British Petroleum's Deepwater Horizon Accident and the Thinking, Engaged Workforce – 13265

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ABSTRACT

On April 20, 2010, hydrocarbons escaped from the Macondo well into Transocean's *Deepwater Horizon*, resulting in fire and multiple explosions. 11 people on the rig died. The billion dollar Deepwater Horizon sank. 4.9M gallons of product flowed from the well for 87 days creating an environmental nightmare for communities bordering on the Gulf of Mexico. BP established a $20B reserve to pay for damages. Investigations and legal culpability continue to this day. In September 2010, the Institute for Nuclear Power Operators (INPO) issued Significant Operating Experience Report (SOER) 10-2, Engaged, Thinking Organizations. The industry had experienced 11 events, 9 in US commercial nuclear utilities, and 2 international, that had disturbing trends. The underlying causes highlighted by INPO were inadequate recognition of risk, weaknesses in application of significant operating experience, tolerance of equipment and personnel problems, and a significant drift in standards.

While the noted INPO problems and the Deepwater Horizon event appear to have nothing in common, they do exhibit similarities in a drift away from expected behavior on the part of front line workers and their supervisors. At the same time, hidden hazards are accumulating in the environment leading to error intolerant conditions. Without a good understanding of this concept, many organizations tend to focus on the person who "touched it last", while missing the deeper organizational factors that led that individual to think that what they were doing was correct.

An understanding of this failure model is important in reconstruction of events and crafting effective corrective actions. It is much more important, however, for leaders in high hazard industries to recognize when they are approaching error intolerant conditions and take steps immediately to add safety margin.

INTRODUTION

Drift and Accumulation Model

Sidney Dekker described complex-adaptive behaviors on the part of workers coupled with the accumulation of hazards that combine over time to produce significant adverse events [1,2]. Tony Muschara (Muschara Error Management Consulting, LLC) developed a mental model to describe this. This model is illustrated in Fig. 1.

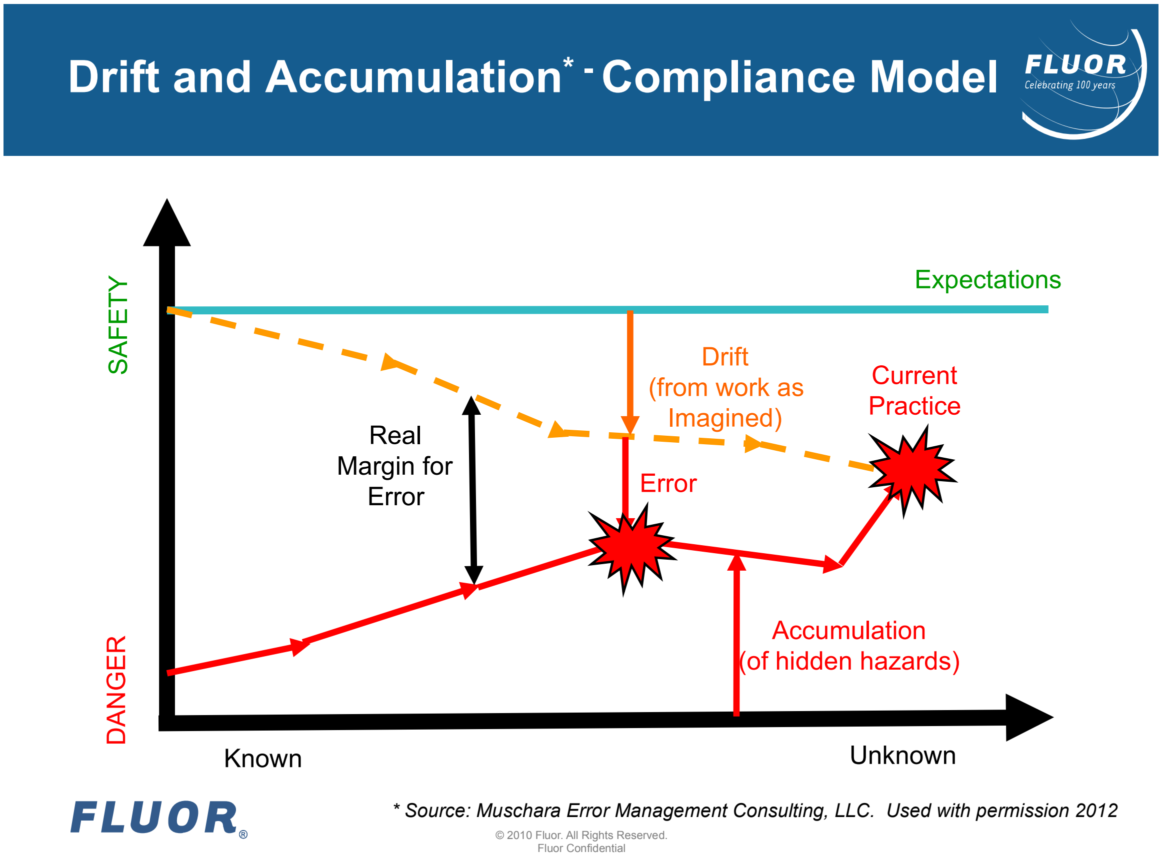

Fig. 1 Drift and Accumulation model

Over time, as workers drift away from the behaviors that managers expect of them (i.e following their procedures and training), the organization knows less and less about what is actually going on. At the same time, hazards are building up in the workplace. These might include temperature, pressure, equipment wear, chemicals, or natural phenomena such as what occurred at the Fukushima Daichi nuclear power station in 2011. At the moment that the worker's actual practice meets the actual hazard, the accident occurs naturally. But in most cases the accident is preceded by an error on the part of the person who touched it last. For organizations at the first stage of cultural maturity (described later), the natural tendency is to blame this person because they "should have known better". By ignoring the behavioral aspects leading up to the accident, these organizations continue to be surprised at failures.

