DISASTROUS DECISIONS

Commentary on the book by
Andrew Hopkins

By Graham Dalzell

Overview:

- How we drill oil wells
- The disaster itself – how it happened; (anonymised)- oil, well and drilling companies
- Andrew's conclusions on the Human, Organisational and Societal Causes
- My thoughts arising on Andrew's conclusions

Drilling the well:

- Oil Company/Drilling Company/Wells Company
- 77 miles from the Louisiana coast
- Re-entry, completion 2and suspension
- 5000 ft water depth
- 13000 ft terminal depth
- Total 18360 ft
- New payzone – uncertainties
- Not thought to be HP HT but still huge potential and high Gas to Oil Ratio (GOR)
- At the limit of experience in GoM and worldwide

What Happened (1):

View You Tube: 3.00 to 28.50

https://www.youtube.com/watch?v=zE_uHq36DLU

- Drilling completed through payzone
- Long string production casing run and installed with 6 centralising packers
- Nitrogen foam cement injected to fill the bottom of the casing and back up the outside of the casing through the payzone to a point above it. Pumps needed 3000 psi not the usual 500.
- 20th April a.m: Pump pressure bled off and check valves in shoe collar appeared to be holding. Wellhead seal assembly installed and tested
- Positive pressure test applied by closing blind shear rams on seabed BOP and applying 2700 psi into the well

What Happened (2)

- Drill pipe run to 8760 ft to carry out negative pressure (underbalanced) test 20th April early p.m. (Underbalances well by replacing some heavy mud with spacer and seawater)
- 17.08: Annular BOP closed on drill pipe to seal well and attempt to bleed down drill pipe failed as fluid leaked down through the annular preventer
- Annular pressure raised to seal well and 50 barrels added to the riser to replace losses.
- 17.27: 15-23 barrels drained off from the drill string
- Two negative pressure tests showed gains and increasing pressure
- 17.52: Kill line from the BOP opened to see if the well was flowing. Reportedly 3-15 barrels of seawater drained off.
- Kill line closed and drill pipe pressure gradually rose
- Seawater pumped into kill line to confirm it was full

What Happened (3)

- Kill line monitored for 30 minutes and showed no flow or pressure but drill pipe pressure remained at 1400 psi
- Debate on source of 1400 psi. Explained as *"The Bladder Effect"*
- 20.00: Test deemed successful.
- Decision taken not to carry out Cement Bond Log (CBL)
- Started proceedings to abandon well by displacing remaining mud with seawater
- 20.52: Annular BOP opened and well went underbalanced
- 21.02: Well started to flow (but not observed) as crew emptying trip tank.
- 21.08: Drill pipe pump pressure should have dropped but increased by 100 psi Retrospective analysis, 39 barrel influx

What Happened (4)

- Sheen test to confirm if seawater could be dumped overboard; seawater pumps shut down but drill pipe pressure increased by 246 psi in 5 ½ minutes. Seawater routed overboard. Well estimated flowing at 9 bl/min
- 21.14: Displacement of mud resumed
- 21.31: All mud pumps shut down and an estimated 300 bl gain taken
- 21.36 Drill pipe pressure rises by 556 psi; discussions start
- 21.40 Mud overflows onto the rig floor then sprays up through the derrick
- Diverter closed and mud directed to the mud gas separator
- Annular BOP closed and drill pipe pressure increased from 300 – 1200 psi
- Mud and hydrocarbons spread onto the rig

What Happened (5)

- 21.47 Gas Alarms
- More gas alarms, gas spread throughout the rig, separator vessel vibrated
- Drill pipe pressure 5730 psi, probably on closing variable bore pipe rams in the BOP
- 21.48: Gas reached engine room and enclosures, engine overspeed, loss of power
- 21.50: Two explosions, one in engine room and one under the main deck
- Extensive starboard damage and damage to BOP hydraulics and communications cables
- Possible damage to topsides drill pipe and possible overpressure from reverse flow
- Drilling rig may have lost station without power
- BOP not sealing and well flowing into riser and possibly drillpipe

What Happened (6)

- 21.52 – 21.57: Crew attempt to shut in well and disconnect lower riser package. Both failed
- 22.00 Abandon ship
- Later; Attempt to close BOP with and ROV failed
- Later; attempted pollution control pitifully inadequate

Direct Causes

- Annulus cement barrier did not isolate hydrocarbons
- Shoe track barrier did not isolate hydrocarbons
- Negative pressure test accepted although well integrity not established
- Influx not recognised until hydrocarbons in the riser (30-40 mins)
- Well control actions (BOP) failed to regain control of the well
- Diversion of mud to separator resulted in gas release on rig
- Fire and gas systems did not prevent ignition
- BOP fail safe did not operate to seal the well

Cement Failure (1)

