Key Issues in Deepwater Drilling in the Future

In the concepts of process safety (defined as containment of hazardous materials; as drilling a wellbore full of pressured hydrocarbons certainly is) interactive complexity and tighter coupling are two key terms that signify increased risk and concern for safety. "Interactive complexity" is a measure of the degree to which we *cannot foresee* all the ways things can go wrong. This may be because there are simply too many interactions to keep track of. More likely, it is because our various theories are simply not up to the task of modeling socio-technical interactions.

"Coupling" is a measure of the degree to which we cannot stop an impending disaster once it starts. This may be because we don't have enough time, because it is physically impossible, or because we don't know how.

The greater the degree of interactive complexity, the less our capacity to *prevent* surprises. The greater the degree of coupling, the less our capacity to *cure* surprises. The greater the degree of interactive complexity *and* coupling, the greater the likelihood that a system is an accident waiting to happen.

In such systems, "operator errors" merely serve as triggers. Trying to find, let alone blame, the particular straw that broke the camel's back is therefore an exercise in futility--a "fundamental attribution error."

Strategies for dealing with Type III messes are therefore quite different from those appropriate for tame problems. Strategies logically follow from the ways problems are conceptualized. Thus, increasing our capacity to prevent unanticipated interactions among components entails simplifying systems (KISS); increasing our capacity to cure them entails de-coupling major components (e.g., build in longer times-to-respond).

Now let’s first address only one trend in deepwater that leads to both interactive complexity and tighter coupling and this trend is the generalized movement of exploration to deeper subsea depths and deeper waters. First, deeper subsea depths are simply the trend we generally see in oil and gas exploration on land as well as sea and that is to explore the shallower geologic horizons first and move deeper over time and this is simply because the shallower sediments are more easily accessed on a cost and risk basis. Therefore as time goes by we general move from the easiest and shallowest prospects to the more difficult, costly and deepest prospects below the mudline. Now, temperature is generally a function of depth in oil and gas basins and this is true in deepwater as well and although the temperatures in the specific sediments of deepwater are mitigated relative to continental crust by its mineralogy they do increase as we explore into deeper subsea depths. Of course pressures increase with this increase in depth similarly. The chemistry of the reservoir fluids we explore change with this pressure and temperature. The gas to oil ratios (GOR) of these oils we are encountering in these deeper zones tend to increase and the existence of purely gas zones becomes more frequent with this same increase in depth, pressure and temperature. Let's simply explore the key significance and issues that increased gas content and higher temperatures and pressures has on the interactive complexity of deepwater drilling systems.

We all know that current deepwater drilling systems include the use of synthetic oil based muds (SOBM) to drill these prospects. People that drill in high temperature and high pressure (HTHP) regions can tell you that the interactive complexity of drilling with oil based muds (OBM) is in well control and the fact that gas diffuses into OBM and solubilizes into the oil phase of this drilling fluid. This gas adds relatively little to the volume of the OBM at the pressures and temperatures above the bubble point of that gas in the OBM as the solvent and therefore is difficult to detect an influx volume (kick or diffused volume). These bubble points of gas, either diffused into the mud system or suddenly introduced as a kick, will be somewhere between the hydrostatic of the bottom of the hole being drilling and the hydrostatic pressure at the surface at the rig floor and therefore this gas will "flash" out of the drilling fluid system at some depth and this depth is a function of the bubble point of the gas in the OBM. The bubble point is usually convoluted with the different chemistries of gases possibly encountered during drilling. At higher GORs and higher temperatures and pressures at these deeper depths subsea there is a general trend to encounter more gas and heavier gases. These heavier gases, methane being the lightest, ethane, propane, and butane each have very different bubble points and therefore will "flash" at very different depths at which different hydrostatic pressures exist. Methane, has the highest bubble point and therefore will "flash" deeper in the wellbore than Ethane that will "flash" higher up in the wellbore, and Propane will "flash" higher than Ethane and Butane higher than all three. The fact that the trend in drilling deeper below subsea will encounter higher temperatures and higher pressures and higher GORs and heavier gases means that these wellbores, at any point in time, will be absorbing more of gas through diffusion and/or kicks, and into hotter and more pressured OBM and these gases will be "flashing" over a broader spectrum of depths bringing more gas into the riser and creating hazards of the socio-technical type in the process. Also, kick detection becomes harder and well control is increasingly complicated de facto. After reviewing these facts it is easy to conclude that drilling deeper subsea depths is adding interactive complexity to deepwater exploration.

Now let's explore tighter coupling or as defined above, "measure of the degree to which we cannot stop an impending well hydrostatic imbalance once it starts." Also, let's now explore the contribution of the trend of moving to deeper and deeper waters to adding more and increasingly tighter coupling to the increasing interactive complexities in deepwater exploration trends in drilling. First, deepwater drilling, as we know involves distinct differences in drilling compared with surface blowout prevention equipment (BOPE). The main difference, that leads to tighter coupling, is the relation of the control function line lengths and response times. The control function line lengths increase proportional to water depth. The response times to BOPE closure increase with control function line lengths and therefore the response time to close BOPE increases with water depth. With increasing water depths will be a relative increase in response time once a kick is detected until the BOPE surface panels are engaged to activate subsea BOPE controls. This increase in response time is by definition considered tighter coupling of increased interactive complexity. Now, add to this an addition to both the tighter coupling and the interactive complexity the fact that as the water depths increase the BOPE is deeper and thus closer to the bubble points of drilling fluid systems that are increasingly saturated with higher volumes of gas. These bubble points thus rise and are fast approaching shallower depths as the denser gases are encountered as a result of the hotter and more pressured geologic depths are drilled with heavier gases (above C1, ie. C2…C4, etc.) and the BOPE equipment is sinking deeper from above, approaching the simultaneous rise in bubble point depths, as the BOPE equipment is deeper and at increasingly higher hydrostatic pressure in the drilling fluid hydrostatic and hydrodynamic annular pressure column. This issue is complicated to explain and ever more difficult to keep one's mind around and specifically these depths and bubble points are functions of complex oil and gas chemistries that are hidden deep in the earth and may only be estimated ahead of time from secondary and tertiary indicators.

Add all of this up and we can easily acknowledge that on this issue alone, and there are others, we are moving to higher interactive complexity and tighter coupling. Another issue, the socio-technical one specific to this issue, is the technical expertise required to move towards higher temperatures and pressures and the issues of gas in SOBM approaching HTHP conditions. Understanding these issues benefits of expertise of an increasingly different sort than deepwater engineers in the past have possessed.

The solution to this challenge and the way forward is Process Safety applied to Drilling (see Process Safety 101) and training deepwater drilling engineers with no experience in HTHP gas well drilling in the nuances of kick detection and well control of drilling in high GOR wells and in particular the issues we face in deeper and deeper water and subsea BOPE systems. Seeking improvements in monitoring the system and the state of the art in kick detection systems and perhaps movement towards more managed pressure drilling control devices such as rotating pressure control devices on our new fleet of deepwater drilling rigs and also adding these to the existing fleet, is needed.

In addition the five attributes of a highly reliable organization (HRO) should be adopted and these are well documented in the literature, namely:

1. Preoccupation with failure (addressing & keeping in mind worst case scenarios).
2. Reluctance to simplify interpretations (not saying, "this is simple, relax")
3. Sensitivity to operations (keeping team members involved in operations).
4. Commitment to resilience (diligent to new solutions and indicators)
5. Deference to expertise (realizing with complexity are needs for experts)