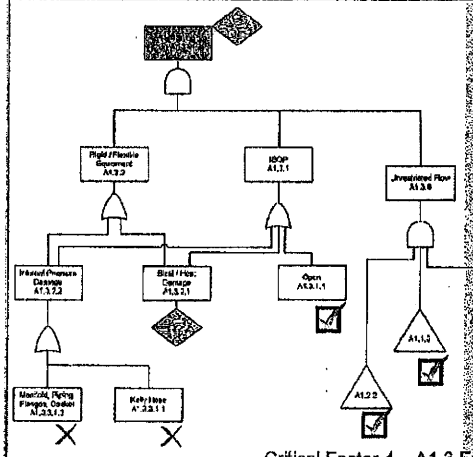
Until approved, this document does not represent the considered view of the Contributor or the Team. In any case, it is subject to revision in light of new information or understanding of the matters referred to.

Deepwater Horizon Incident Investigation – CF4-NTF3 Drill string system

Status: DRAFT XXX	APPROVED
Date: 26 May 2010	Critical Factor: CF4 – A1.3 Drill String System Fail
Contributor(s): Surface Process Safety Team	
Fault Tree Question: Did HC release to atmosphere via a component failure of the Drill String System?	Topic:
The Fault Tree to the right describes the following: IBOP is (open or damaged) and in communication with the well formation and the pipe system loses containment (rigid or flexible).	 Critical Factor 4 – A1.3 Fault Tree
Persons interviewed:	Review of USCG and MBI witness statements
Reference document / filename:	
Flame Height.ppt Photos of fire	Well Model – Flow Rates Well Model - Flow Rates.pdf
Telemetry well data – cement and mud pressures Cement%20and%20Drill%20Pipe%20Pres	Well Model - Open Surface Valve Well Model - Open Surface 4Inch Valve.ji
P&ID – Mud Gas System, Simplified	HRBS-P78-000-P0032-1,2,3,4

Mud%20System%20 5-22-2010.ppt

Note to File

This note draws on draft modeling results. It does not repeat the qualifications, limitations, or conditions to which the modeling results are subject. For these, reference to the modeling studies is required.

A1.3.0 - Unrestricted Flow

CF4-A1.1 confirmed that HC from the well formation was in communication with the drill pipe and rise assembly. Further, a well imbalance existed. CF4-A1.2 confirmed the BOP was activated and the effect of the VBR closing as shown in the telemetry data was to increase the drill string pressure to less than 6,000 psi prior to loss of signal.

A1.3.1 - iBOP Open or Closed?

A time series of drill pressure data is available up to the apparent loss of power which coincides with witness testimony of the time of the first explosion. Actual recorded telemetry drill pipe pressure was not static and in fact rose above 5,700 psi just prior to witness stated time of the initial explosion. Since drill pipe pressure is measured upstream of the iBOP, this confirms that the iBOP was open.

Based upon the above, A1.3.1.1 is considered to the satisfaction of the team to be confirmed.

A1.3.2 – Pipe Equipment, Hoses, and Associated Flanges

A1.3.2.2 – Internal Pressure Damage
As stated above, the iBOP was confirmed open which allows pressure to all upstream components in the drill pipe system. The original rig design data shows the mud supply system piping, and equipment rated for a maximum allowable pressure of 7,500 psi. The piping and equipment pressure rating is higher than the internal pressure was subjected to as recorded by telemetry data. The team is satisfied that unless contradictory information is discovered it is unlikely that the mud supply system piping equipment, hoses or associated flanges, failed to internal pressure exposure.

Based upon the above, the postulation that rigid or flexible components failed due to internal over pressure is considered false.

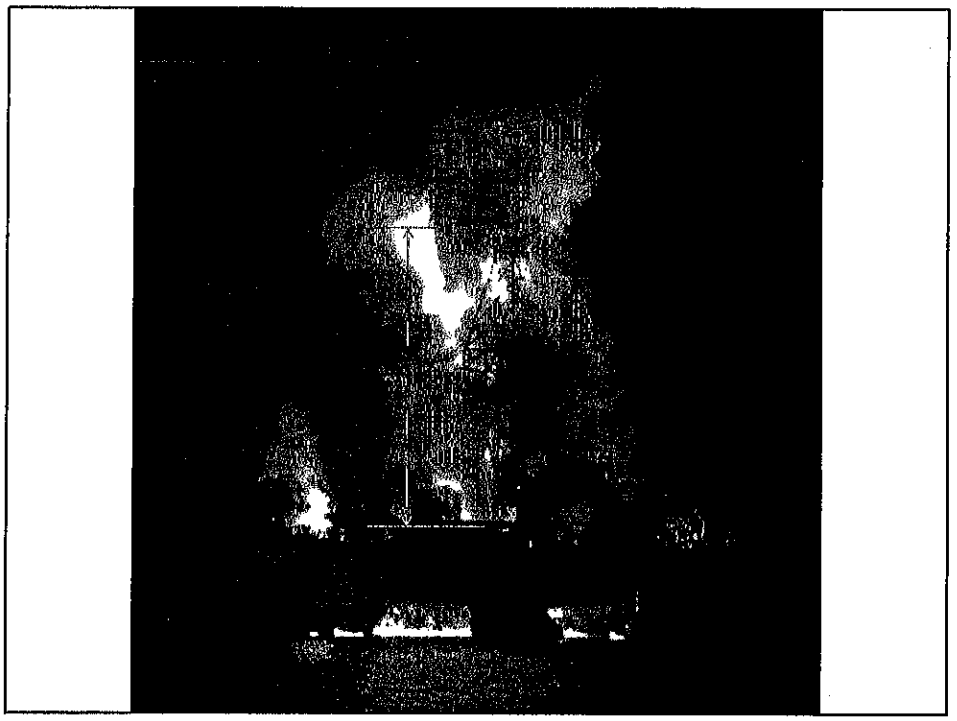
A1.3.2.1 – Fire Radiant Heat and/or Blast Damage

Fire and blast damage subsequent to an initial ignition and incident on either rigid or flexible (e.g. hoses, etc.), components could have provided an open continuous HC path to atmosphere. Potential failure of these components remains inconclusive due to lack of physical evidence or witness statements in support of this postulation. Radiant heat and blast wave modeling analysis was not conducted to ascertain this scenario and thus A1.3.2.1 remains inconclusive.

Conclusion

Based upon available information, the team is satisfied that the iBOP was open and in communication at the time of the incident, and the mud supply system components could have failed due to external incident heat and/or blast pressures as a result of the initial explosion.

Did HC release to atmosphere via a component failure of the Drill String System? INCONCLUSIVE