- Well design and installation increased the risk of an offset casing; 6 rather than 21 centralisers
- Well company proposal to use N_2 cement leading to potentially unstable foam slurry and N_2 breakout (bubbles)
- Supposedly tested by Wells Co. but results may not have been received
- No fluid loss additives
- Small volume of cement relative to the displacement volume

Cement Failure (2)

- 4 potential cement failures;
  - Loss into the payzone
  - Channelling
  - Instability (N_2 breakout)
  - Contamination
- Risk of porous cement, cavities, insufficient cement to fill well above payzone with good mix
- 3140 psi rather than 5-600 psi to open shoe track valve *(we hope we haven't blown something)*
- Full mud returns taken as indication of successful cement job. *(Assumed no loss into payzone therefore it was where it was intended to be)*
- Declared a success so no cement bond log

WHY SO MANY POTENTIAL FAILURES AND WHY SUCH CONFIDENCE IN THE ONE TEST RESULT

Shoe Track Failure

- Shoe track cement did not seal the bottom of the casing
- Both shoe track check valves failed to seal or were damaged
- Did the high pressure needed to run the cement damage the valves?
- Not specifically tested – only part of the negative pressure test for the cement

WHY DID THEY FAIL and

WHY WASN'T IT IDENTIFIED?

Negative Pressure Test Accepted

- Purpose; to confirm overall integrity of cement, shoe track, casing and wellhead seal assembly
- Leak across annular BOP inhibited readings
- Underbalanced test indicated twice that pressure in the drill pipe was rising; clear indication of leakage into the casing
- Bleed off volumes more than normal
- Drill pipe pressure rise not investigated
- *"Bladder Effect"* given reason
- Accepted after good results from third conflicting test. Different results inexplicable

WHO IT ACCEPTED AND WHY?

Influx not recognised in time

- Early response maximises well control
- Drill pipe seawater pump pressure increased
- Continued to increase with pumps switched off
- Time delay 21.08 to 21.51
- Estimated 1000 barrel influx (160000 litres) Riser and well casing volume 2600 barrels
- SIMOPs operations including mud pit cleaning
- No monitoring and measurement of the mud returns (Volume in should equal = Volume out)

WHY DID NO ONE RECOGNISE IT FOR 40 MINUTES

Gas Vented Onto the Rig

- Gas already in riser above the BOP
- Flow routed to separator (only for small flowrates) not to overboard diverter (high flow)
- Normally manually controlled through choke manifold
- Excess flow, excess pressure, possible loss of level gas venting at mud pits and high level vent
- Increased back pressure downhole and increased pressure in the drill pipe with possible rupture
- Gas engulfed the rig

WHY DID THEY NOT RECOGNISE THE DANGER AND TREAT IS AS A MINOR KICK?

Gas Ingress, Ignition and Explosion

- Gas detectors did not shut down air intakes and ignition sources
- Rig and safety systems designed to default criteria
- No requirement for gas dispersion and explosion modelling for credible events
- Rig not designed for credible explosions

WHY ARE RIGS NOT DESIGNED TO MATCH WHAT COULD OCCUR?

Why did the BOP not seal the well?

- Annular and pipe rams don't close off drill pipe and have soft (leaky) seals
- Explosion damaged topsides control cables and hydraulics; couldn't operate the emergency disconnect which operates the shear rams
- Automatic mode did not function completely on control/hydraulic failure (complete backup on the sea bed)
- 2 control pods, one with flat batteries and the other with defective solenoid
- Later ROV operation failed to close shear rams, possibly but to pipe position, joints flow conditions or insufficient pressure

WHY WAS THE BOP NOT FULLY SERVICABLE?

Underlying Causes; Hopkins and Dalzell

- Risk Perception
- Failure of Defence in Depth
- Confirmation Bias
- Consensus Decision Making
- Corporate Decentralisation and Engineering Responsibility
- Operational vs. Engineering Safety
- Drilling /Gulf of Mexico Culture
- Prescription rather than Safety Case

Risk Perception

- Which risks were being managed; commercial or safety?
- No acknowledgement that major accident risk is a commercial risk
- Not on oil company Major Accident Reporting (MAR) system
- No meaningful analysis of the effects on the rig
- Was it identified as a higher risk well?
- How was that reflected in the design?
- Was it communicated to those on board drilling the well and approving the tests?
- Was it just routine – job done, go home?

ARE WE AFRAID TO SAY

"ITS DANGEROUS _ TAKE CARE"?

