

Drilling platforms are of various kinds, with many of them these days dynamically positioned via GPS to whatever accuracy is needed. Alongside the riser pipe are attached two smaller lines (3 or 4-inches in diameter), the Choke and Kill lines, that have valves that enter the BOP among the various "rams" that can hold and seal (or shear) various diameters of pipes in a redundant fashion. The DH well, aka "Macondo 252" is more complex[2] than the wells in Kuwait. Slide 2 shows the diameters and depths of the various steel "casings" of DH, beginning at the "mudline" at 5067-ft depth below sea surface (BSS), to a total depth of 18,360 ft below the sea surface, where the rock temperature is 262º F.

[2] http://www.energy.gov/open/documents/3.1_Item_2_Macondo_Well_07_Jun_1900.pdf



ML @ 5067' MD/TVD
30.240" ID (28" Adapter)
16" supplemental adapter @ 5227 in 22" extension joint 18.375" ID (1.25" wall pipe above)
14
14
JET
36" x 2.0", X-65 HC-100/MT-FR x 36" x 1.5", X-56, D90/MT
8.6
PP
8.7
FIT/LOT
36" @ 5,312' MD/TVD (254' bml)
48° F
16" rupture/burst disk sub 6047'
26" X 32-1/2"
28" 218.27ppf X-52, S60/MT
Seawater
TOC @ ~ 5067' MD/TDV (mudline)
8.6
PP
9.8
FIT/LOT
28" @ 6217' MD/TVD (1150' bml)
65° F
567' MD - Bot of 5-1/2" 21.9 ppf S-135 (3450' of pipe)
TOC @ ~ 5067' MD/TDV (mudline)
Seawater
Seawater
22", 277.01#, X-80, H90/MT EXTENSION JT X 22", 224.28# X-80, S90/MT
26"
Seawater
18" supplemental adapter @ ~7489' 18.250" ID
9.0
PP
10.1
LOT (DH-MW)
22" @ 7937' MD/TVD (2891' bml)
94° F
16" rupture/burst disk sub 8304'
18-1/8"x22" Rotary Steerable
18' 117# P-110,HYDRIL 511
9.7 - 10.1 ppg SOBM
TOC @ ~8040' MD/TVD
8,367' MD (3-1/2" - 800' pipe)
10.1
PP-DH
11.55
LOT
18" @ 8969' MD/TVD (3902' bml)
122° F
16" rupture/burst disk sub 9560'
16.5"x20" Rotary Steerable
16" 97# P-110, HYDRIL 511
10.9 - 11.1 ppg SOBM
TOC @ ~10,500' MD/TVD
TOL @ 11,153' MD/TVD
11.1
PP
12.55
FIT
16" @ 11,585 MD/TVD (6518' bml)
162° F
Sidetrack 11,700' MD/TVD - TOC @ ~12,100' MD/TVD XOVER 12,487.64' TOL @ ~12,803 / 12,792 TVD
14-3/4" x 16-1/2" Rotary Steerable
13-5/8" 88.2# Q-125, H523 Weatherford
11.8 - 12.3 ppg SOBM
12.1
PP
14.7
LOT
13-5/8" @ 13,145' MN / 13,133' TVD
TOC @ 13,760'MD
TOL @ 14,759' MD / 14,748 TVD
12-1/4"x14-1/2" Rotary Steerable
11-1/8" 71.8# Q-125, H523 Versaflex
12.8 - 13.3 ppg SOBM
13.1
PP
14.7
LOT
11-7/8" Liner @ 15,103' MD / 15,092' TVD
14.0 SOMB
TOC @ 15,934'MD
10-5/8"x12-1/4" Rotary Steerable
9-7/8" 62.8# Q-125, H523 Versaflex
13.6 - 14.0 ppg SOBM
13.9
PP
16.0
FIT
9-7/8" Liner @ 17,168' MD / 17,157 TVD
TOC @ 17,300' MD
M56 Formation 18,083' MD to 18,206' MD DP (18,066' MD to 18,190' MD WLM) 12.6 PPG Pore PRessure
8-1/2"x9-7/8" Rotary Steerable
7"32# x 9-7/8" 62.8 HCQ-125 H513 x Q-125 H523
14.0 ppg SOBM
Top Float Collar 18,114.93' MD
12.5 - 13.9
PP
TD @ 18,360' MD / 7" Shoe @ 18,303.92' MD
262° F
9-7/8" Hole 17,168' - 18,130'
8-1/2" Hole 18,130' - 13,360'

This beautiful PDF slide also shows the pressure at depth, in terms of the “pounds per gallon” of mud that would balance the “pore pressure” of the formation. What is the pressure implied by “12.6 ppg” at a depth of 18,360 ft below sea level? Recalling that in the Earth’s gravitational field $P = \rho g\, h$ and that one gallon is 231 cubic inches allows one to write

P (psi) = [ρ/10 (ppg)] x [h/10,000 (ft)] x (10/231) x (12 x 10^4) = **5195 psi x [ρ/10 (ppg)] x [h/10,000 (ft)].** For 12.6 ppg mud and h = 18,360 ft, this works out to be 12,017 psi.