The Accident [3]

On the evening of April 20, 2010, drilling mud was being replaced with seawater in preparation for moving the Transocean Deepwater Horizon to a new location. The well had achieved a depth of 18,360 ft, and was one of the deepest wells ever completed. The crew was highly competent, but had experienced many difficulties with this rig. They were behind schedule and eager to get the rig moved. Unknown to them, hydrocarbons were leaking into the well bore and heading toward the rig itself. At 2149 the hydrocarbons reached the rig and ignited. The fire burned for 36 hours, killing 11 people, seriously injuring 17. After 36 hours, the rig sank, but hydrocarbons continued to spill into the Gulf of Mexico for 87 days, releasing 4.9M gallons of product. The spill became a national event.

DESCRIPTION

BP'S Investigation [3]

On September 8, 2010, BP released its internal investigation. Their investigation team looked at the physical causes for the accident. The team identified 8 key findings:

1 The annulus cement barrier did not isolate the hydrocarbons.
2 The shoe track barriers did not isolate the hydrocarbons. Having
3 The negative-pressure test was accepted although well integrity had not been established.
4 Influx was not recognized until hydrocarbons were in the riser.
5 Well control response actions failed to regain control of the well.
6 Diversion to the mud gas separator resulted in gas venting onto the rig.
7 The fire and gas system did not prevent hydrocarbon ignition..
8 The BOP emergency mode did not seal the well.

BP's investigation team represented the 8 key findings graphically in terms of failed barriers using James Reason's Swiss Cheese model [4] in Fig. 2.