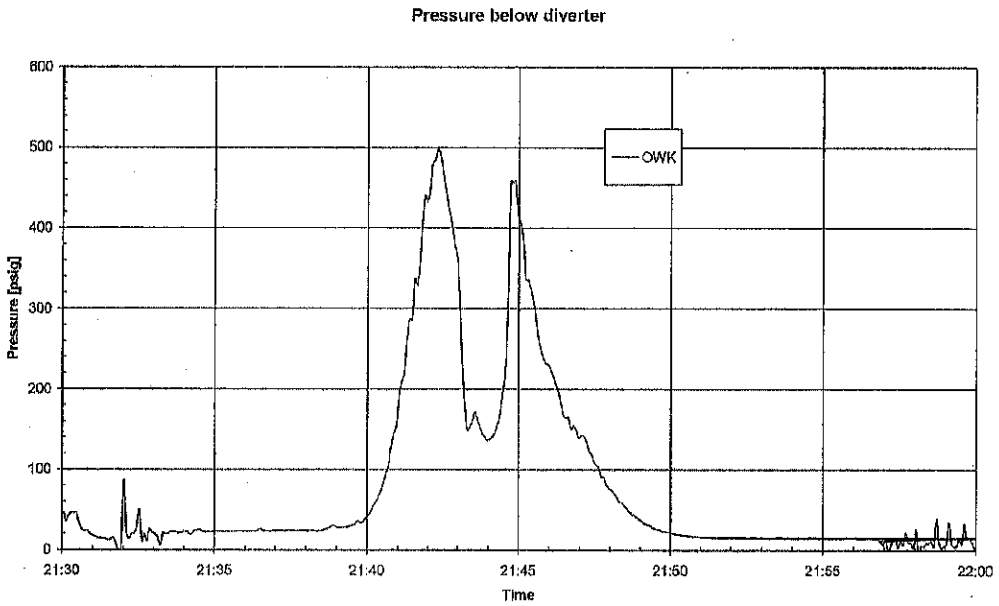


Fig. 1: Backpressure created by surface piping

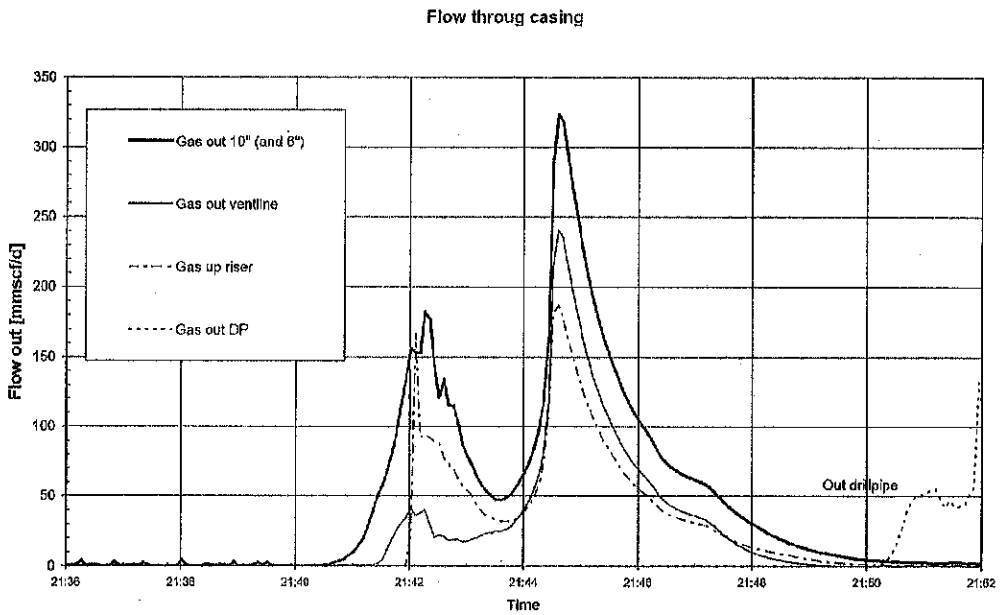
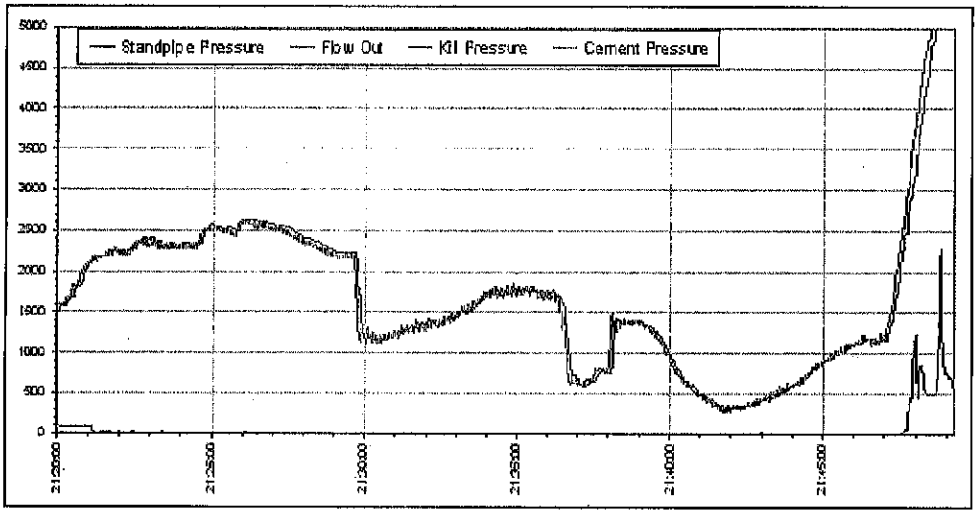
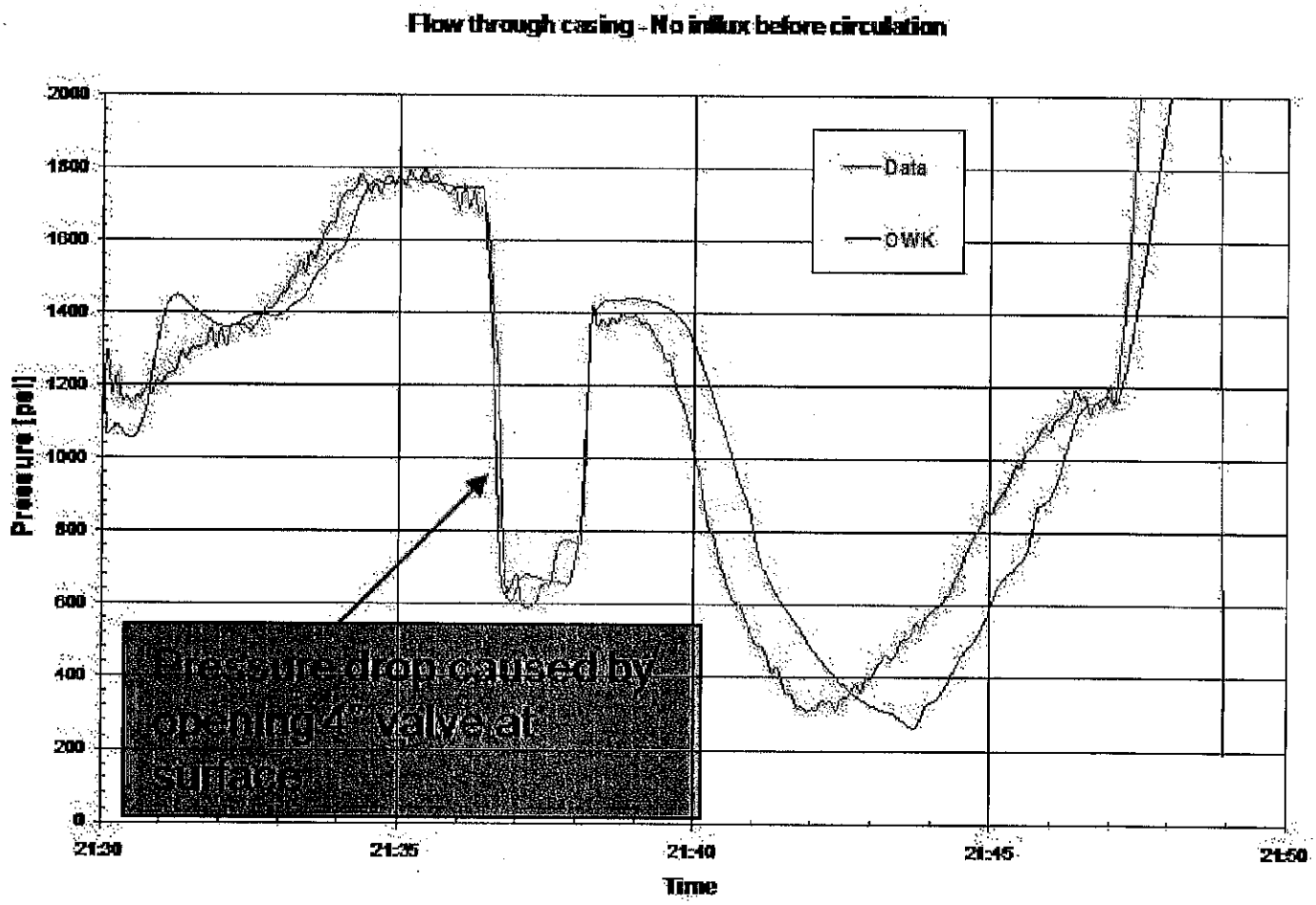
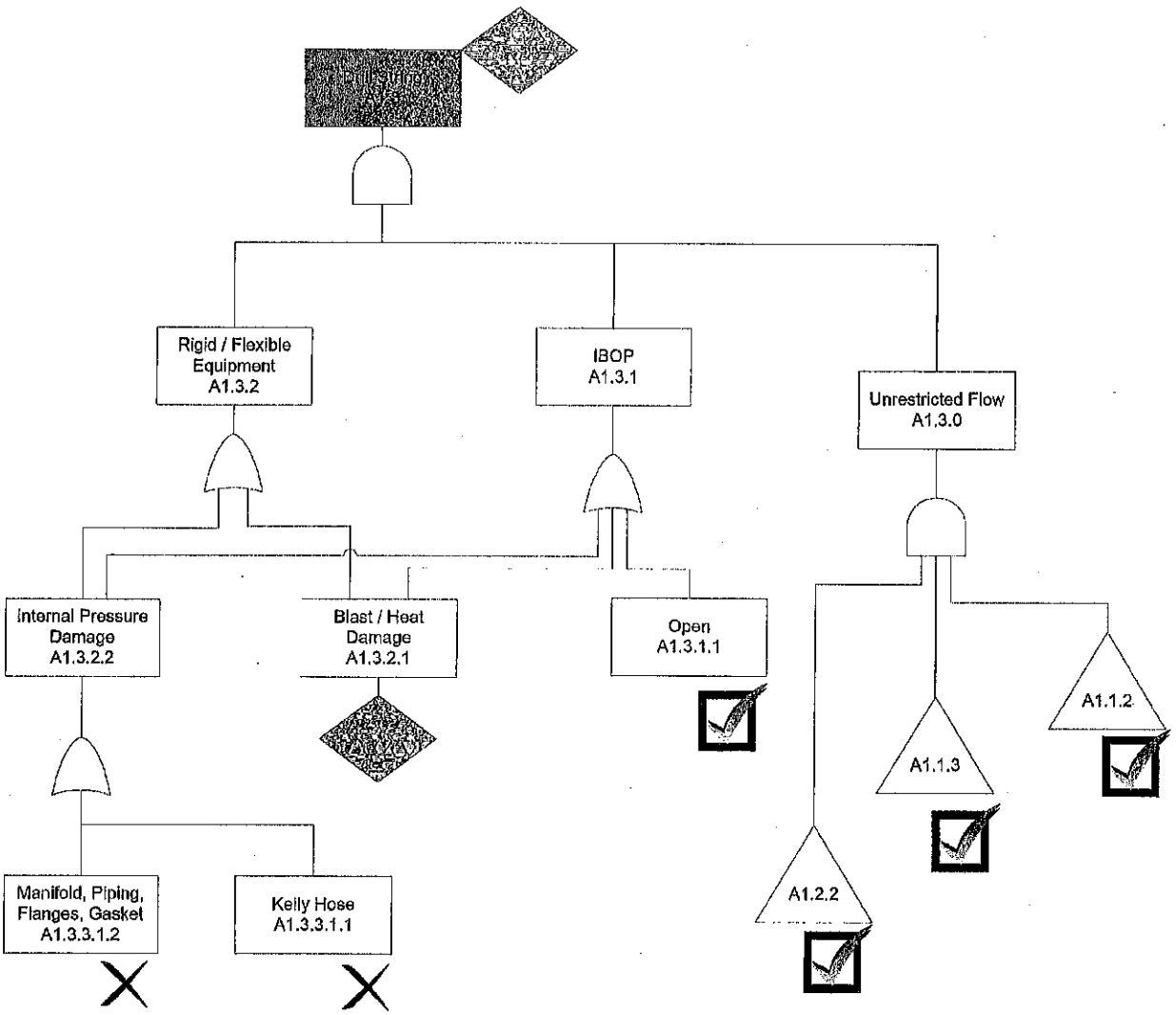
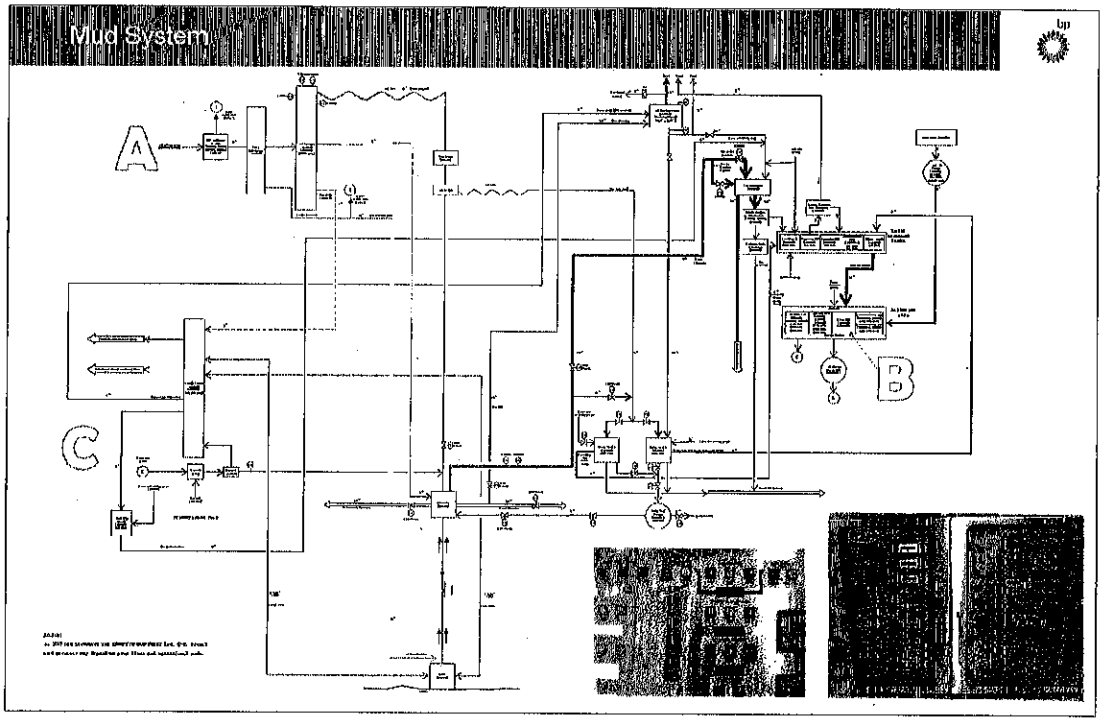


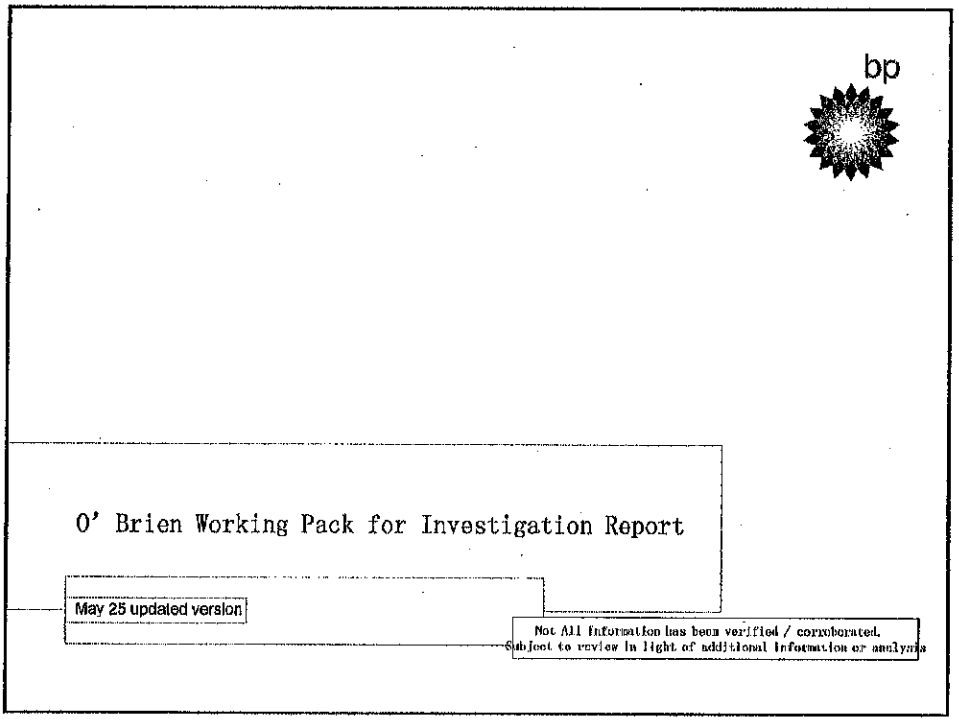
Fig 4: Gas flow rates


Standpipe Pressure
Flow Out
Kill Pressure
Cement Pressure
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0