On April 20, with warning signs missed, there was a whoosh, and a stream of solids and fluids shot up the pipe. The gas (methane) caught fire, and the drilling platform sank two days later. Eleven men died 115 were rescued. My own involvement with DH began on May 11, when I was called by Secretary of Energy Steven Chu to participate with a small team of outside scientists, together with many from government laboratories and the Department of Energy national laboratories (Livermore, Los Alamos, and Sandia), in order to provide scientific support and analyses for government direction of BP activities in stopping the flow of oil into the Gulf or collecting as much oil at the source as possible. We had no assignment to mitigate the impact of the oil release, so were not primarily involved with the first underwater use of dispersant sprayed into the rising column hydrocarbons.

Our team had no mandate to investigate the accident itself, despite its relevance to the well configuration and what could be done in order to stem the flow. Initially BP had not characterized the flow quantitatively except to indicate that it was small. Later the government and BP[3,4] characterized the flow from the well as "1000 barrels of oil per day (bopd)," and then "5000 bopd." In fact, the science team was able to derive an estimate of the flow by the use of simple scaling laws, resulting in an official statement of August 2 that the initial flow into the Gulf had been 62,000 bopd, decreasing to 53,000 bopd before the well was capped on July 15. The decline was due largely to partial depletion of the contents of the sandstone reservoir.

When the platform sank, the 1500-m-long riser to the DH drilling platform broke free at its top and fell along the seafloor, still attached to the top of the LMRP, in turn attached to the top of the BOP. The LMRP and BOP together weigh several hundred tons and extend about 30 m above the seafloor. The 21-in-diameter steel riser kinked a meter or so above its attachment flange, and first videos by remotely operated vehicles (ROV) showed oil and gas emerging from several tears in the heavy steel riser at the kink (Slide 3)

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[3] The Wikipedia article is substantial and largely but not entirely correct: http://en.wikipedia.org/wiki/Deepwater_Horizon_oil_spill
[4] Much reliable information is now available at www.oilspillcommission.gov

Slide 3. Diamond-wire saw in position to attempt to cut the riser. Video[5] shows the oil and gas billowing from several tears in the "kink" of the 21-inch-diameter riser.

Most of the hydrocarbons emerged from the end of the fallen riser on the seafloor 1500 m away, with the gas emerging from the upper half of the horizontal pipe cross-section and

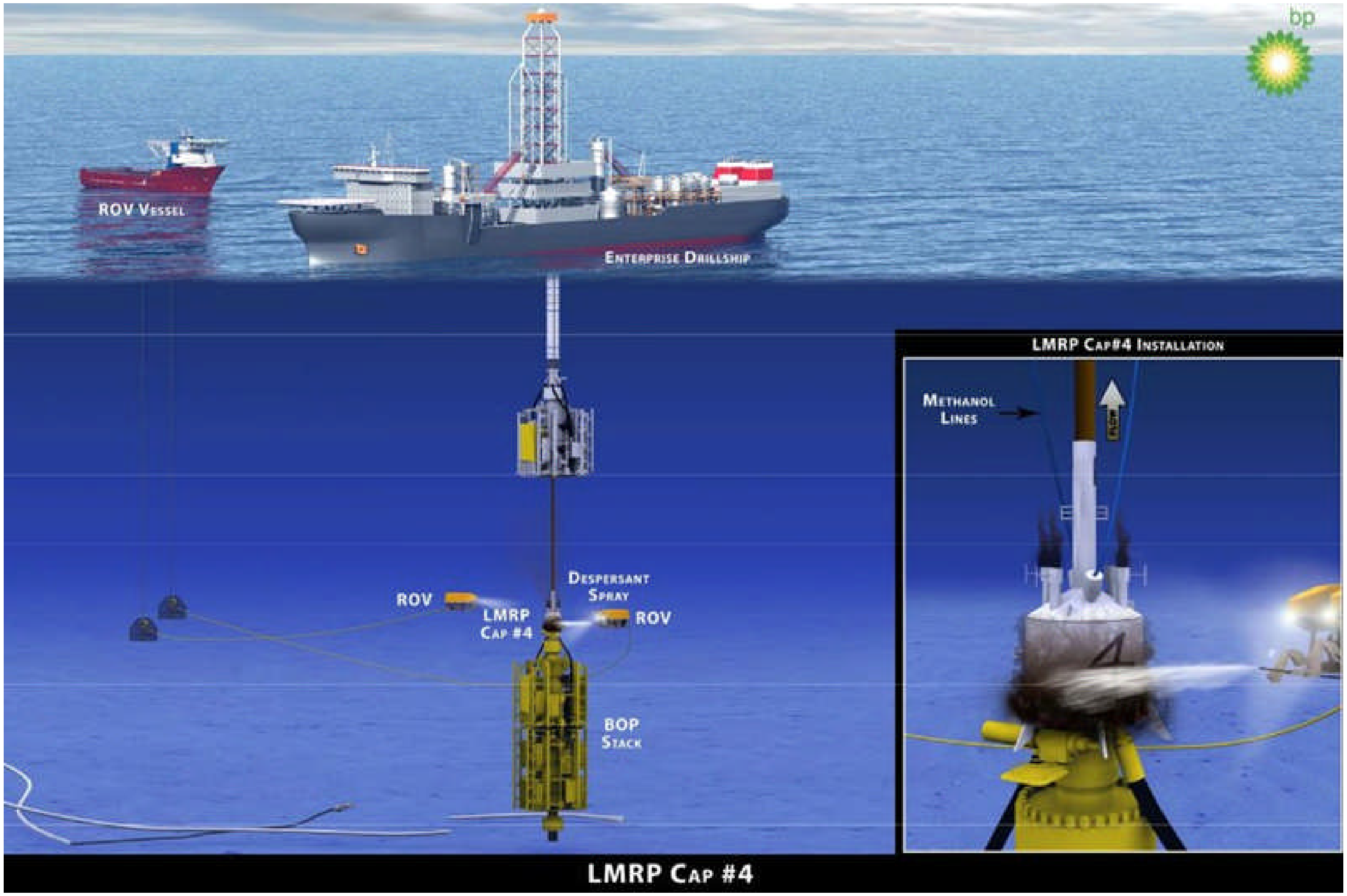
[5] This clip and others are for public use from www.BP.com