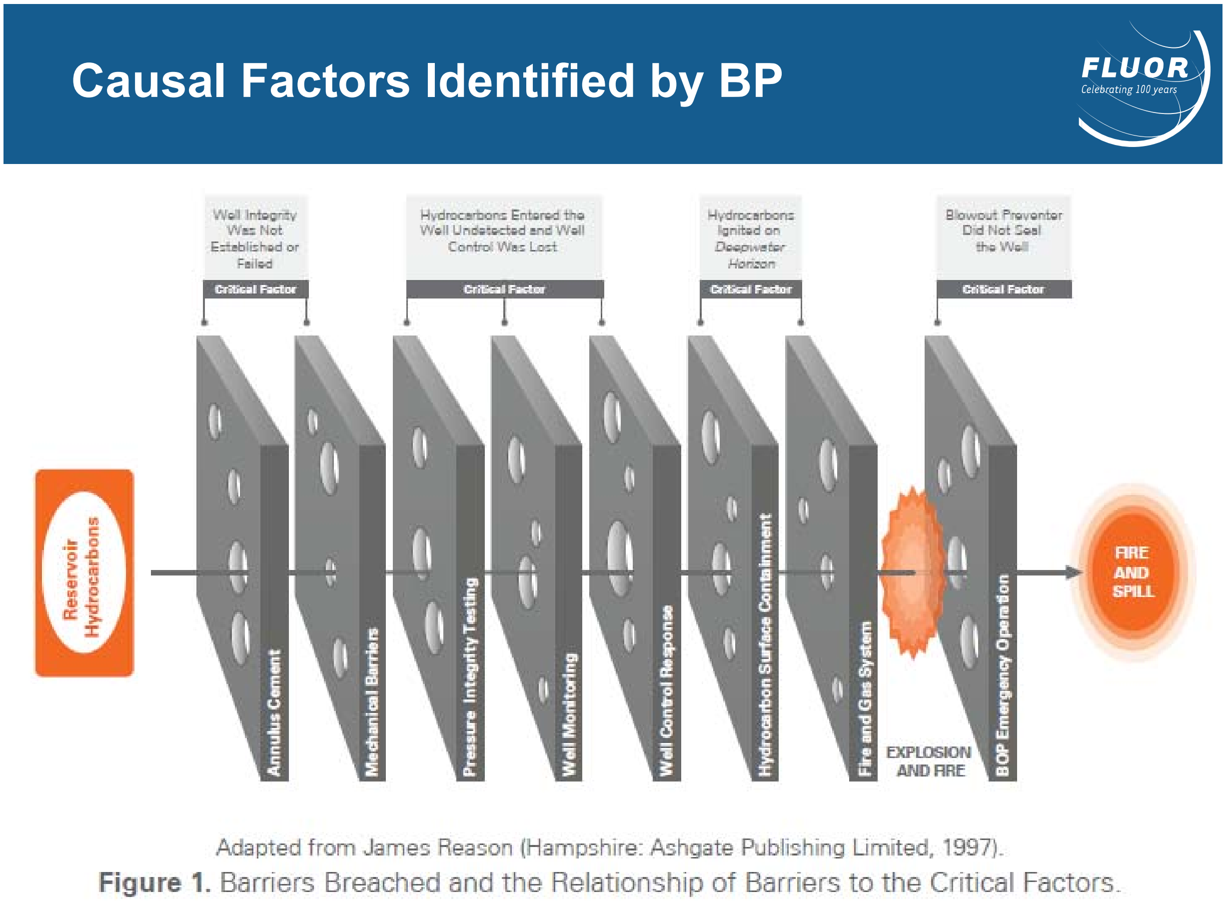

Fig. 2 Causal Factors Identified by BP

BP's Investigation Process

Action to commence the internal investigation began within 24 hours of the initial explosion. BP used its own investigation process, coupled with the accident chronology and Fault Tree Analysis. Information available to the investigation team included partial real-time data from the rig, documents from development of the Macondo well's development and construction, witness statements, results from public hearings, and information provided by other companies including Halliburton, Transocean and Cameron. Access to physical evidence was limited by security. The team settled on the most likely explanation of the physical failure of the well to be nitrogen breakout of the annulus cement and failure of the Shoe Track cement and Float Collar. The team discounted a potential flow path through the seal assembly and potential flow path through the annulus and casing as unlikely. The likely failure mechanisms are illustrated in Fig. 3.

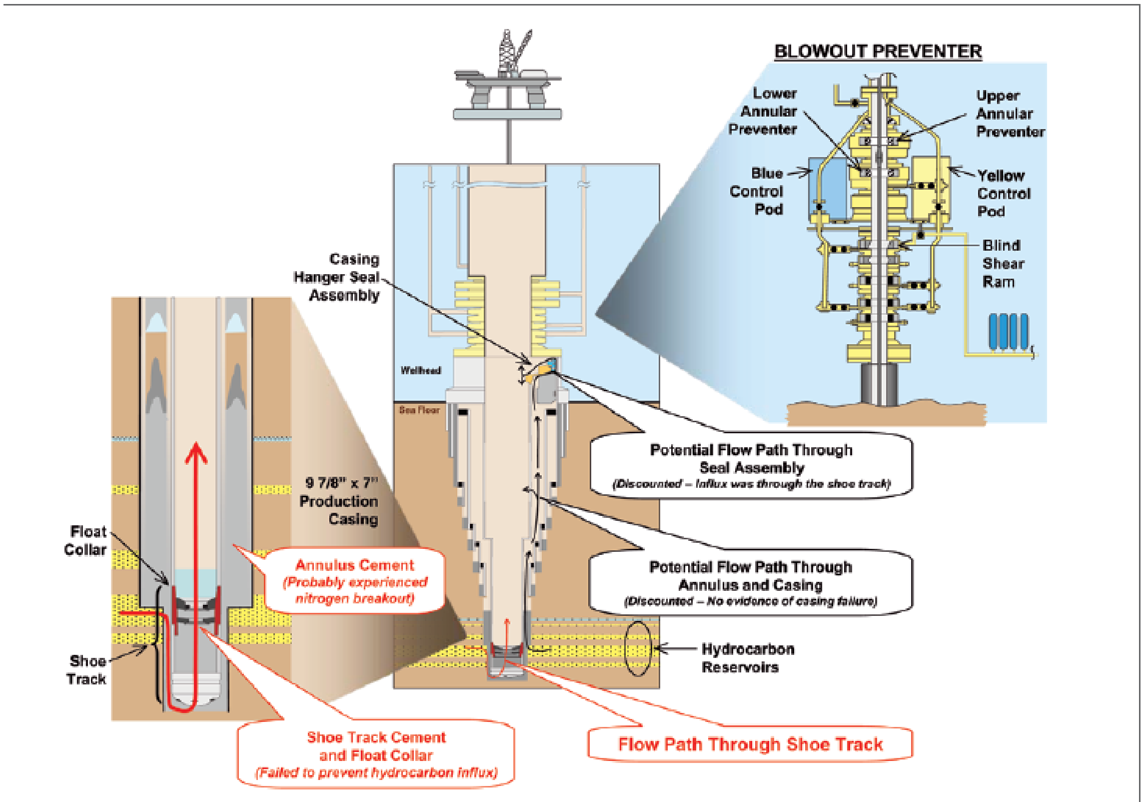

Fig. 3 Graphic representation of postulated failure mechanisms for Deepwater Horizon

Recommendations of the BP Investigation Team [3]

The BP investigation team had 8 recommendations:

1. Strengthen procedures and engineering practices
2. Improve technical and operational capability and competency
3. Strengthen audit and verification practices
4. Improve process safety performance management
5. Improve cementing services assurance
6. Improve well control practices
7. Improve rig process safety through better HAZOP performance
8. Improve BOP design and assurance

DISCUSSION

What's Missing in this Investigation?

This investigation report is typical of many technical investigations in high hazard industries. It tends to focus on the actions of the person who touched the system last, rather than the underlying organizational problems that led the front line operator to think that what they were doing was correct. The recommendations revolve around creating more procedures, more training, and more QA in the hopes that this won't happen again. The reason for this is that it follows a fairly linear understanding of causality that follows Newton's Third Law (for every action there is an equal and opposite reaction). The fault tree analysis used by the BP investigation team lends itself to the sequential model for accident investigation. It investigates causal factors as a snapshot in time, but not the complex adaptive behaviors of individuals working within tightly coupled systems. This model, called the Systemic Model by Erik Hollnagel [5]. In the case of Deepwater Horizon, there were many systems operating in some dynamic tension all the time. The difference here was that the normal variability that the rig operators were experiencing was far different from any that they had ever experienced. Additionally, there were factors deep below the Gulf seabed for which they had no understanding.