Flow through casing - No influx before circulation
Pressure [psi]
2000
1800
1600
1400
1200
1000
800
600
400
200
0
21:30
21:35
21:40
21:45
21:50
Time
Data
DWK
Pressure drop caused by opening 4" valve at surface


Rigid / Flexible Equipment A1.3.2
IBOP A1.3.1
Unrestricted Flow A1.3.0
Internal Pressure Damage A1.3.2.2
Blast / Heat Damage A1.3.2.1
Open A1.3.1.1
A1.1.2
A1.1.3
A1.2.2
Manifold, Piping, Flanges, Gasket A1.3.3.1.2
Kelly Hose A1.3.3.1.1




bp
O' Brien Working Pack for Investigation Report
May 25 updated version
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

Terms of Reference and Team Composition
TransOcean Deepwater Horizon Rig Incident
Investigation Into the Facts and Causation
(April 23, 2010)

bp

The President of BP Exploration & Production Inc. agreed the following Terms of Reference and has requested that Mark Bly, Group Head of Safety & Operations, lead the investigation team[1]:

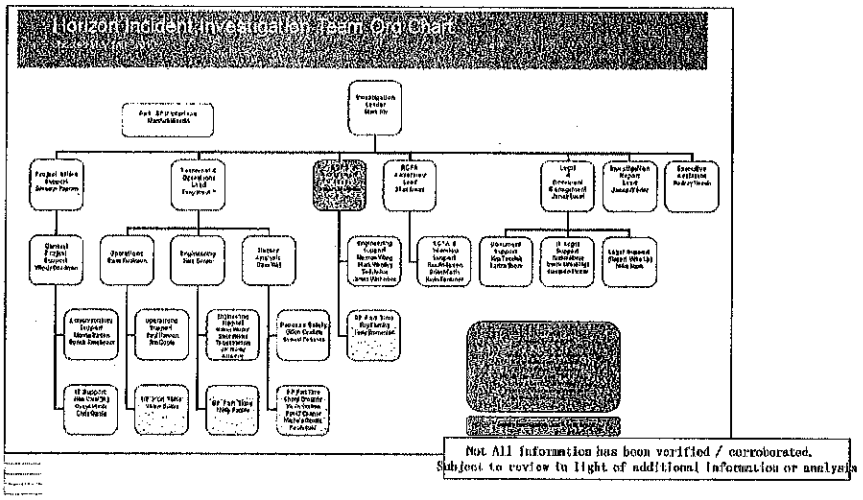
The scope of the investigation to find the facts surrounding the uncontrolled release of hydrocarbons and efforts to contain the release aboard the TransOcean drill ship Deepwater Horizon, located approximately 40 miles south of Venice, LA at Mississippi Canyon 252, BP's Macondo prospect is as follows:

1. Collect evidence surrounding the incident[2]
2. Determine the actual physical conditions, controls, and operational regime related to the incident to understand:
   a. Sequence of relevant events
   b. Reasons for initial release
   c. Reasons for fire
   d. Efforts to control flow at initial event
3. Prepare a report to include:
   a. Background
   b. Timeline
   c. Description of incident
   d. Critical factors
      i. Immediate Causes
      ii. System Causes
   e. Proposed Recommendations
4. Administrative
   a. All activities of the fact-finding teams will be approved in advance by the respective team leader
   b. Retain all incident investigation team documents (including notes, drafts, electronic documents and emails) relating to the fact-finding and the incident
   c. Maintain confidentiality of our discussions
   d. BP person at each interview
   e. No questions or tasks to BP contractors without BP approval

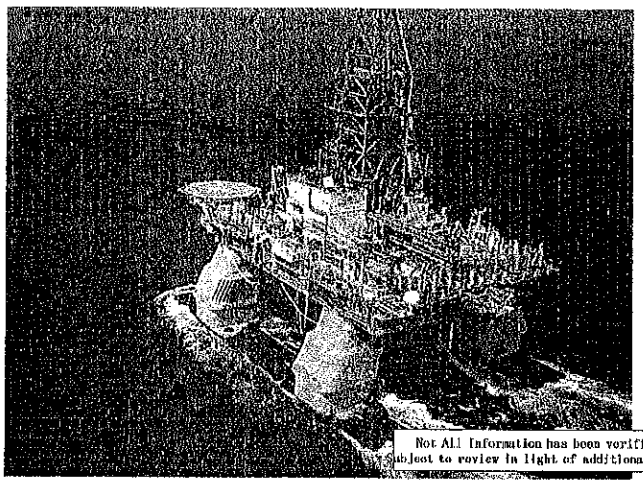
[1] James Lucari, Managing Attorney – BP Legal HSSE and Regulation, has been assigned to provide legal advice and counsel to Mr. Bly in his role as investigation team lead.

[2] Given the business and regulatory relationships involved in this conte[illegible] Not All Information has been verified / corroborated, by physical evidence, data and information that is in the custody and/or [illegible]ubject to review in light of additional information or analysis access to this information may affect its ability to complete the terms o[illegible]

Org chart here

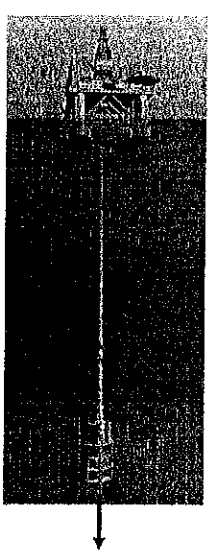


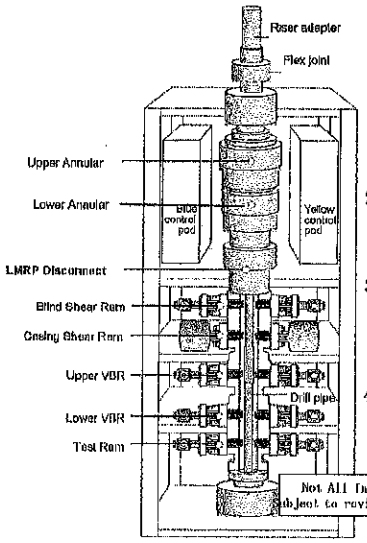
Deepwater Horizon Drill Rig



Not All information has been verified / corroborated.
Subject to review in light of additional information or analysis

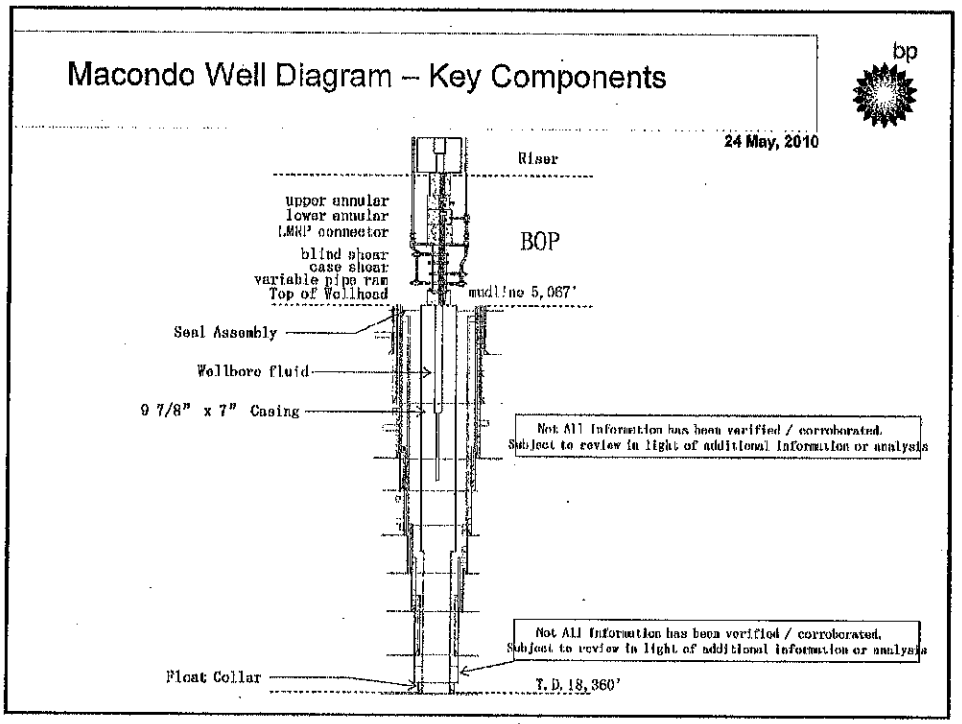
BOP Schematic





1. Provides means of securing well if flow occurs
2. Seals well and allows monitor of well bore pressure
3. Enables well to be circulated and returned to static conditions
4. In an emergency, can shear drill pipe and disconnect riser, leaving BOP in place and the well secure

Not All Information has been verified / corroborated, subject to review in light of additional information or analysis



Go into the structure– Fault Tree construction (basic logic of barrier breakdown)