the oil from the lower. At the seafloor ambient pressure of about 150 bar (15 megapascal--MPa) gas has a density of 0.21 g/cc and is more buoyant than oil, but oil itself with a density of about 0.6 is highly buoyant in seawater of density 1.02 g/cc, accounting for the great difference in local environment between the deepwater wild well and a wild well on land.

The BOP and LMRP were damaged prior to or during the catastrophic accident and did not perform their function of stopping the flow of oil and gas, despite the fact that the hydraulic actuators on the various valves and rams were, in fact, "closed." Attempts were made to capture some of the oil emerging from the broken end of the riser, but only small amounts were "contained" in this way until the broken riser was cut, not without difficulty, by enormous hydraulically operated shears, to make way for a more efficient hydrocarbon collection system. Here is a still from an ROV video of the gas/oil plume emerging from the (relatively) clean-cut 21-inch-diameter riser. (Slide 4).

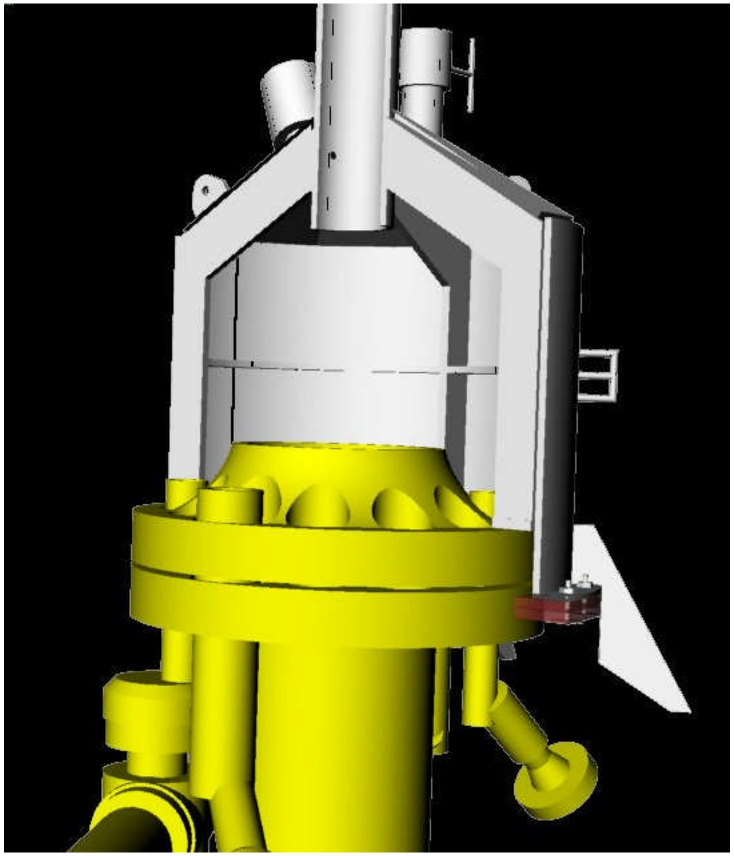
Slide 4. A still from an ROV video of the gas/oil plume emerging from the clean-cut 21-inch-diameter riser.
The oil is orange in color.

A covering dome or bell, "TopHat," attached to a riser was used to take oil and gas to the surface, where it was separated and the oil collected while the gas (and some of the oil) was "flared" (burned). Mixing the oil with seawater before burning prevents the usual smoky flame that one would get from flaring crude oil. Up to 25,000 bopd was collected in this way, as depicted on Slide 5.



Slide 5. Schematic of the TopHat 4 for capturing as much of 50% of the Deepwater Horizon flow.

The massive block rubber seal affixed to the Tophat was broken in handling, so substantial amounts of oil still emerged from below the skirt of the Tophat, as shown in Slides 5a and 5b.



Slide 5a. The TopHat4 as conceived, mounted on the seafloor structure (yellow). The block rubber gasket is shown in red.

Slide 5b. Oil billowing from below the skirt of the TopHat4.

Nevertheless, even with the small pressure difference[6] of the order of 0.1 bar between the skirt and the top of the Tophat, when one of the ports on the Tophat was opened to the sea it was possible to estimate the flow through that port and thus the total flow from the well. The derived flow agrees reasonably well with the later calculation by the government team of 50-66,000 bopd for the flow. At a world price of $75/bbl, the 50,000 bopd number corresponds to a price for that oil on the market of $3.75 million per day or $1.3 billion per year.

The wells in Kuwait suffered explosive cutting of their superstructure, and many were producing at a rate that when the oil or gas was flared to the atmosphere provided a fluid velocity that allowed entrained sand to act as an abrasive cutter. As detailed in our 1991 paper, the wells were quenched unprecedentedly rapidly because the primary approach was not the traditional one of putting out the flame and *then* dealing with the oil and gas, but rather to *stop the flow* in various ways, as with a massive steel needle that could be put into the cylindrical well bore. If the tapered needle does not suffice, one can have an inflatable "packer" on the needle that expands against the well bore and stops the flow. After that, a pit can be dug around the casing, and conventional large-diameter tubing and valves attached to the now-quiet well in order to provide a normal "Christmas tree" to conduct the effluent into gathering lines and pipelines in the normal fashion.