While the BP investigation team was composed of world class engineers and scientists, their original charter was limited to the physical causes of the accident. The team did not look at the previous major accident that BP had experienced at the Texas City refinery that exploded in 2005 with the loss of 15 people [6]. That accident was investigated by the Chemical Safety Board (CSB) and was the largest investigation ever undertaken at the time by the CSB. The CSB issued four recommendations to the BP Board of Directors (BOD). Only one of those recommendations was accepted by BP. The three recommendations not accepted included:

2005-4-I-TX-R11 Appoint an additional non-executive member of the BOD with specific expertise in refinery operations and experience and process safety . Appoint this person to be a member of the Board of Ethics and Environmental Assurance Committee.

2005-4-I-TX-R12 Ensure and monitor that senior executives implement an incident reporting program throughout BP's refinery organization

2005-4-I-TX-R13 Ensure and monitor that senior executives use leading and lagging indicators to measure and strengthen safety performance in BP refineries.

While BP never accepted the above recommendations they did restructure some of the BOD functions in late 2010 to accomplish the CSB recommendations. One of the important changes made by the BOD was to include ADM Skip Bowman on the Board. Admiral Bowman was one of the members of the Baker Panel, which performed an interim investigation of the Texas City accident. The Baker Panel, chaired by former Secretary of State James Baker was a high level team of experts looking into the causal factors of that accident and looked deeply into the organizational factors of the accident. Admiral Bowman was the former director of Naval Reactors, then going on to become the CEO of the Nuclear Energy Institute (NEI) after retiring from the Navy.

Learning From Success and Failure

Prior to the Texas City accident and Deepwater Horizon, British Petroleum was a very successful company on paper. Fig. 4 illustrates many of their business metrics, which are necessarily lagging indictors.

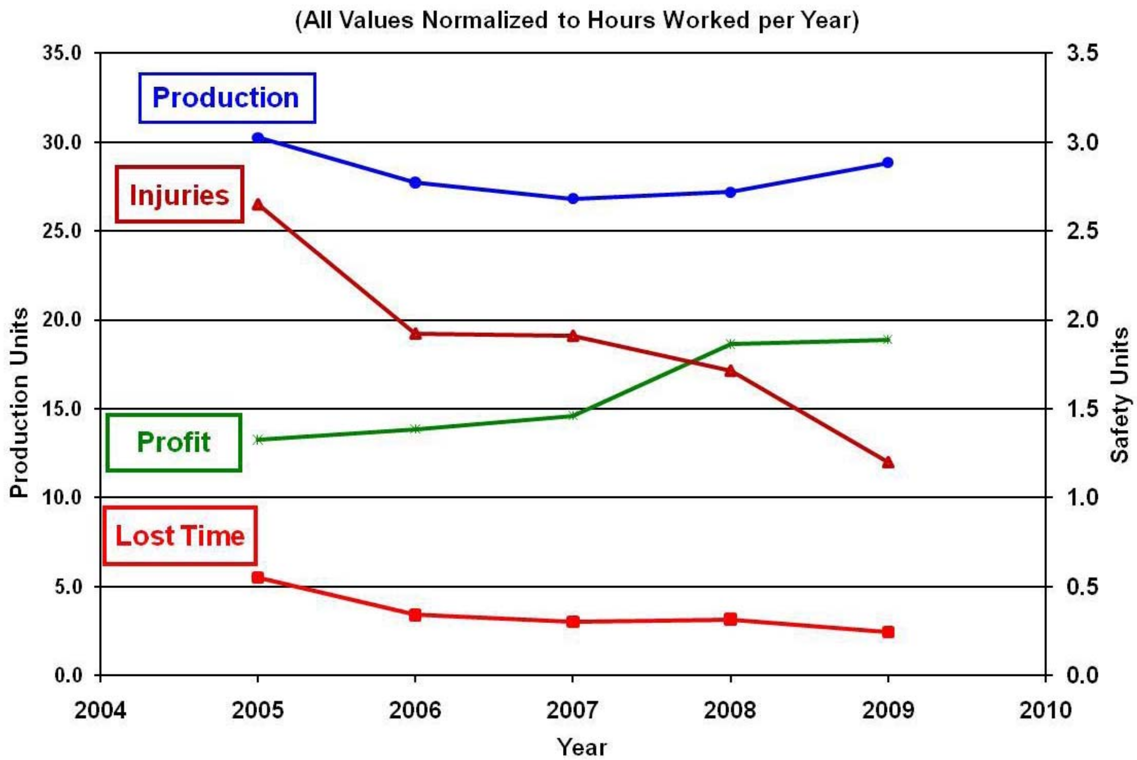

Fig. 4 Key Business Metrics for British Petroleum

Superimposing major accidents over these important business metrics shows a different story in Fig. 5.