Against these - Immediate causes

Cement - Isolate formation

Float collar - check valve @ bottom, hold cement in place while set

Seal Assembly - casing hung in wellhead

seal assembly provide seal between outside of casing string & inside

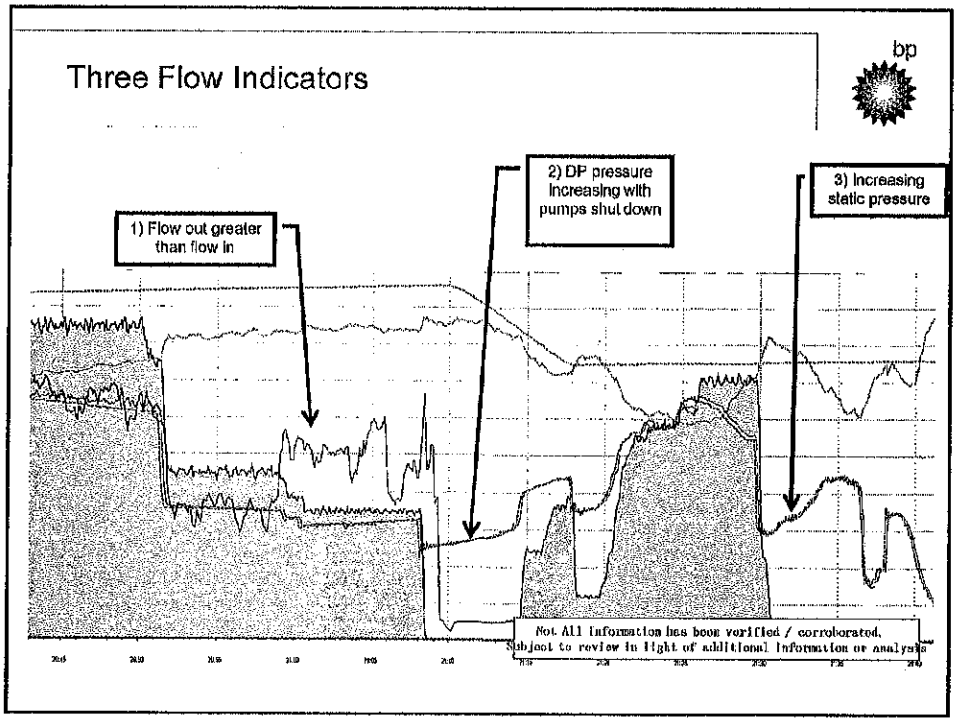
Critical Factors

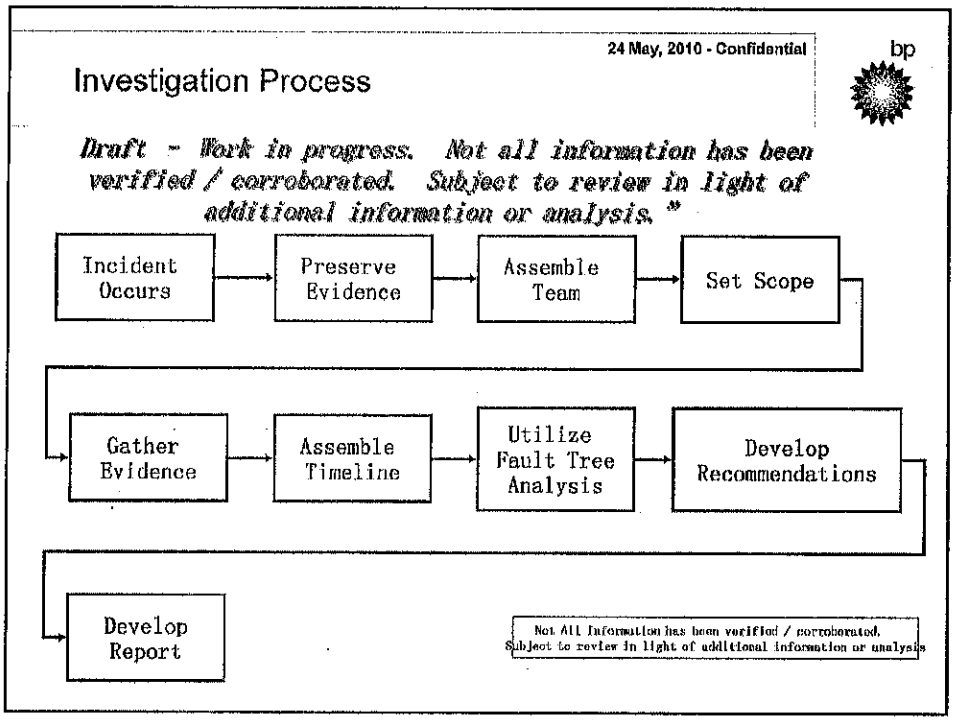
1. Failure of two physical barriers - cement & float **or** seal assembly
2. Unrecognized influx (opportunities missed during the integrity test to see this). Unrecognized onset of flow conditions. Response did not control
3. Ignition source.
4. BOP' s failed to control & secure the source even on subsequent attempts

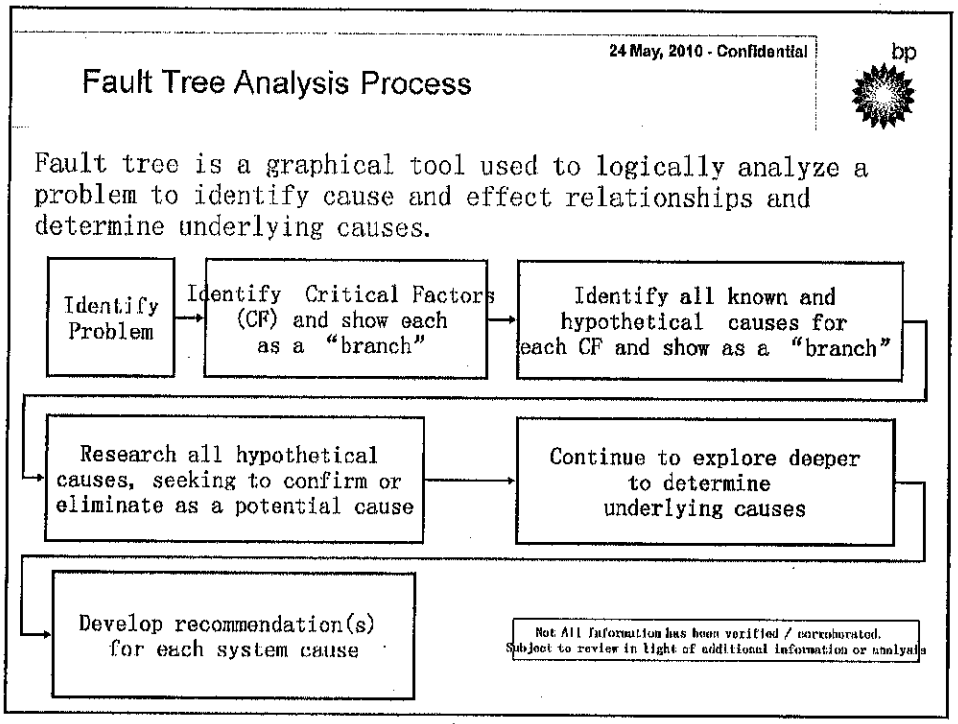
bp

Timeline here

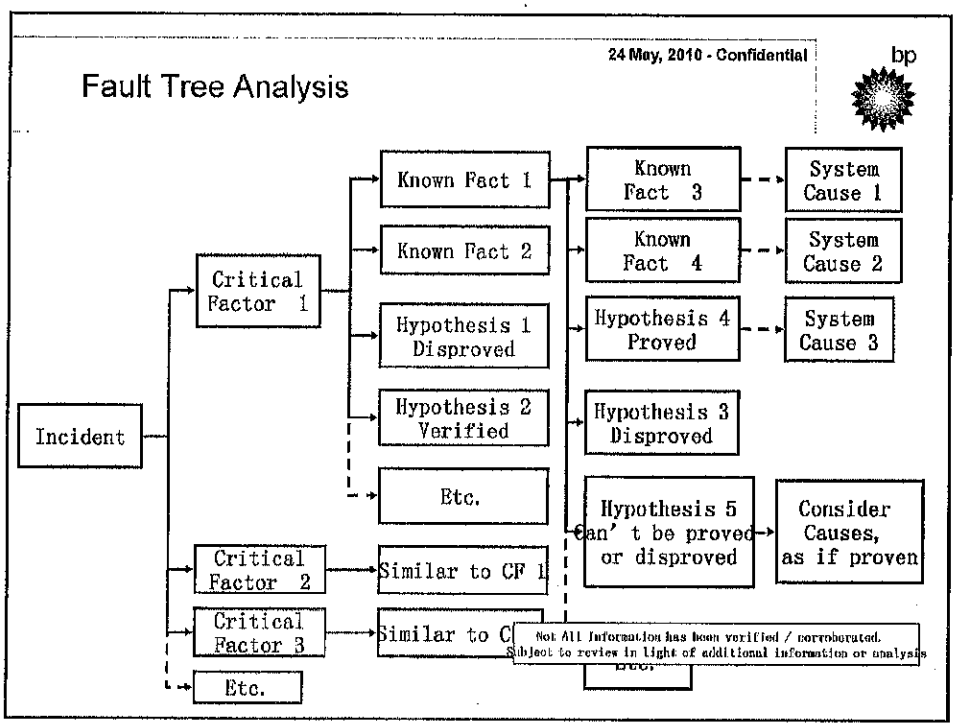
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis


Three Flow Indicators
bp
1) Flow out greater than flow in
2) DP pressure increasing with pumps shut down
3) Increasing static pressure
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis


24 May, 2010 - Confidential
bp
Investigation Process
Draft - Work in progress. Not all information has been verified / corroborated. Subject to review in light of additional information or analysis."
Incident Occurs
Preserve Evidence
Assemble Team
Set Scope
Gather Evidence
Assemble Timeline
Utilize Fault Tree Analysis
Develop Recommendations
Develop Report
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis



Critical Factors are events or conditions leading to an undesired event, which if eliminated, could have either prevented the occurrence or reduced its severity.



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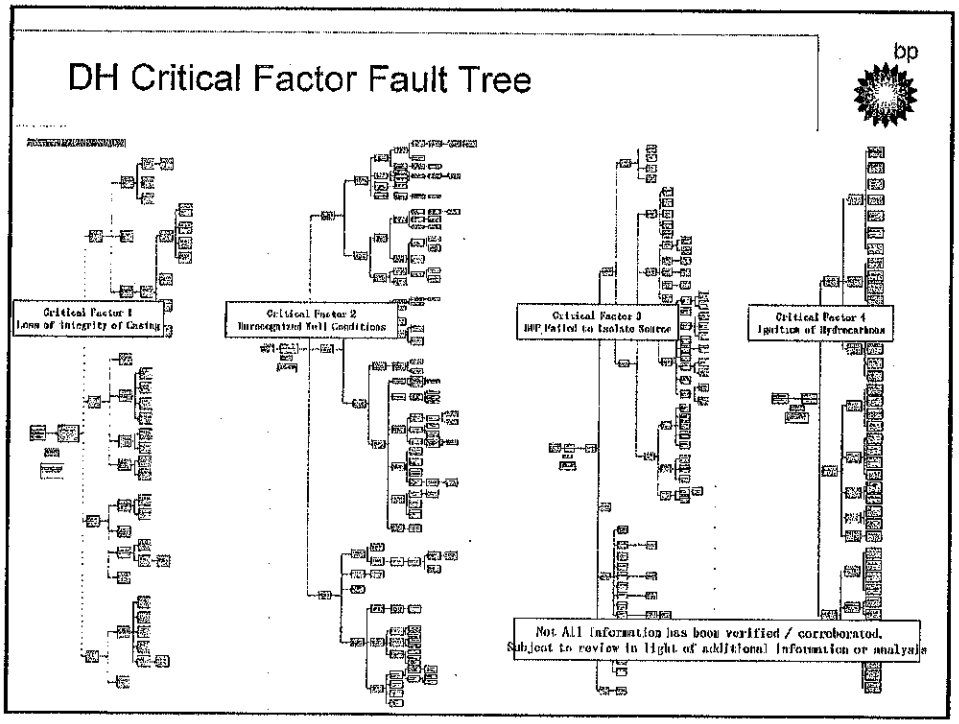
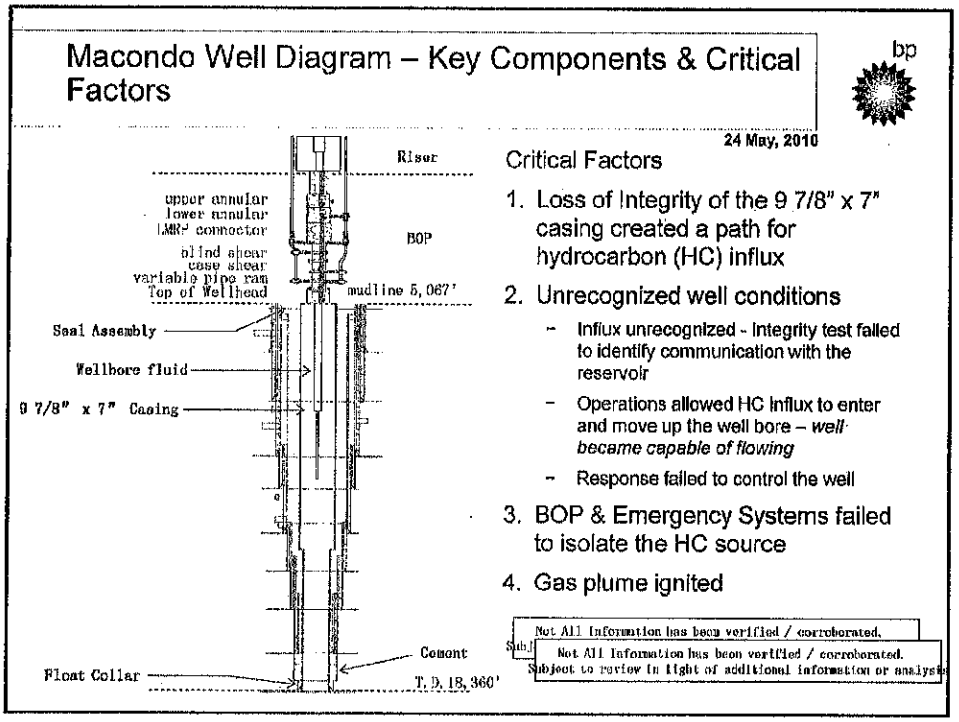