Failure of Defence in Depth (1)

1. Failed Cement; *questionable design, collars not used, N_2 cement awaiting test results, insufficient depth above the payzone, test only examined one failure mode, no Cement Bond Log*
2. Failed Shoe Track; *potential damage not recognised, no practical separate integrity test*
3. Negative Pressure Test; *problem identified discussed; search for the positive answer (Confirmation); normalisation of warning signs; second kill line test gave results they wanted but two different connections to same source gave pressures of 1400 and zero psi.*
4. Failure to Monitor and React; *drilling crew prevented independent mud logger from doing her job; tanks off line; overboard dump of sea water; indication that higher pump pressure needed to displace water/mud; drillpipe pressure rising with pumps shut off*
5. BOP Pipe Rams Activation Delay and Failure; *significant differential pressure on first operation, annular seal leaked, pipe-rams may have held but can't close on drill pipe joint*
6. Routing of Mud Returns to Separator; *action appropriate for minor gas influx (a kick) not loss of well control; separator could not handle flows and pressures*

Failure of Defence in Depth (2)

NOT INDEPENDENT BARRIERS

Perception that the cement job was a success pervaded the rig leading to:

- The cement log being considered unnecessary
- A confirmation bias interpreting the negative pressure test as OK
- A perception that mud logging was unnecessary
- Other warning signs being ignored for 40 minutes
- Incorrect decisions to route mud to separator (minor gas shows)

Failure of Defence in Depth (3)

NO UNDERSTANDING OF THE POTENTIAL HAZARD EFFECTS AND CONSEQUENCES

- Ignition; *engines within range of credible gas cloud, detection/damper shutdown too slow/ineffective; no overspeed protection*
- BOP Shear Rams; *hydraulic lines and control cables vulnerable to explosion, independent fail safe subsea systems both compromised; design could not cut offset pipe or pipe joints (10% of drill string)*
- No means of capping the well
- No effective environmental response

Consensus Decision Making (1)

GROUP THINK

- Who leads and influences the decision making process?
- Do they have an open mind?
- What are their personal dynamics – influential, bullying?
- What are their drivers?
- Are they competent; qualified and experienced?
- Is there single point accountability and do they have that competence?

Consensus Decision Making (2)

WHO WERE INVOLVED IN JOINT DECISION MAKING?

- Well Design; *Oil Co./Wells Co.*
- Cement Specification; *Wells Co./Oil Co.*
- Casing run with 6 rather than 21 spacers; *Drilling Co./Oil Co Rep.*
- Cement Job approval; *Oil Co Rep/ Drilling Co.*
- No Bond Log; *Drilling Co/Oil Co. Rep.*
- Negative Pressure Test Acceptance; *Oil Co/Drilling Co.*

Corporate Decentralisation and Engineering Responsibility

- Decentralisation identified as contributor to Texas City explosion
- Should engineers report to the project or operating group or should technical authorities report to a Chief Engineer?
- Can a centralised system respond to all situations?
- Have operating companies lost too much expertise and are they too dependent upon suppliers, consultants and contractors?
- Balance; engineering competence/judgement vs. procedures?
- Who writes the procedures and checks they are OK?

WERE THE OIL COMPANY REP AND THE WELLS TEAM SUFFICIENTLY RESOURCED, COMPETENT *and CONFIDENT* TO APPROVE THE WELL DESIGN, SUPERVISE AND BE RESPONSIBLE FOR THE DRILLING AND COMPLETION?

Drilling /Gulf of Mexico Culture

- History – onshore drilling
- Macho can do culture
- Arrogance – we know best
- Demarcation lines:
  - Oil companies know geology, reservoirs, find and produce oil and gas
  - Well companies know well design and operation
  - Drillers drill and control wells

DID THE CULTURE AND BLURRING OF TRADITIONAL RESPONSIBILITIES CONTRIBUTE TO THE BLOWOUT?

Operational vs. Engineering Safety

- Hopkins argues that Occupational Safety was predominant and Process Safety should have been applied to drilling.
- Why Process? What about structural, electrical, marine, rail, aviation and other branches of engineering
- Instead; a framework for risk management based on:
  - The risks from the hazard; frequent & minor to catastrophic
  - The tolerability of the consequences
  - The ability to prevent and/or control the consequences
  - The relative dependence of human vs. engineering controls

Prescription rather than Safety Case

- Safety Case developed out of process events
- Traditional tools and techniques for cause analysis inappropriate for drilling
- Cause analysis rather than cause management
- Statistical risk assessment may not be appropriate
- Drilling industry has not really applied consequence assessment; default blowout rates

HAS THE SAFETY CASE WORKED IN THE NORTH SEA- PARTICULARLY FOR DRILLING?

Where do we as Safety Engineers fit in?

- Do we and should we have line responsibility?
- Can we take that responsibility if we are on contract or consultants?
- How would we support a dynamic situation such as drilling?
- Does our perception of hazard and risk skew the picture?
- How does our behaviour affect the decisions?

Further Discussion for SARS

- Better framework for overall corporate risk management
- Better framework for major accident hazard management according to the characteristics
- Study of the personal dynamics, drivers, influences, responsibilities and outputs from risk assessments
- Value and necessity of risk awareness and communication