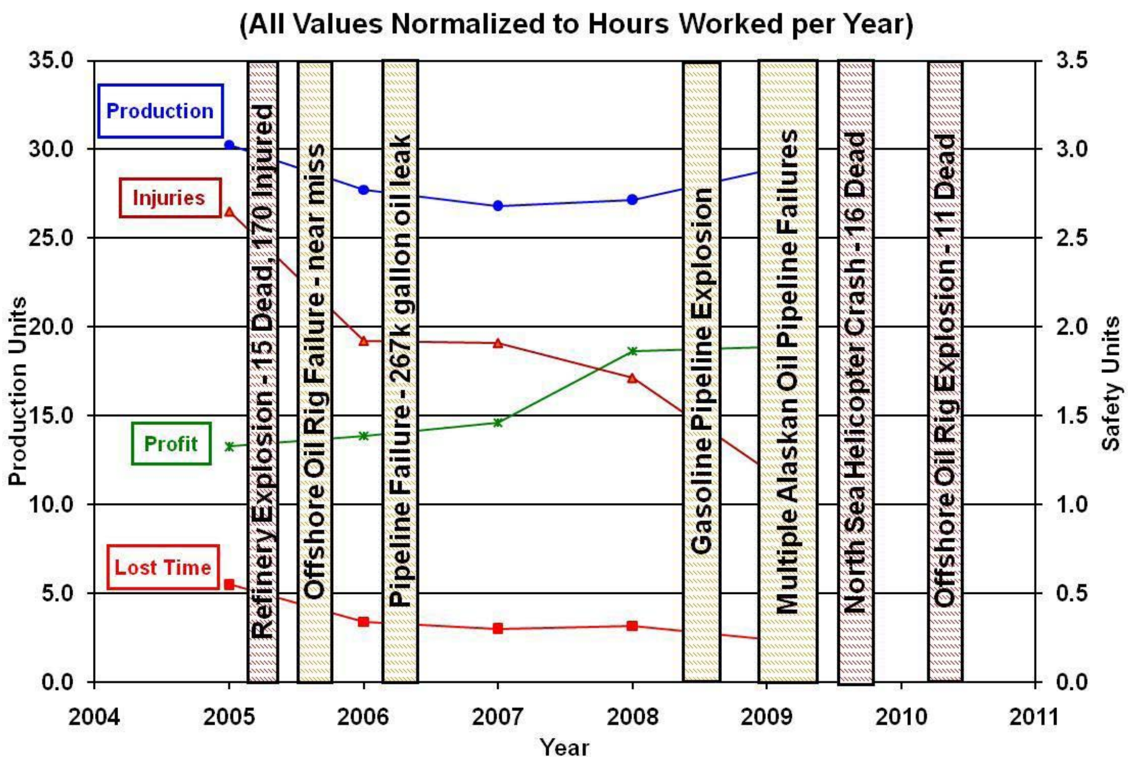

Fig. 5 British Petroleum accident timelines and key business metrics

The CSB noted that BP at Texas City focused on the lagging worker injury rates as an indicator of safety success, conflating industrial safety with process safety. It was evident that this safety philosophy never really changed at BP in many of their business units, despite losing over $3B in the Texas City refinery fire and explosion. The Deepwater Horizon accident cost was nearly 7 times that accident. On the day of the Deepwater Horizon accident, a high level team of BP executives was on board to give awards for good industrial safety performance.

THE PRESIDENT'S COMMMISSION [7]

On May 22, 2010, President Barack Obama announced the creation of the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling. The commission was co-chaired by former Senator Bob Graham and former EPA director William K. Reilly. Members of the commission included politicians, lawyers, and environmental activists. The commission delivered its report in January 2011. The report was written as a narrative and was extensive and far-reaching. The recommendations included providing more regulatory oversight for offshore drilling, restructuring of the Minerals Management Service (MMS) and creation of an INPO like organization for the oil industry.

The National Commission's results were strikingly different from BP's internal investigation. The CSB was directed by Congress to provide their own investigation, since they were so familiar with BP's operations following their investigation of the Texas City refinery fire and explosion. It is anticipated that the CSB investigation will be different from these two as well. The question one might reasonably pose is "how come?"

Principles of Accident Investigation

This leads to principles of accident investigation:

WYLFIWYF

What you look for is what you find

WYFIWYF

What you find is what you fix

WYSIATI

What you see is all there is

Because accident investigations are shaped by who is on them, careful consideration must be given to the members and how they are chartered. BP's internal investigation was comprised mainly of engineers and scientists, and focused on the physical causes of the accident and the bad decisions of the rig operators. The President's Commission was focused on the consequences and extent of the event with an eye toward reducing regulatory risk. The CSB tends to take a more overarching view of the event, focusing especially on the organizational factors that would lead the players in the accident to believe that what they were doing that led to the accident made sense at the time. They always look at Human Performance in the major investigations.

Drift and Accumulation and the BP Deepwater Horizon Accident

An understanding of the Drift and Accumulation model in the context of the Deepwater Horizon accident reveals that the rig crew departed spectacularly from expected actions based on the telemetered data recovered after the accident. But the history of the rig showed that this was a particularly difficult drilling location, and they were significantly behind schedule and over budget. Although the crew was highly qualified and experienced, they had learned to adapt their performance of rig functions over time until they were well outside what the management team expected of them. The management team for the three corporate entities (BP, TransOcean, and Halliburton) did not really understand the relationships that assured process safety on the rig, and how those relationships had eroded over time. They focused instead on the lagging indicators of budget, schedule and industrial safety rates. The net result was a drift away from management expectations.