[6] Resulting from the relative buoyancy of gas/oil mixture and seawater.

For DH, the damaged wellhead was 1500 m below the sea surface, so that gas expansion and resulting erosion velocity was limited. But work needed to be done by highly capable ROVs that can do construction work as an extension of the human operators on the mother ships, observed in real time at BP's headquarters in Houston and eventually put live onto the internet for public viewing .

The option of quenching the flow into water of the Gulf by installation of a valve was the first to be considered, and if the 9-in casing of the well were known to be intact and sealed at its top with its rubber gasket, that would have been an excellent approach. But the oil reservoir tapped by the well had an initial pressure of almost 12,000 psia (pounds per square inch—absolute), and the pressure that could be confidently tolerated by the BOP is no more than 9000 psia. Because the mixture of gas and oil was thought to have a density of only 0.3, the hydrostatic head of the fluid column between seafloor and reservoir was only 3000 psia, so that the BOP would barely tolerate a valve that closed the flow, which would eliminate the non-hydrostatic friction loss of the fluid on its way from the reservoir to free egress to the seafloor.

But if the 9-in casing hanger were damaged, then the wellhead pressure could communicate with the "16-in" diameter casing, which has (as can be seen by the diagram on the doe.gov site) six "burst disks" at various levels in the pipe, (and six "collapse" disks). Although the burst disks are small, it was calculated that they would indeed burst and then pressurize the “18-in” casing that would allow high-pressure hydrocarbons into the rock formation at levels where the rock could fracture indefinitely as a result of transfer of hydrocarbons from the deep reservoir to the intermediate rock.

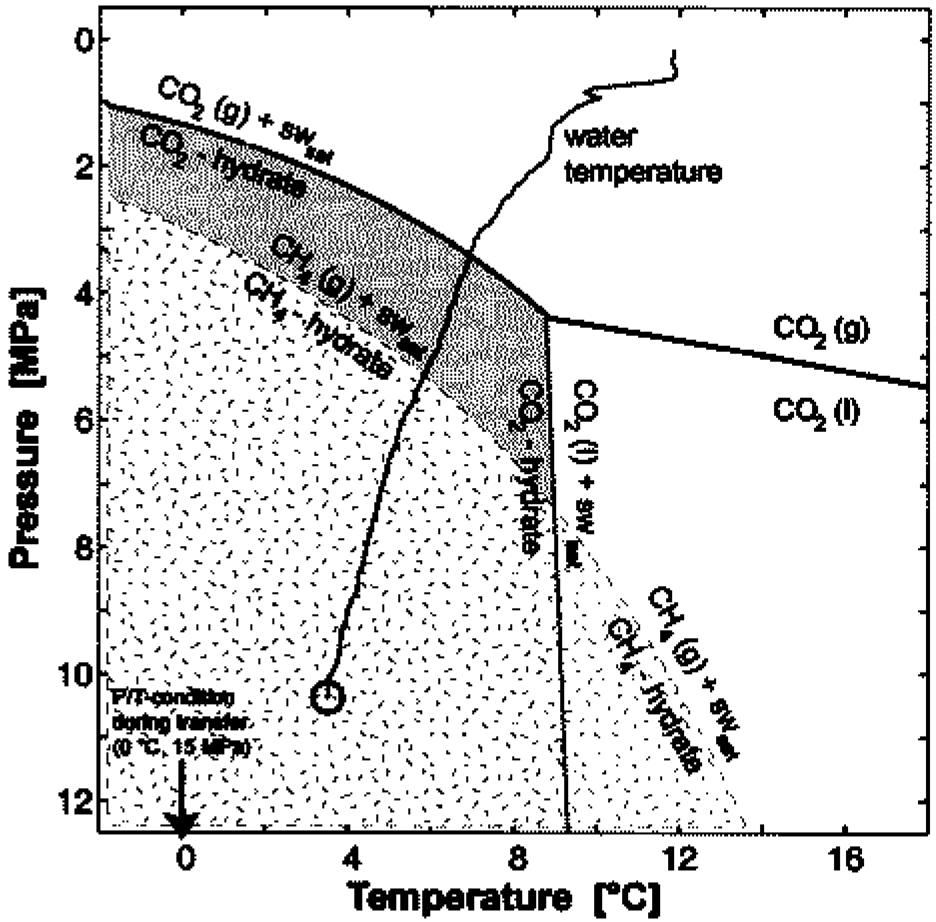
Closing the well was thus not an option unless one could determine that the 9-in casing hanger was intact.

There are striking differences between a wild well at 1500 m depth and one on the surface. The Devil’s Cigarette Lighter comes to mind (Algerian desert, 1961) and other wells. The Devil’s Cigarette Lighter was an enormous “torch of gas from Hell”, whereas the Lakeview Gusher of 1910 never did catch fire during its 17 months of flow but produced large lakes of oil in the scrub land near Bakersfield, California. It spewed 380 million gallons (9 million barrels of oil, as compared with the 4.9 million barrels from the DH.

Of the 690 wells beheaded by Saddam Hussein in 1991, 640 were on fire. In many cases the wells formed enormous lakes of crude in the desert, extending into the Persian Gulf.