DH Critical Factor Fault Tree
bp
Critical Factor 1
Loss of Integrity of Casing
Critical Factor 2
Unrecognized Well Conditions
Critical Factor 3
BOP Failed to Isolate Source
Critical Factor 4
Ignition of Hydrocarbons
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

Critical Factor Relationship Chart

Critical Factor Description Here

Immediate Cause	System Cause	Corrective Action
Item 1	Explanation	Steps to be taken
Item 2	Explanation	Steps to be taken
Item 3	Explanation	Steps to be taken

Not All information has been verified / corroborated.
Subject to review in light of additional information or analysis



Go into the structure– **Fault Tree** construction (basic logic of barrier breakdown)

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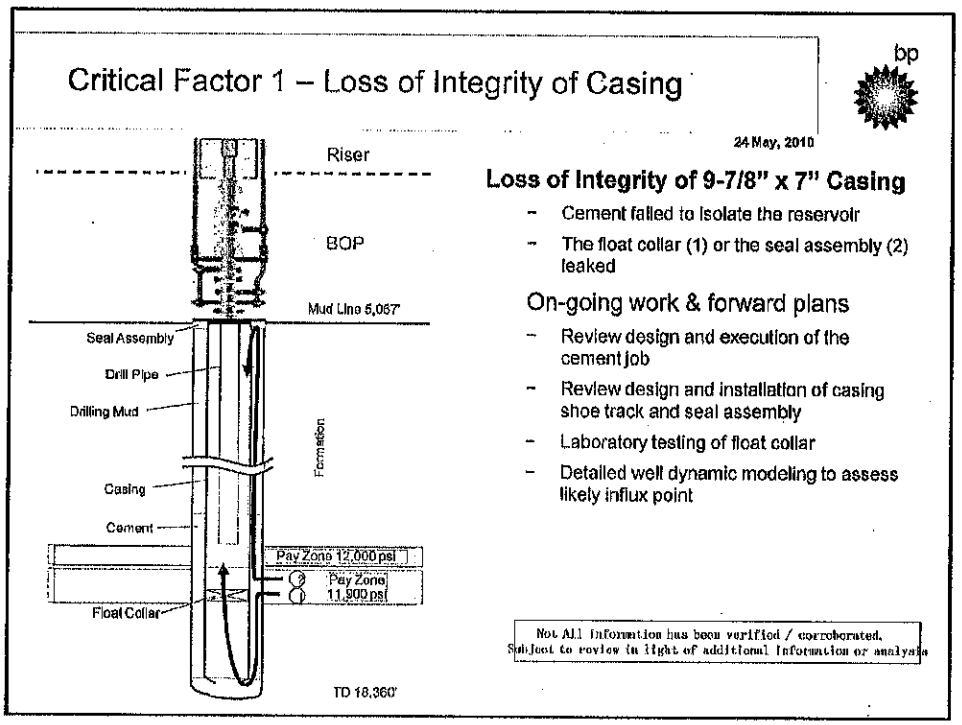
Critical Factor 1 - Loss of Integrity of Casing

Immediate Cause	System Cause	Corrective Action
Loss of Primary Annular Containment	TBD	TBD
Seal Assembly Failure	TBD	TBD
Float Collar (Shoe) Failure	TBD	TBD

Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis



Cement Job

Pump volumes and return ok. Basic view from field - good cement job.

But know cement did not isolate

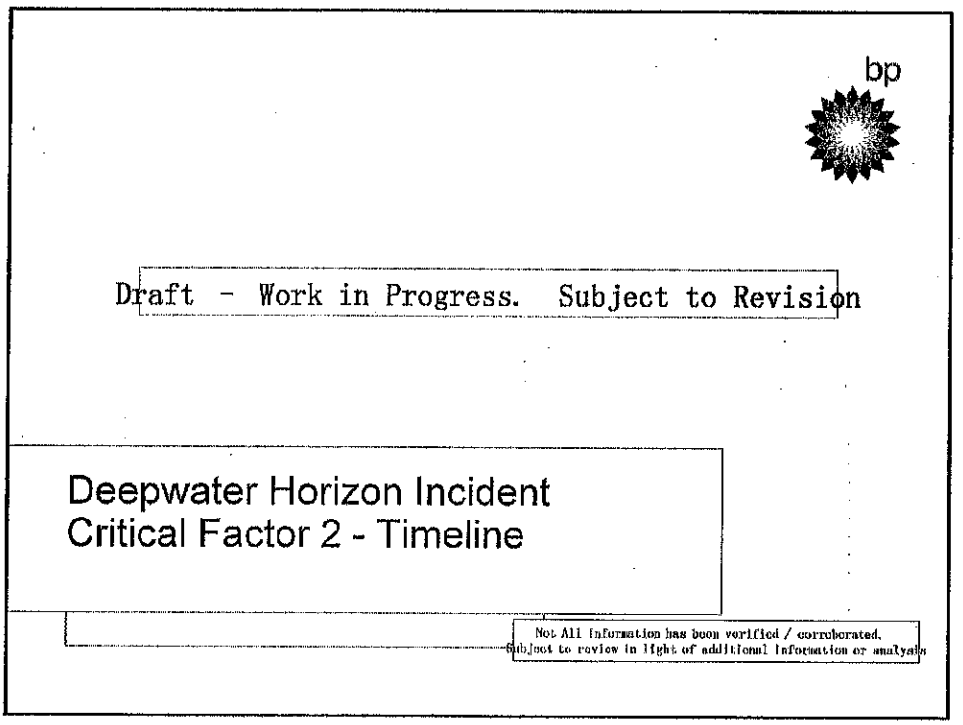
Areas of interest: float shear out, centralizers, slurry mixture, shoe

Plausible failure scenario

Seal assembly appears to be text book running operation, high reliability

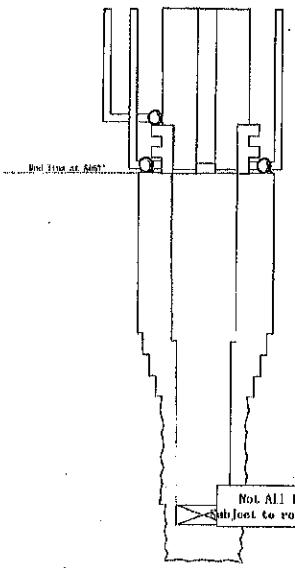
Areas of interest - not locked down at time of incident - possibility to lift of seat

Plausible failure scenario


bp
Draft - Work in Progress. Subject to Revision
Deepwater Horizon Incident
Critical Factor 2 - Timeline
Not All information has been verified / corroborated.
Subject to review in light of additional information or analysis

Run Casing – Convert Float Equipment

00:30 – 17:30
4/18/10
4/19/10



Data

- Run 7" x 9-7/8" production casing
  - Crossover at 12487'
  - Float Collar at 18114'
  - Shoe at 18304'
  - 56' of rat hole
- Laid out three joints of 7" due to damaged threads
- Saw 10k weight bobble at 18218 (only time string took weight during run)
- 9 attempts to convert float equipment
  - Sheared at 3142 psi vs 600-700 psi design

Interpretation

- Circulating pressure below normal after shearing float collar

Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

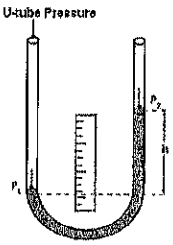
Cement Job

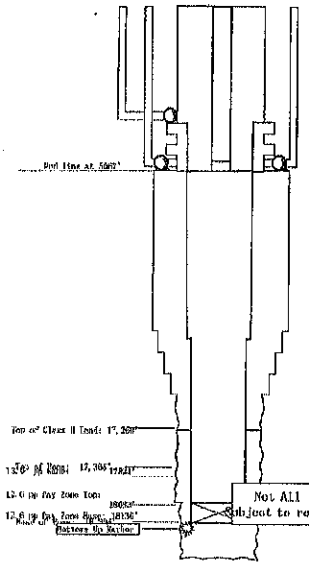
bp

17:30 — 00:30

4/19/10
4/20/10

U-tube Pressure





Data

- Circulate 342 bbl before cement job
- Pump nitrified foam cement
  - Pumped 60 bbl cement
- Estimated TOC at 17260'
- Bumped plug with 1150 psi
  - Cement in place at 00:35
  - Bled back 5 bbls to 0 psi
  - Minimal calculated U-tube pressure after job (nearly balanced)
- 14.0 ppg mud in rat hole with 16.7 ppg cement in shoe track

Interpretation

- Job pumped per plan - no cement losses observed
- Minimal U-tube may have prevented definitive float test
- Potential for contamination of cement in shoe track due to density difference between cement and mud

Not All Information has been verified / corroborated, subject to review in light of additional information or analysis

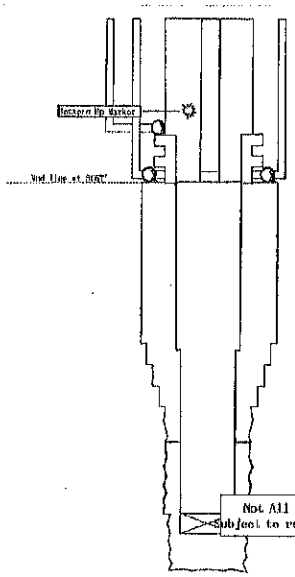
Set Seal Assembly - Lay Down Landing String

bp

00:30 – 07:00

4/20/10

Close Upper VBR's to test seal assembly. Test successful



Data

- Release running tool
- Set seal assembly at 5059' to seal the 9-7/8" casing annulus
- Successful pressure test of seal assembly
- Setting and testing procedure as per plan
- Begin tripping out

Interpretation

- Set and test of seal assembly is normal

Not All Information has been verified / corroborated. Subject to review in light of additional information or analysis

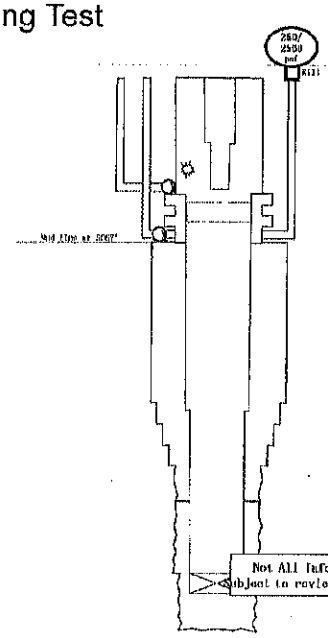
Trip in and Casing Test

bp

07:00 – 12:00

4/20/10

12:00 – Close BSR. Pump down kill line to test casing to 250/2500 psi for 30 min



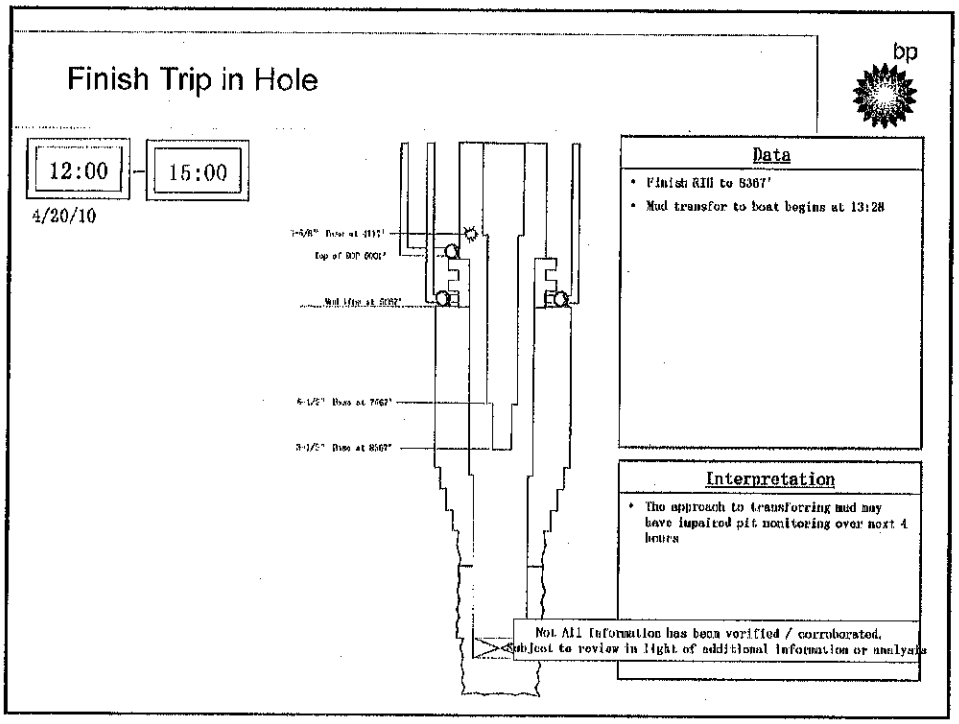
Data

- Run in with tapered string for cement plug:
  - 6-5/8" x 5-1/2" x 3-1/2" drill pipe
- Stop at 4700' (above BOP)
- Close blind shear rams
- Positive test casing to 250 and 2500 psi