At the same time pressures were building deep within the well that were unknown to the crew. The concrete used to seal the well was flawed and allowed leakage. The BOP did not work the way it was envisaged and failed as the last physical barrier. The mitigation barriers of fire system design, Mud Gas separator design, and crew emergency response all failed. Thus hidden hazards built up until the action of the rig operators to remove the drilling mud, replacing it with sea water, triggered the accident. That decision to move forward with the drilling mud replacement was not an error or a mistake. It was a purposeful decision that was correct, based on the information the rig operators had at the time.

INPO SOER 10-2

In September 2010, the Institute for Nuclear Power Operators (INPO) issued Significant Operating Experience Report (SOER) 10-2, Engaged, Thinking Organizations. The industry had experienced 11 events, 9 in US commercial nuclear utilities, and 2 international, that had disturbing trends. The underlying causes highlighted by INPO were inadequate recognition of risk, weaknesses in application of significant operating experience, tolerance of equipment and personnel problems, and a significant drift in standards. A macro analysis of the 11 events revealed that 2 occurred during normal operations, 2 as a result of degraded conditions, and 7 were as a result of maintenance, usually during refueling outages when schedule pressure is high.

A side by side look at both the BP Deepwater Horizon fire and explosion and the Texas City fire and explosion events reveals similar underlying causal factors. While it would be inappropriate to believe that the US commercial nuclear power industry is on the verge of accidents on the scale of Deepwater Horizon, leaders can look at common factors to look at their organizational culture to learn some cheap lessons.

Safety Culture and the Engaged, Thinking Workforce

One of the better documents describing culture in technical organizations is the International Atomic Energy Agency (IAEA) TECDOC 1329 (2002) [8]. In it, the document describes three levels of cultural maturity.

- Safety based on rules and regulations
- Safety is an organizational goal
- Safety can always be improved

Graphically, these levels are presented in Fig. 6.

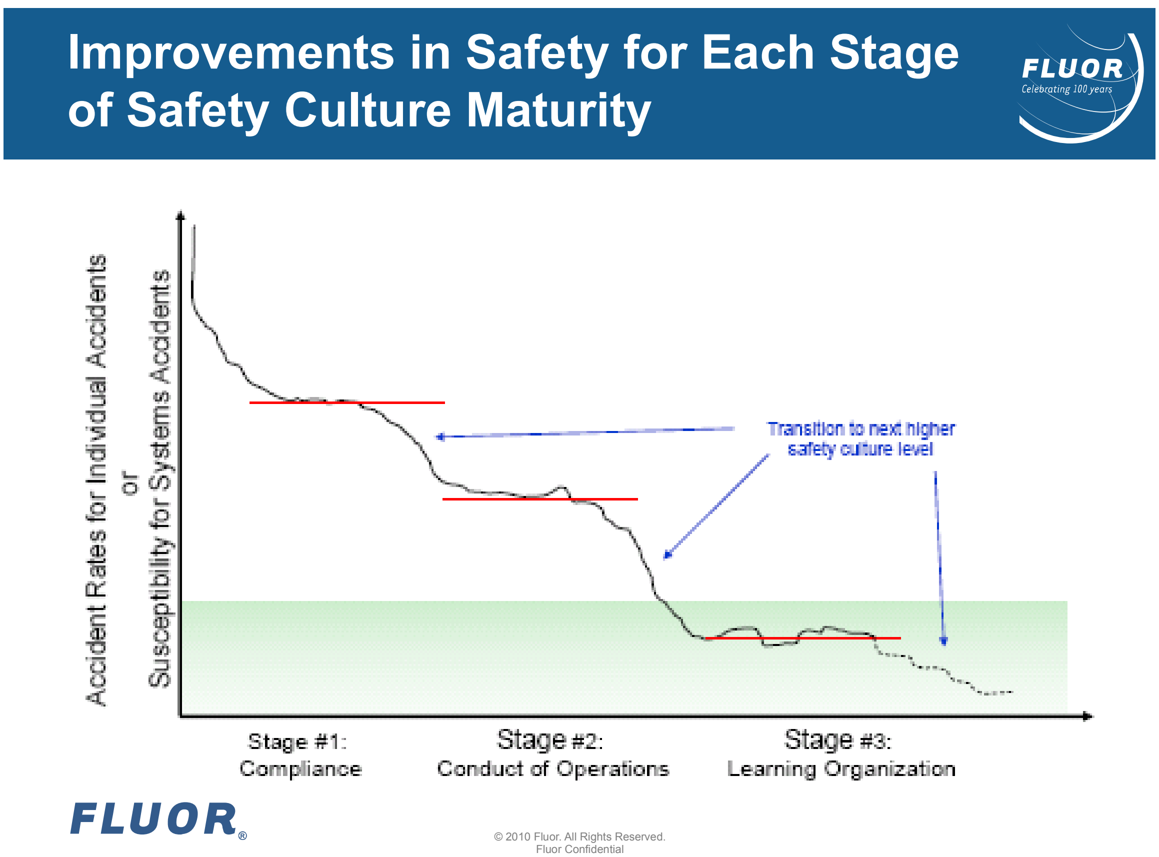

Fig. 6 IAEA Cultural Maturity Model

Stage 1 – Safety based on rules and regulations

This is the most basic level. These organizations consider safety as something imposed by external forces. As long as they follow the rules they are “good enough”. These organizations tend to be reactive in nature with little communication or collaboration. Managers are seen as enforcement of rules that may or may not work, and workers are rewarded for obedience and results. Long term consequences are ignored. These organizations are always surprised that their injury rates aren’t better. They fail to see that their mediocre injury rates generally track mediocre financial performance. British Petroleum might be considered to be operating at this stage at the time of Deepwater Horizon.