In contrast, as can be seen in the slides, at the seafloor there are no humans present to observe, and the ROVs do not have to be protected from the blistering heat of gas and oil fires, but there is another hazard at depth, and that is the formation of methane hydrate—

a rock-hard compound of methane and water that is stable[7] in deep water on the seafloor the world over, within the methane-hydrate stability diagram as shown in Slide 6.



(Ignore the notation "P/T-condition during transfer (0 C, 15 MPa)"; the diagram is from another document that is concerned with CO2 hydrate as well)

Slide 6. Methane-hydrate stability diagram. Please ignore the CO_2 hydrate curves.

[7] Methane hydrate slowly dissolves in seawater.

In fact, the first well-intentioned large containment dome or cofferdam that had worked in shallow waters failed because the copious flow of methane from the well combined with seawater at seafloor ambient pressure of 150 bar and about 5 C to form methane hydrate that plugged a riser to the surface so that the dome was useless—a result predictable by simple modeling of the proposed operation. With no effluent, the accumulation of hydrocarbon in the dome rendered it buoyant, so that it was necessary to keep it from rocketing to the surface, thereby endangering the many ships working in the vicinity of the well.

After the riser was cut, efforts to capture the effluent had more success, because the stream from the well is hot, and despite a potential small admixture of seawater, is above the stability limit of methane hydrate at seafloor ambient pressure. I have shown a slide of the setup in which about half of the flow from the well was being taken up the riser to be flared or collected on surface ships. BP took pains to prevent inflow of seawater into the riser, by allowing a massive leak from the TopHat skirt, when a small admixture of seawater into the hot hydrocarbon stream could not have created hydrates.

From May 26-29 an effort was made to implement a “dynamic top kill” in the flowing well, which was doomed to failure. The idea was to inject heavy mud, in this case water-based, of density such that a mud column from the reservoir to the surface would provide sufficient hydrostatic pressure that gas or oil could not emerge from the reservoir into the casings of the well. The reason for the adjective "dynamic" is that the well was flowing at a rate that was later determined to be 50-66,000 bopd, so that if the mud were to fulfill its intended purpose of displacing the hydrocarbon in the casing, it would need either to move in "plug flow" down the casing or globs of mud would need to sink faster than the upwelling hydrocarbon.

Plug flow would be possible if the pressure at the wellhead (within the failed BOP) could be raised above the "shut-in pressure" either by shut-in or by pumping mud at such a rate that the pressure at the wellhead exceeds the shut-in pressure; this was not to be permitted and was not achieved.

As for globs of mud falling down the well cylinder against the flow of hydrocarbon, given the scaling laws for speeds and size, it is clear that a glob of mud almost the size of the casing—perhaps 10-cm in diameter—would fall at greater than the necessary speed, but such an interpenetrating fluid situation is unstable to what is called Kelvin-Helmholtz instability. The Bernoulli pressure at the bounding surface of the droplet and the upwelling fluid ($0.5\ \rho V^2$) far exceeds the surface tension of the globule, for globules of a size that they would fall by gravity against the upward current. In the future, greater attention to the rheology of the mud could preserve globules against the K-H instability; indeed a mechanism that would encase the mud in sausage casing (literally) could ensure that it would fall through the rising oil column. Details of its fate at the bottom of the well also need to be analyzed.

When as a test, mud was injected at a few barrels of mud per minute above the closed "rams" in the failed BOP, copious mudflow was evident through the cracks by the kink of the riser; when the primary mudflow aggregating 30,000 barrels over a few hours at a rate of 80 barrels per minute was injected into the well, there was only the usual gas and oil flow apparent at the riser kink.

I was watching these ROV videos via the internet, as could any member of the public, so my own view is that the mud was going down the so-called "9-in casing," or via some other path into the reservoir. In all, 30,000 bbl of mud was pumped into the well, the volume of which was less than 3000 bbl. Hence, at least 27,000 bbl of heavy mud either went into the reservoir by hydro-fracturing or through a convoluted path out the end of the broken riser onto the seafloor. With the failure of the top kill, BP proceeded with "junk shots," in which solid scraps of various materials such as rubber were injected into the wellhead via the Choke or Kill line, with the intention of plugging the leaks in the BOP, for instance around the Blind Shear Ram. I had argued against the junk shot, and we were told by BP, on May 25, that "[t]he junk shot is no longer on the flow sheet. It is not an option under consideration."[8] Nevertheless, it was attempted, several times.

[8] http://www.oilspillcommission.gov/sites/default/files/documents/Containment%20Working%20Paper%2011%2022%2010.pdf (P. 17)

When the top kill ceased, gas and oil flow resumed within seconds, with no apparent residual effect of the Topkill. An alternative hypothesis was that there was no seal at the 9-in casing hanger, and that hydrocarbons were coming up from the “16-in annulus” (the annular space between the 9-in casing and the 16-in casing) while the Topkill was being attempted, with the mud going down the 9-in casing at the same time as the hydrocarbons were flowing unimpeded up the annulus.

More complicated possibilities existed, with the 9-in casing being blocked at its base, but that casing being broken at the “crossover” between 9-in and 7-in casing diameters. In any case, after the failed dynamic top kill, operations resumed to collecting as much gas and oil as possible through Tophat 4, and bringing in more ship capacity on the surface to do the same.

> A lesson for the future is that the industry should master seafloor storage and separation of mixed oil and gas on various scales—ranging from a buffer of a few seconds to days or weeks of product storage.