Interpretation

- Positive casing test is successful
  - Pressures and volumes are as expected

Not All Information has been verified / corroborated. Subject to review in light of additional information or analysis

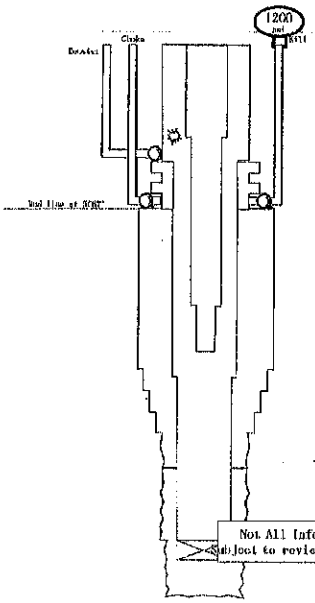

Finish Trip in Hole
bp
12:00
15:00
4/20/10
Data
• Finish RIH to 8367'
• Mud transfer to boat begins at 13:28
Interpretation
• The approach to transferring mud may have impaired pit monitoring over next 4 hours
Not All Information has been verified / corroborated, subject to review in light of additional information or analysis

Displace Boost, Choke, and Kill Lines

bp

15:04 – 15:54

4/20/10



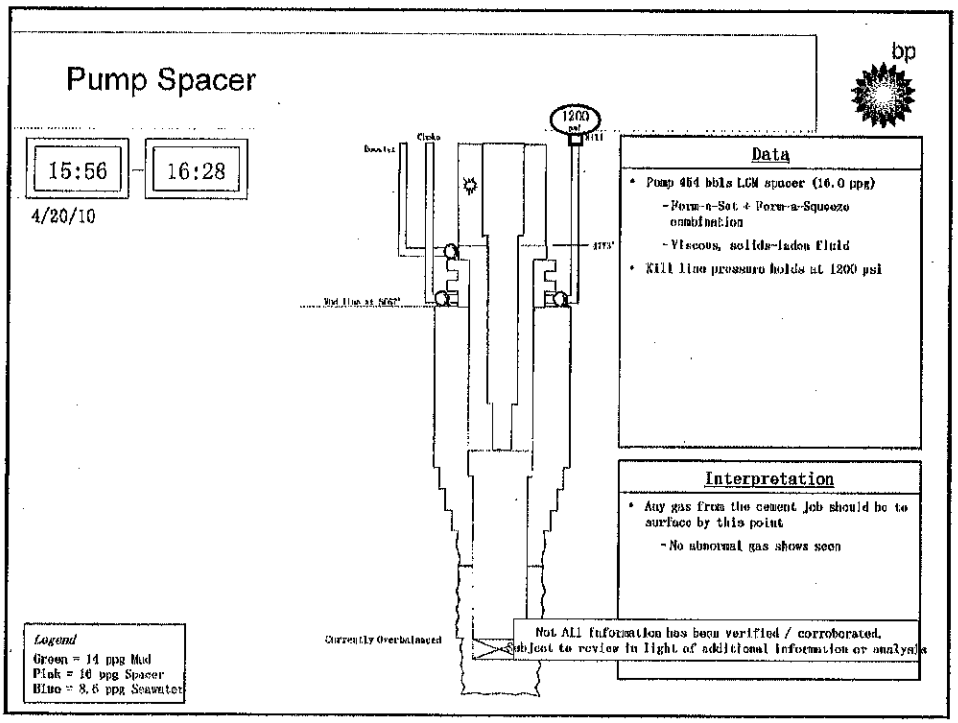
Data

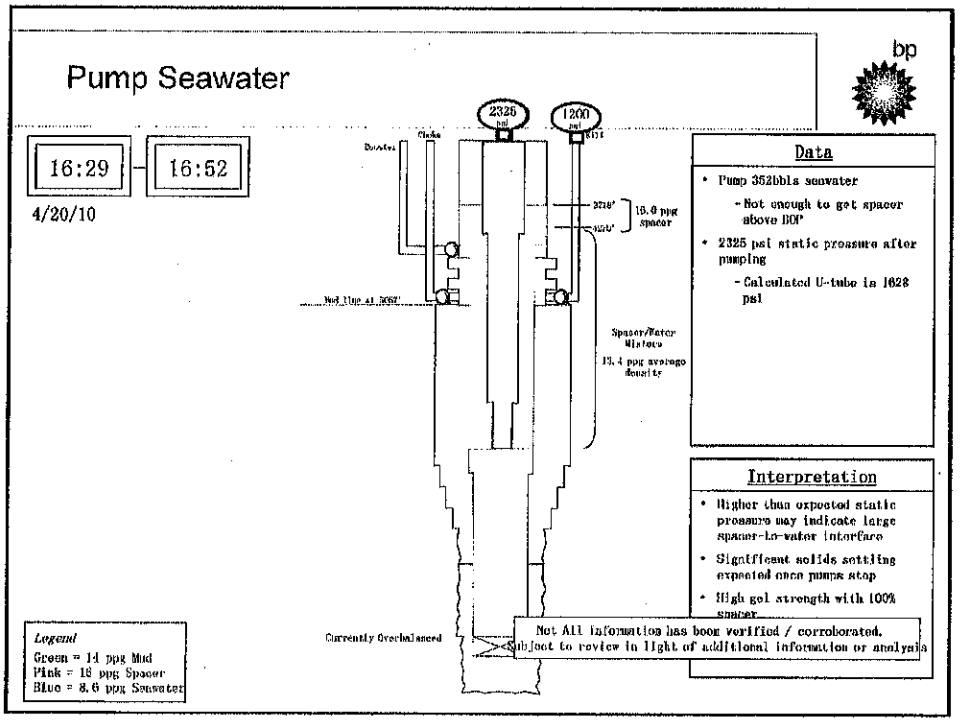
- Displaced booster line w/ seawater
- Displaced choke line with seawater
- Displaced kill line with seawater
- 1200 psi trapped in kill line

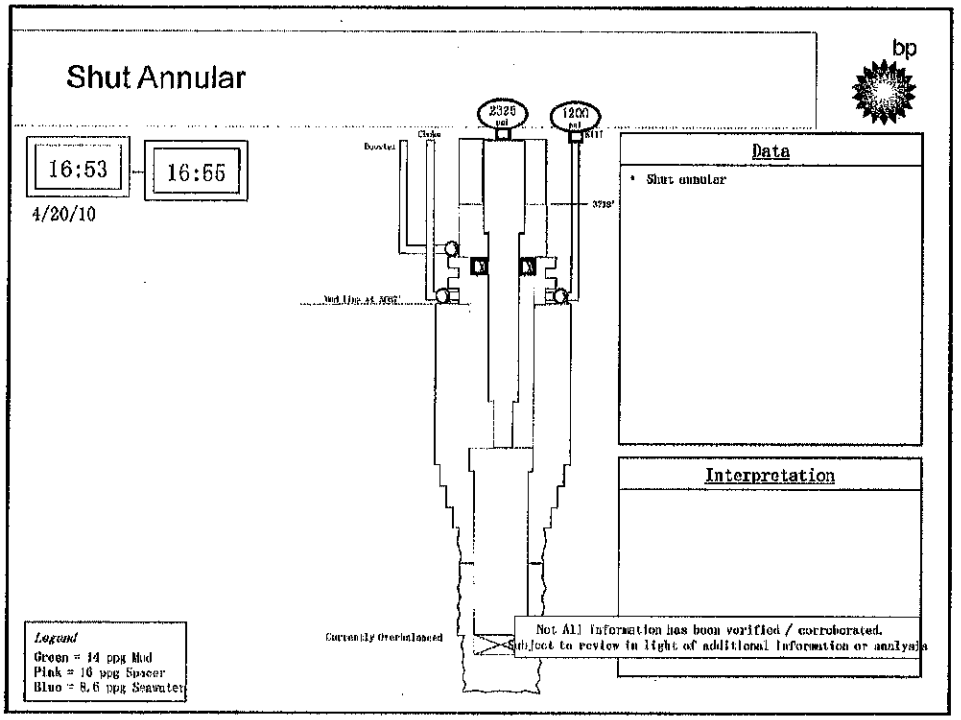
Interpretation

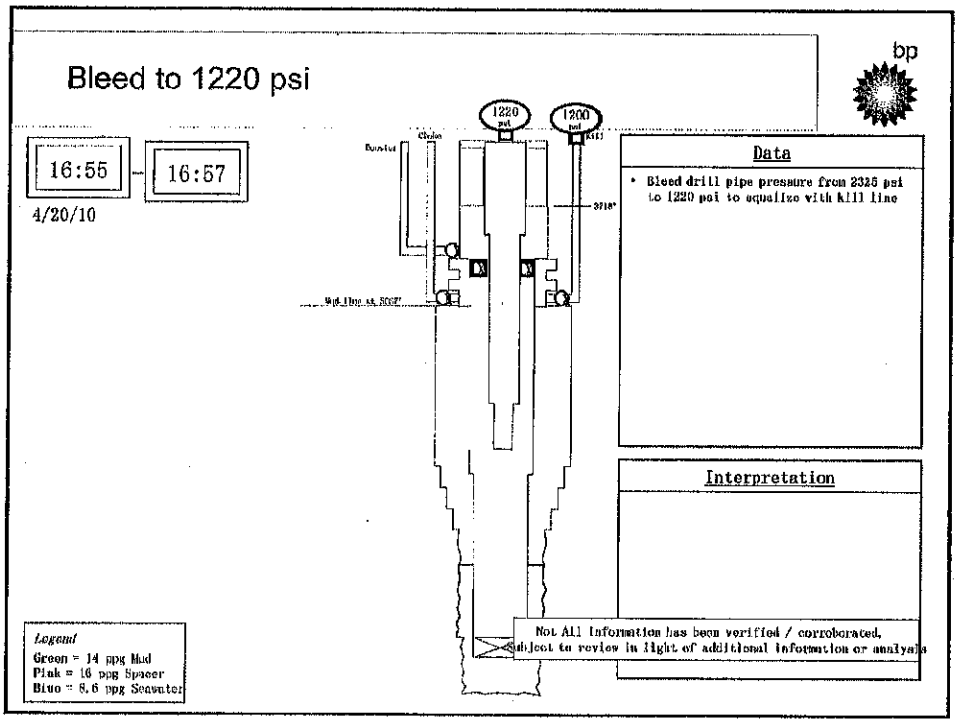
- Close booster, choke, and kill line bottom valves after displacements