Stage 2 – Safety as an Organizational Goal

These organizations consider safety to be an important goal of the entire organization regardless of external requirements. Within both commercial nuclear power and the Department of Energy (DOE) this is referred to as the “Conduct of” model. They are aware of cultural issues, but not necessarily of the behavioral attributes that contribute to them. They are less reactive than organizations at Stage 1. There is more accountability for good performance, and management’s response to problems is to impose more training and procedures. They fail to understand why those added controls don’t work in the long run. These organizations benchmark other companies to gain improvement insights, but their commitment to internal learning, especially through effective post-job reviews is stunted. Problems at the Human-Machine interface (HMI) are addressed in order to make them more efficient, not necessarily to understand the opportunities for adaptive engagement by workers. People are rewarded for exceeding goals, but without regard for long term consequences. Most commercial nuclear power plants who are INPO members would fall into this maturity level. Their Drift and Accumulation model for this level of cultural maturity is represented in Fig. 7.

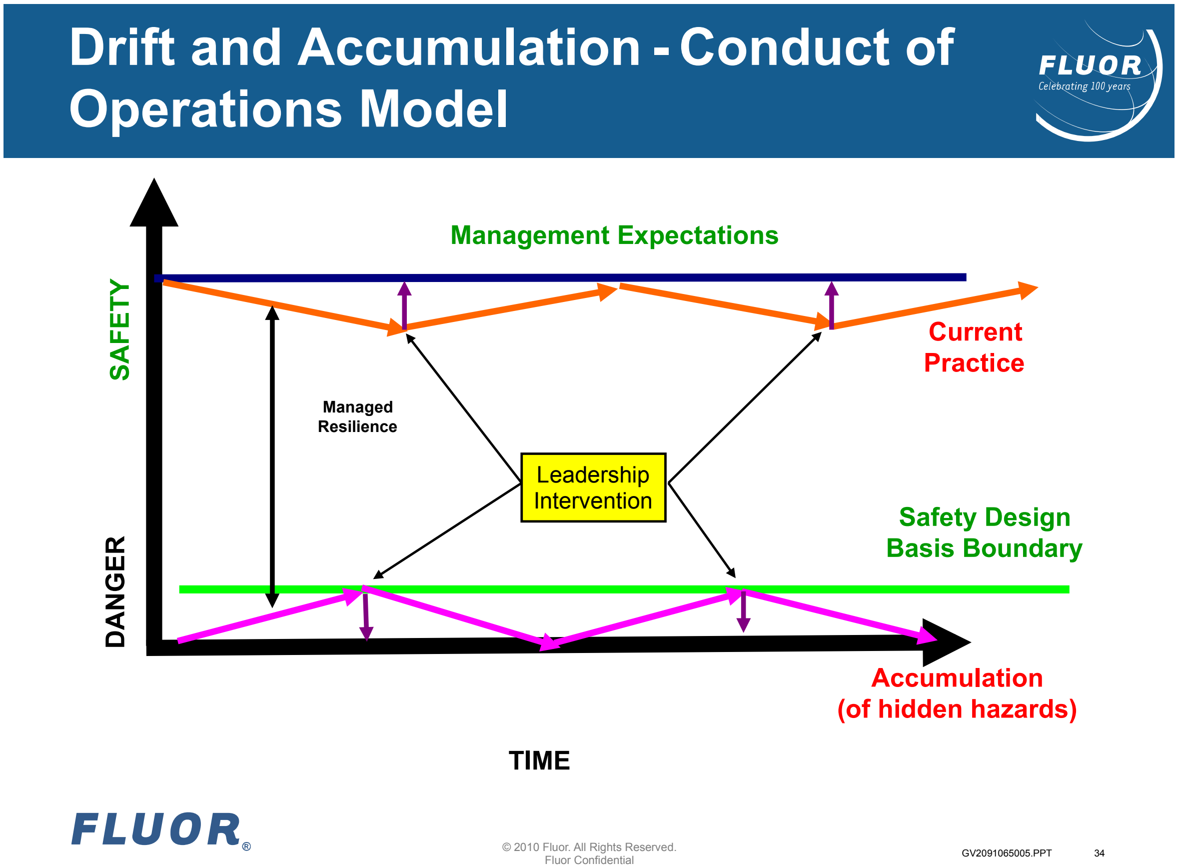

Fig. 7 Drift and Accumulation for Conduct of Operations level of cultural maturity

Stage 3 – Safety can always be improved

These organizations are few in number, and are leaders in both safety and financial performance. They are committed to continuous learning and always manage to outpace their competitors. They are referred to a Learning Organizations, or more recently, High Velocity [9] or Highly Reliable Organizations (HRO). Problems are anticipated and managed before they occur. Collaboration and communication are strong. There is no conflict between safety and production. Every occurrence of process variability is viewed as a learning opportunity. Managers are viewed as coaches and mentors. While these companies learn both externally and internally, their most commonly used tool for learning is the post-job review. People are rewarded for improving processes and results. Very few organizations meet these criteria. Recognized examples include flight deck operations on US Navy aircraft carriers, US Forest Service wildland fire fighters, FAA regulated air traffic controllers, Toyota, and Alcoa. Their Drift and Accumulation model is represented in Fig. 8.