The failure of the Top Kill and the Junk Shots is reported by the OilSpill Commission staff to have brought a sea change in the relationship between BP and the government, with two government officials asserting the right to attend a BP planning session.[9]

But hurricane season was approaching, during which time the ships could not be there on the surface, and a more durable solution was sought (which to my mind should have been pursued in parallel by BP over the previous months and by the industry over the previous years).

Two "relief wells" had been initiated early on, as is conventional for wild wells on land or in the ocean. A relief well sometimes has the task of intercepting the bore of the wild well, and providing an alternative open path for collection of the hydrocarbons, to enable the valves at the surface of the wild well to be closed without excessive pressure at the wellhead.

But before the relief well was completed, BP, with the approval of the USG, affixed a three-ram Capping Stack to the top of the failed blowout preventer. This was done by using the ROVs to unscrew the six massive bolts in a large flange visible in the slide, and bolt the Capping Stack to the top of the BOP system. The Capping Stack was equipped with two sensitive pressure gauges, which were used together with one of the valved

[9] Ibid, P. 18

vents from the Capping Stack to the Gulf water to calculate the flow from the well into the Capping stack.

The valves were cautiously closed, and the pressure at the wellhead rose to a still acceptable level against the seafloor ambient. Fortunately, even the damaged BOP sustained this pressure, and when the valve was closed, the pressure remained essentially constant, following some transient due to the cooling of a gas bubble that had been adiabatically heated by the increase in pressure. It was determined that there was no large leak of reservoir fluids from the well, and on July 15 the well was shut-in with no further leakage into the Gulf.

At this point, with hydrocarbons no longer flowing at the well, BP proposed and was authorized to do a static top kill, in which heavy synthetic oil based mud (SOBM) was introduced (thus without danger of hydrate formation) via the choke or kill line through the open test ram in the failed BOP. About 3000 bbl of SOBM was thus introduced, with a leader and a follower of base oil, in order to reduce the hydrostatic pressure at the wellhead to near-seafloor ambient. BP carried out the injection of mud on August 2. On August 5, BP completed displacement of much of the mud by a total of 500 bbl of cement, but with the probability that the well annulus was not filled with mud or cement.

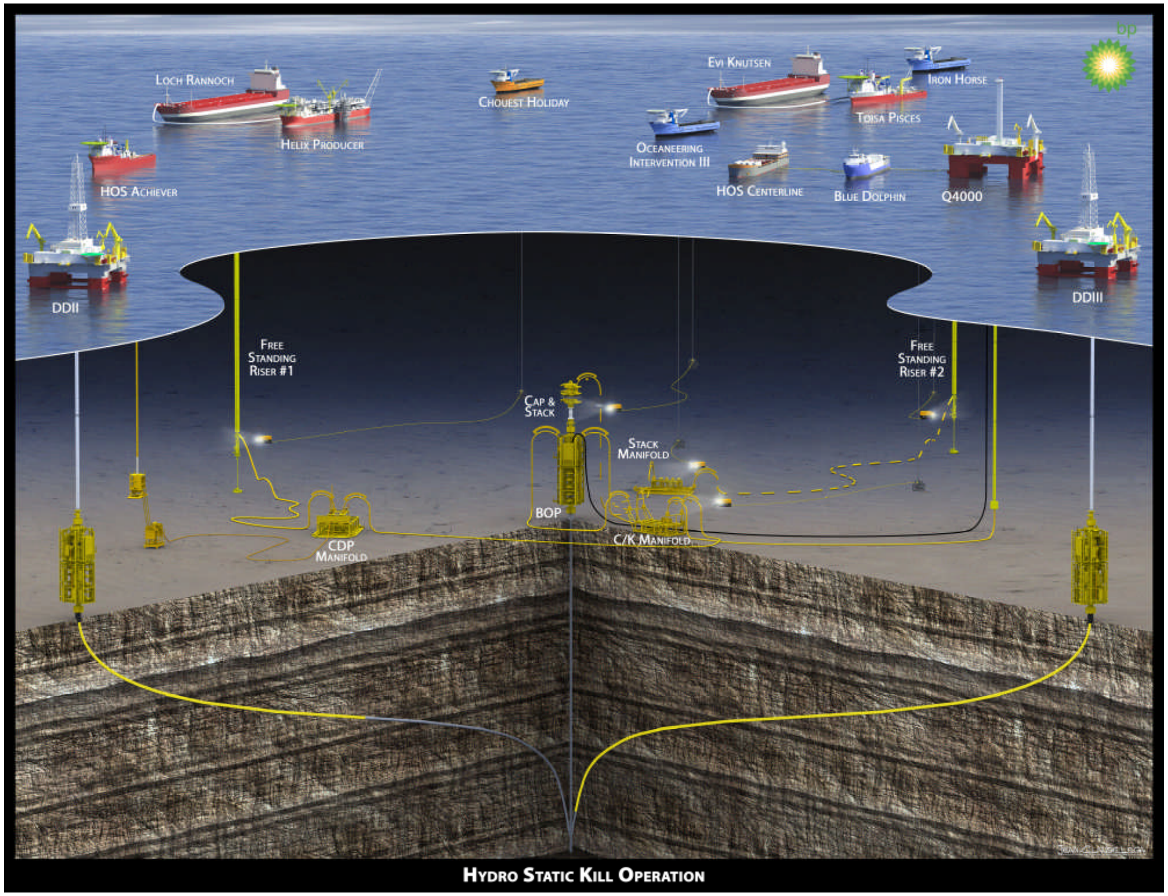
Written as of August 20, 2010, before relief-well operations.