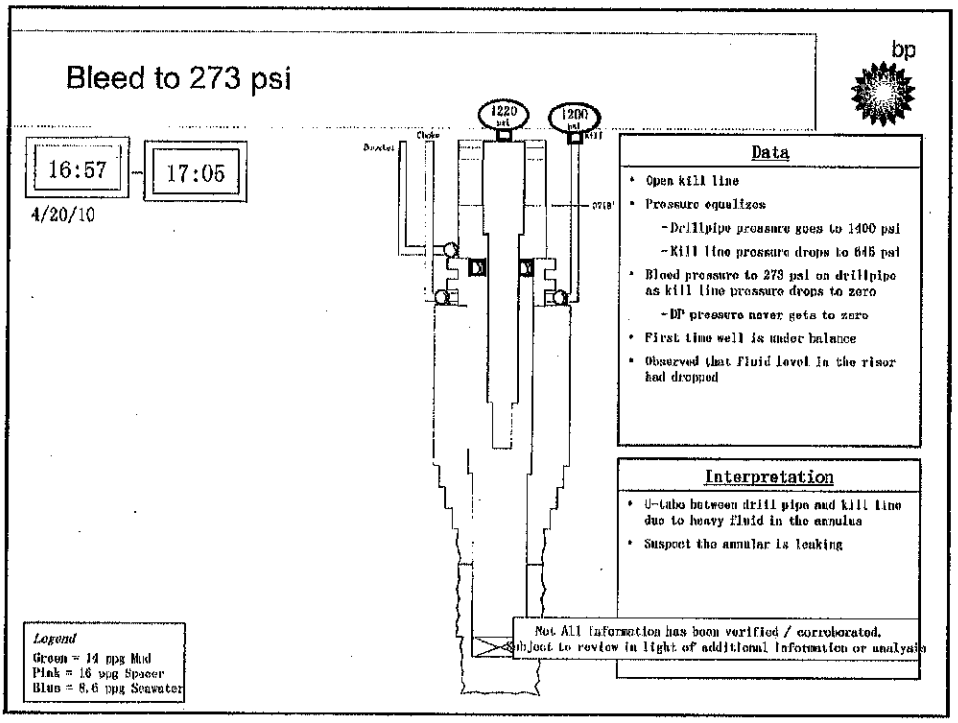
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

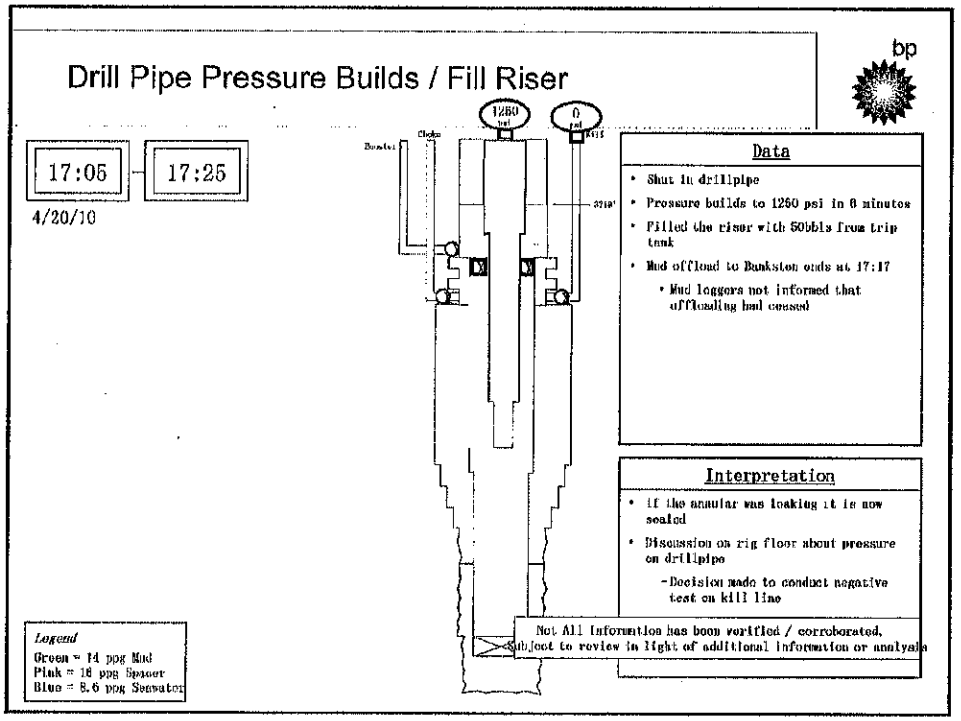

Pump Spacer
bp
15:56
16:28
4/20/10
1200
Choke
Data
• Pump 464 bbls LCM spacer (16.0 ppg)
- Form-a-Set + Form-a-Squeeze combination
- Viscous, solids-laden fluid
• Kill line pressure holds at 1200 psi
Interpretation
• Any gas from the cement job should be to surface by this point
- No abnormal gas shows seen
Currently Overbalanced
Not ALL information has been verified / corroborated, subject to review in light of additional information or analysis
Legend
Green = 14 ppg Mud
Pink = 16 ppg Spacer
Blue = 8.6 ppg Seawater

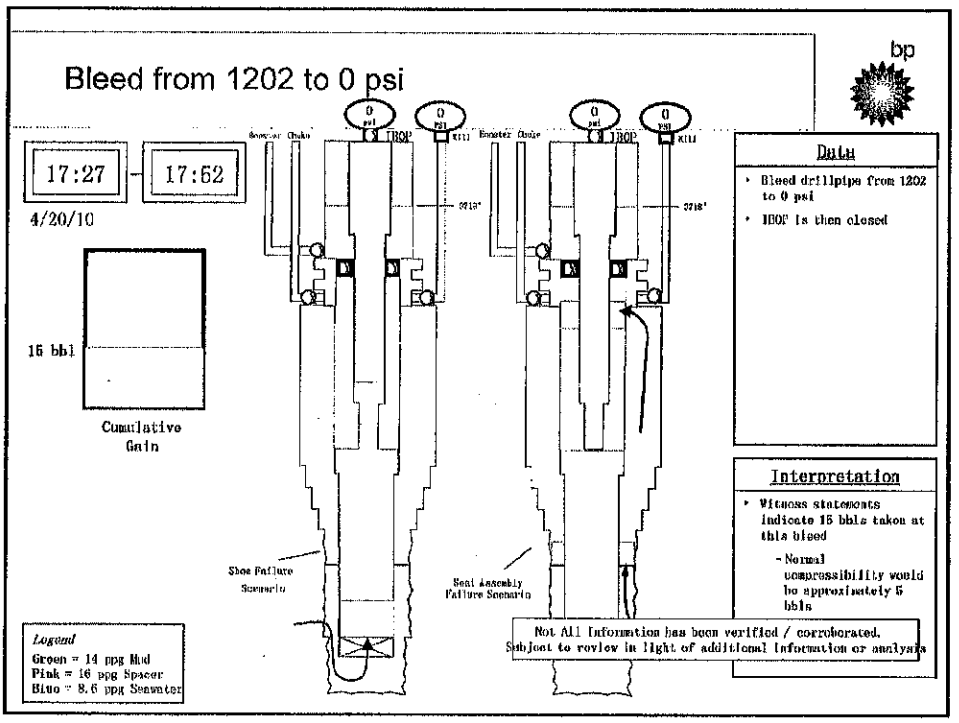

Pump Seawater
bp
16:29
16:52
4/20/10
2326
1200
15.6 ppg spacer
Spacer/Water Mixture
13.4 ppg average density
Currently Overbalanced
Data
• Pump 352bbls seawater
- Not enough to get spacer above BOP
• 2325 psi static pressure after pumping
- Calculated U-tube is 1628 psi
Interpretation
• Higher than expected static pressure may indicate large spacer-to-water interface
• Significant solids settling expected once pumps stop
• High gel strength with 100% spacer
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis
Legend
Green = 14 ppg Mud
Pink = 16 ppg Spacer
Blue = 8.6 ppg Seawater

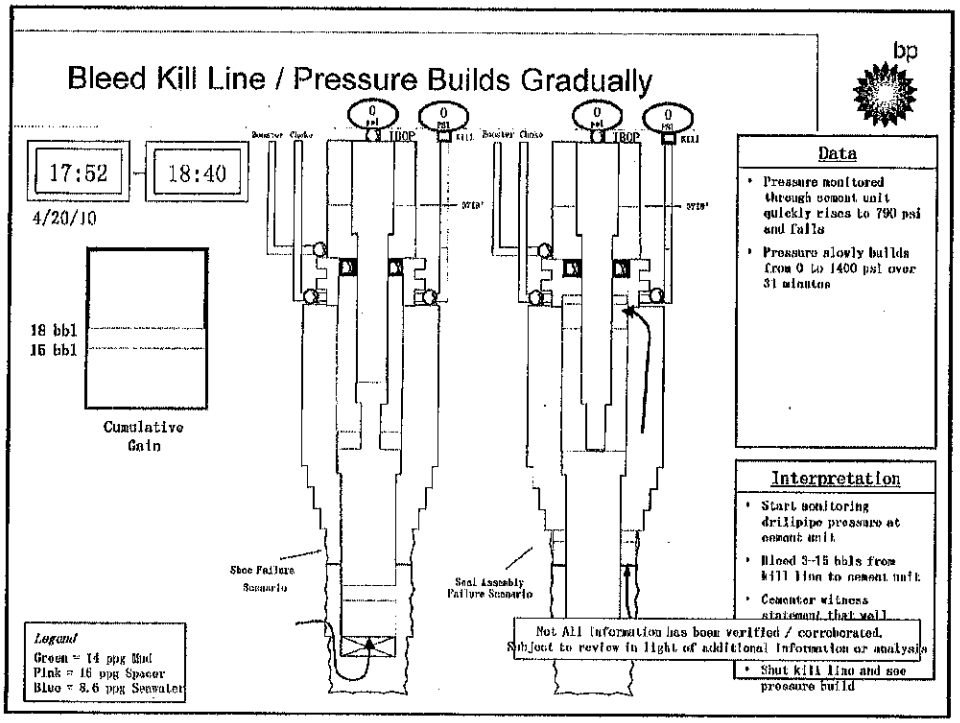

Shut Annular
bp
16:53
16:55
4/20/10
2325
psi
1200
psi
Booster
Choke
3738'
Mud Line at 5067'
Currently Overbalanced
Data
• Shut annular
Interpretation
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis
Legend
Green = 14 ppg Mud
Pink = 16 ppg Spacer
Blue = 8.6 ppg Seawater

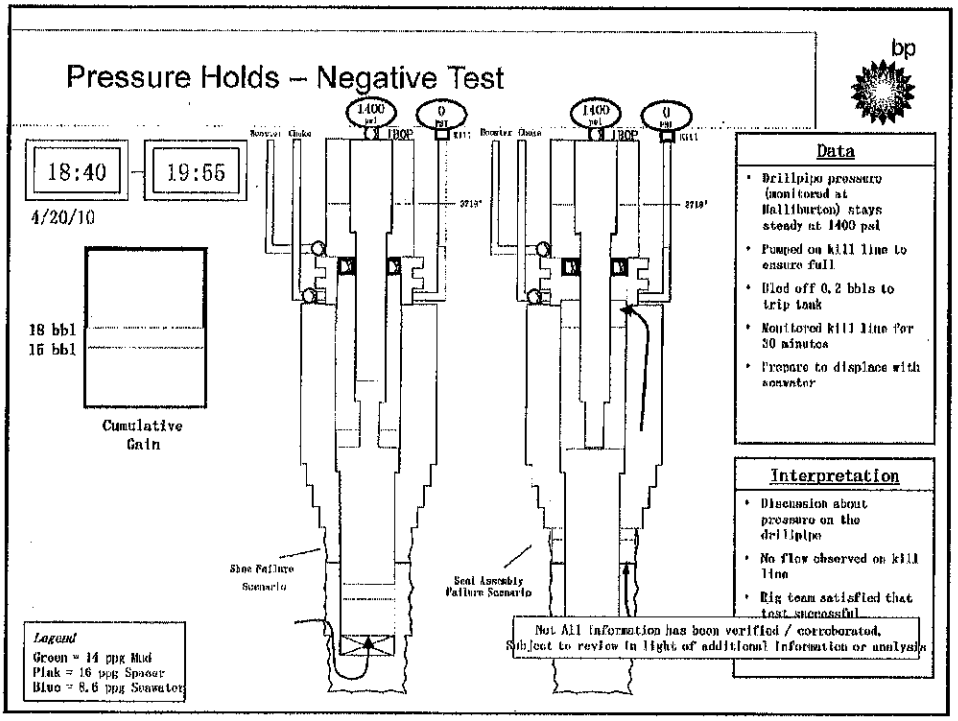

Bleed to 1220 psi
bp
16:55
16:57
4/20/10
1220 psi
1200 psi
Data
• Bleed drill pipe pressure from 2325 psi to 1220 psi to equalize with kill line
Interpretation
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis
Legend
Green = 14 ppg Mud
Pink = 16 ppg Spacer
Blue = 8.6 ppg Seawater