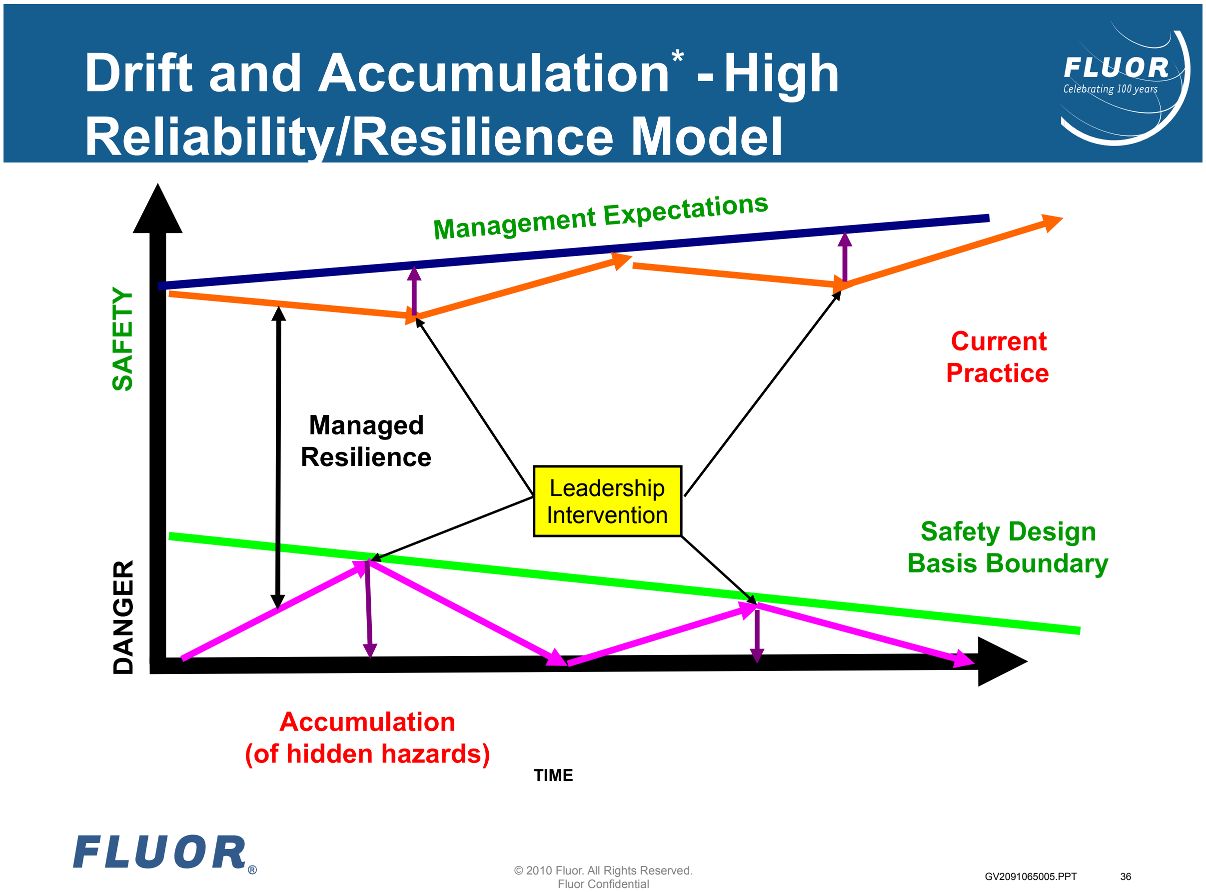

Fig. 8 Drift and Accumulation for Learning Organization level of cultural maturity

CONCLUSION

In summary, the role as leaders is not to define safety as the absence of accidents. Instead, the leader's role is to assure the presence of *defenses* in processes, procedures and methods. "What we do for a living is to keep failure from being successful" [10].

As is demonstrated from BP's Deepwater Horizon event, being content with merely following the minimum standards for operations does not assure success. This requires a level of cultural maturity in high hazard industries rarely achieved; where workers and managers are engaged collaboratively in what is actually going on within the organization that leads to deep thinking about why things don't go as planned. After many high profile process safety failures, BP has been jolted into awareness that what was successful in the past, will not assure success in the future. After restructuring at the BOD level, cultural changes are now filtering down through the corporation.

Todd Conklin describes four attributes of good leaders [10]:

- They are fixated on failure
    - An accident that can be predicted is one that can be prevented
- Seek to reduce operational complexity
- Respond with urgency to precursor events
- Respond deliberately to accidents and major events

In moving forward, using Deepwater Horizon as an example, there are three things leaders can do to improve engagement and thinking. First, leaders can and should look at error reduction techniques and tools. Errors will always occur, but there are Human Performance tools widely available to reduce them. Secondly, leaders should get engaged with reducing the natural gap between "work as expected" and "work as done". This requires them to be out in the field engaging collaboratively with their workers in a coaching and mentoring role. Finally, leaders must discover better ways to see and prevent hazards from building up in the workplace. This requires attention to process safety as well as industrial safety. This last recommendation is the hardest, because, over time, hazards become accepted and invisible. The best tool for leaders in high hazard industries to achieve these recommendations is the post-job review. This tool leads to continuous learning and improvement.

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