In this case, the relief well will have the task of injecting heavy mud into the wild well, Deepwater Horizon, so that the mud will flow up the annulus path to the surface, once the "capping stack" valve is opened and communication from the top of the annulus ensured, for instance by perforation of the 9-inch casing near its top. Any fluid in the annulus must evidently be displaced by mud and eventually by cement from the relief well.

The simplest approach to allowing mud and cement from the relief well to displace the current contents of the annulus is to open a valve on the capping stack, which, under some circumstances might allow 1000 bbl of oil to flow into the Gulf-- less than 30 minutes of the unconstrained flow through the failed BOP that persisted almost 3 months. An alternative would be to master the technology of having even a relatively small buffer tank at seafloor that could hold the gas-oil mixture in the amount of 1000 bbl (about 150 cubic meters) above seawater, until it could be taken away. The hydrocarbons would be isolated from seawater by a slack diaphragm—a technology widely used in many fields.

The cementing was completed August 5 and appears to have been successful, in that the pressure at the wellhead has been steady for the last 10 days or so, with no evidence of leaks into the rock formation or up around the outside of the casing of the well. But it is not at all clear whether the cement went down to the reservoir through the 9-in central casing of the well or crossed over and went down through the 16-in casing of the well.

The operation is well covered by a briefing[10] by BP's Kent Wells, of which I provide here a static Slide 7.



SLIDE 7. From an animated BP video briefing by BP's Kent Wells, covering Static Kill and relief well, DD3.

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[10] http://bp.concerts.com/gom/kentwellstechupdate_072110a.htm

In an interview on August 18, National Incident Commander, Admiral Thad Allen, noted the constraint that when DD3 makes the intercept with heavy mud, and if the annulus of Deepwater Horizon is filled with light hydrocarbons, the wellhead must not be over-pressured.

Clearly the solutions include opening valves on the wellhead, and either taking the hydrocarbons into a TopHat filled with methanol or base oil, or into a storage tank on the seafloor, initially filled with base oil to avoid hydrocarbon formation.

BP has announced that following its success in opening of the wellhead to ambient seawater, the failed BOP will be replaced with the BOP that has been mounted on the DD2 relief well, and that the DD3 relief well operation and cementing will be delayed until September.

With due attention to every detail of this activity, the mudding and cementing of the annulus of the Deepwater Horizon well should be completed safely and the well transferred to the routine "P&A"—Plug and Abandonment.

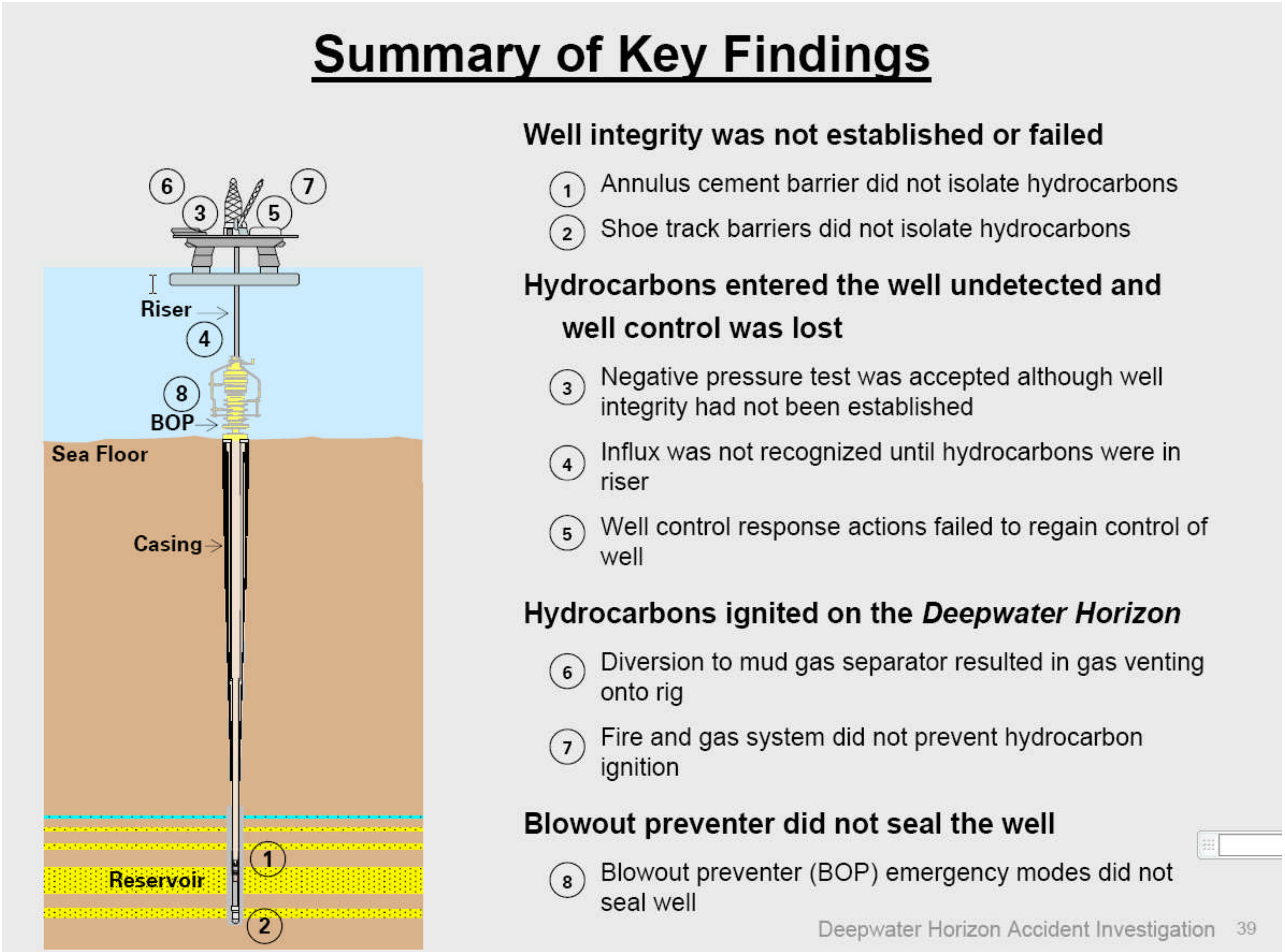
Afterlude

The BP Internal Investigation and Report[11]

Much useful detail can be gleaned from the Report, such as I have mentioned in showing details of the BOP and LMRP from an Appendix of that document. Here I show a slide from the BP "Presentation Brief,"[12]

[11] http://www.bp.com/sectiongenericarticle.do?categoryId=9034902&contentId=7064891 See the full report and also important appendices.

[12] http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/incident_response/STAGING/local_assets/downloads_pdfs/Deepwater_Horizon_Accident_Investigation_static_presentation.pdf



BP Presentation accompanying BP Accident Investigation report of September 8, 2010

National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling

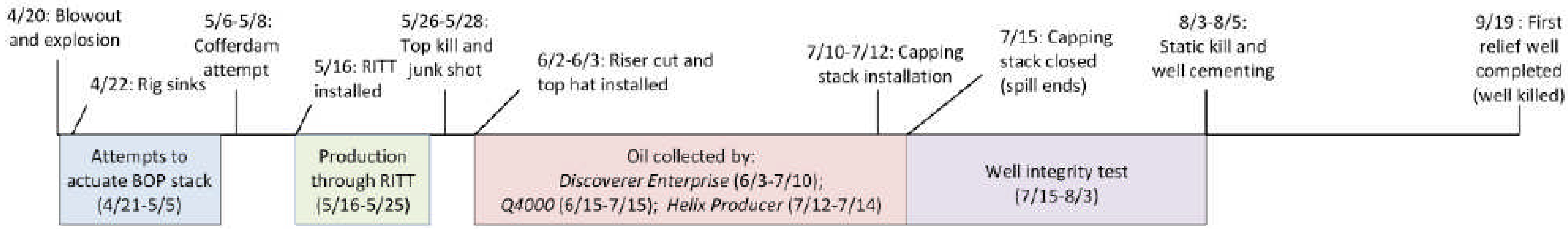
What follows, together with some of the previous slides, I credit to the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling,

- Senator Bob Graham, Co-Chair
- William K. Reilly, Co-Chair
- Frances G. Beinecke
- Donald Boesch
- Terry D. Garcia
- Cherry A. Murray
- Frances Ulmer

At a time when the U.S. Congress is largely defunct and the U.S. economy in ruins, the Oil Spill Commission13 is a light on the horizon. The Commission and its investigative staff have so far done a great job. Furthermore, there is wonderful access to the Commission meetings via streaming video and also archived at its website, together with slide presentations from the staff, including, e.g., this timeline:

[13] www.oilspillcommission.gov

B. Killing the Well



The performance of the Commission staff is an outstanding example of competence and public service by lawyers and other specialists. We have good people in the government and some in the House and the Senate, but we have arrived at an organization and incentive structure such that the whole is far less than the sum of its parts.

The task given by President Obama to Secretary of the Interior Salazar and Secretary of Energy Steven Chu was to stop the oil spew and to make sure that it never happens again. I think that Secretary Chu and his team did have significant positive influence in stopping the spew, but the task of ensuring it does not recur is being competently handled, thus far, by the Oil Spill Commission.

It is truly fortunate that, despite the many errors cited in BP's internal investigation that led to this preventable disaster, BP is a company with vast technical, organizational, and financial resources. Soon after the disaster occurred, BP leadership announced that it took full responsibility for making it right, not limited to the legal liability limit of $75 million of the 1990 Oil Spill Liability Trust Fund act. Indeed, BP will pay for its own actions in responding to the spew, as well as for costs incurred by the U.S. Government and the affected States. The greatest liability, though, is imposed by the Clean Water Act, which imposes a civil fine of up to $1100 per bbl into the water, rising to $4300 per bbl in cases of gross negligence or willful misconduct. At the government estimate of about 5 million barrels of oil, the smaller fine would be as much as $5.5 billion, and the larger fine up to $21 billion.

Within the past days, BP has indicated that it will challenge the U.S. assertion of 205 million gallons, as soon as it develops an accurate estimate itself. As I indicated, BP showed no interest in quantifying the spew, maintaining that whether spew as “small,” 1000 bopd, or 5000 bopd, its response would not be affected. It was quite apparent from the beginning that BP had a great incentive to argue ultimately that the spew was small, in order to minimize the potential fines. A BP measurement of the flow rate would have reduced BP’s staff freedom of action to so argue.

Now I am ready for questions and comments.

Thank you for your attention.