Bleed to 273 psi
bp
16:57
17:05
4/20/10
1220 psi
1200 psi
Choke
Data
Open kill line
Pressure equalizes
-Drillpipe pressure goes to 1400 psi
-Kill line pressure drops to 645 psi
Bleed pressure to 273 psi on drillpipe as kill line pressure drops to zero
-DP pressure never gets to zero
First time well is under balance
Observed that fluid level in the riser had dropped
Interpretation
U-tube between drill pipe and kill line due to heavy fluid in the annulus
Suspect the annular is leaking
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis
Legend
Green = 14 ppg Mud
Pink = 16 ppg Spacer
Blue = 8.6 ppg Seawater


Drill Pipe Pressure Builds / Fill Riser
bp
17:05
17:25
4/20/10
1250
0
Data
• Shut in drillpipe
• Pressure builds to 1250 psi in 6 minutes
• Filled the riser with 50bbls from trip tank
• Mud offload to Bunkston ends at 17:17
• Mud loggers not informed that offloading had ceased
Interpretation
• If the annular was leaking it is now sealed
• Discussion on rig floor about pressure on drillpipe
-Decision made to conduct negative test on kill line
Not All Information has been verified / corroborated, Subject to review in light of additional information or analysis
Legend
Green = 14 ppg Mud
Pink = 16 ppg Spacer
Blue = 8.6 ppg Seawater


Bleed from 1202 to 0 psi
bp
17:27
17:52
4/20/10
15 bbl
Cumulative Gain
Data
Bleed drillpipe from 1202 to 0 psi
IBOP is then closed
Interpretation
Witness statements indicate 15 bbls taken at this bleed
- Normal compressibility would be approximately 5 bbls
Shoe Failure Scenario
Seal Assembly Failure Scenario
Legend
Green = 14 ppg Mud
Pink = 16 ppg Spacer
Blue = 8.6 ppg Seawater
Not All Information has been verified / corroborated. Subject to review in light of additional information or analysis

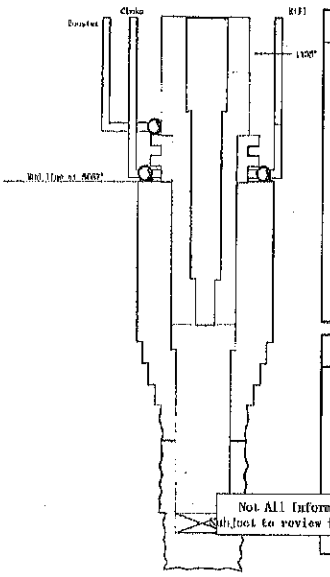

Bleed Kill Line / Pressure Builds Gradually
bp
17:52
18:40
4/20/10
18 bbl
15 bbl
Cumulative Gain
Data
• Pressure monitored through cement unit quickly rises to 790 psi and falls
• Pressure slowly builds from 0 to 1400 psi over 31 minutes
Interpretation
• Start monitoring drillpipe pressure at cement unit
• Bleed 3-15 bbls from kill line to cement unit
• Cementer witness statement that well
• Shut kill line and see pressure build
Shoe Failure Scenario
Seal Assembly Failure Scenario
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis
Legend
Green = 14 ppg Mud
Pink = 16 ppg Spacer
Blue = 8.6 ppg Seawater


Pressure Holds – Negative Test
bp
18:40
19:55
4/20/10
18 bbl
16 bbl
Cumulative Gain
1400 psi
DPP
0 psi
Kill
Booster Choke
BOP
Shoe Failure Scenario
Seal Assembly Failure Scenario
Data
Drillpipe pressure (monitored at Halliburton) stays steady at 1400 psi
Pumped on kill line to ensure full
Bled off 0.2 bbls to trip tank
Monitored kill line for 30 minutes
Prepare to displace with seawater
Interpretation
Discussion about pressure on the drillpipe
No flow observed on kill line
Rig team satisfied that test successful
Not All Information has been verified / corroborated. Subject to review in light of additional information or analysis
Legend
Green = 14 ppg Mud
Pink = 16 ppg Spacer
Blue = 8.6 ppg Seawater

Displace to Seawater

19:55 – 21:14

4/20/10



Data

- Pumped 1304 bbl seawater
  - Using rig pumps and booster
- Shut down for sheen test - spacer back
  - 1017 psi on DP when shut down
- Sheen test passes
- Crew instructed to divert returns overboard

Interpretation

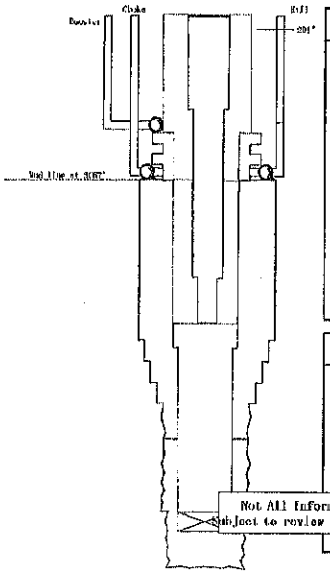
- Flow out greater than flow in commencing at 20:58 while slowing pumps for spacer return
- Second indication of flow at 21:08 when pumps shutdown for sheen test
  - Pressure builds to 1263 over 5.5 minute period

Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

Resume Displacement

21:14 — 21:49

4/20/10



Data

- Resume displacement
  - Pump another 265 bbls
  - Returns going overboard
  - Flow meter bypassed - unable to monitor flow out
- Pumps stop at 21:31
- Significant pressure buildup starting at 21:47
- Data lost at 21:49
  - Last pressure reading 5700 psi

Interpretation

- Pumps stop at 21:31 - suspect problem identified with well
- 4 calls made from rig floor and Chief Mate discusses well with Tool pushor on rig floor
- Suspect explosion at 21:49

Not All Information has been verified / corroborated. Subject to review in light of additional information or analysis

EDS (Emergency Disconnect)

Draft - Work in Progress. Subject to Revision

24 May, 2010

- The EDS function is activated from the surface (either the bridge or drill floor). Its function is to seal the well and disconnect the vessel from the well.
- The EDS sequence :-
  - Operator on rig pushes the EDS button
  - Blind shear rams close cutting drill pipe and sealing the well
  - Choke and kill line valves are closed and lines unlatched
  - LMRP is unlatched and disconnects
  - The EDS sequence is complete and rig moves away from well.
- Witness accounts. EDS was activated from Bridge after explosion at 21.56.
- EDS failed to seal well and LMRP failed to disconnect.

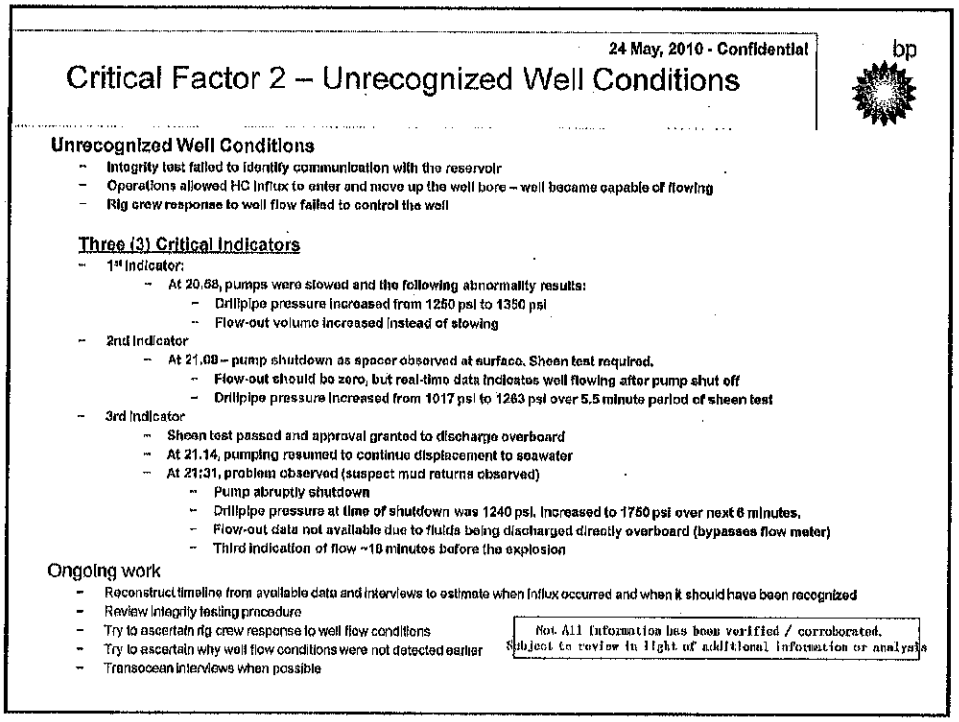
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

BOP - AMF (Dead-man) Function

bp

- The AMF would have been expected to seal the well after loss of the three functions (hydraulics, communications and power) from the surface at some point between the explosions and the rig sinking.
- The AMF is an emergency sequence that activates the blind shear rams to seal the well.
  - Activation time for the AMF is 37 seconds
- The AMF sequence:
  - The BOP senses the loss of hydraulics, communications, power from the surface (all three need to be lost) and arms the AMF.
  - The AMF Activates the Blind shear rams cutting drill pipe and sealing the well.
  - Note that the AMF does not disconnect the LMRP.
- There is no evidence to suggest that the AMF in this case activated effectively to seal the well.

Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis



24 May, 2010 - Confidential

bp

Critical Factor 2 – Unrecognized Well Conditions

Unrecognized Well Conditions

- Integrity test failed to identify communication with the reservoir
- Operations allowed HC influx to enter and move up the well bore – well became capable of flowing
- Rig crew response to well flow failed to control the well

Three (3) Critical Indicators

- 1st Indicator:
  - At 20.58, pumps were slowed and the following abnormality results:
    - Drillpipe pressure increased from 1250 psi to 1350 psi
    - Flow-out volume increased instead of slowing
- 2nd Indicator
  - At 21.09 – pump shutdown as spacer observed at surface. Sheen test required.
    - Flow-out should be zero, but real-time data indicates well flowing after pump shut off
    - Drillpipe pressure increased from 1017 psi to 1263 psi over 5.5 minute period of sheen test
- 3rd Indicator
  - Sheen test passed and approval granted to discharge overboard
  - At 21.14, pumping resumed to continue displacement to seawater
  - At 21:31, problem observed (suspect mud returns observed)
    - Pump abruptly shutdown
    - Drillpipe pressure at time of shutdown was 1240 psi, increased to 1750 psi over next 6 minutes.
    - Flow-out data not available due to fluids being discharged directly overboard (bypasses flow meter)
    - Third indication of flow ~18 minutes before the explosion

Ongoing work

- Reconstruct timeline from available data and interviews to estimate when influx occurred and when it should have been recognized
- Review integrity testing procedure
- Try to ascertain rig crew response to well flow conditions
- Try to ascertain why well flow conditions were not detected earlier
- Transocean interviews when possible

Not All information has been verified / corroborated.
Subject to review in light of additional information or analysis

Last integrity test - so called

Negative test started @ 15:00 - ended 20:02 (long time) typically 1hr

In looking back: there were anomalous pressures and several discussions regarding the test.

Witness statements about bleeding off volume.

Difficult to tie down - only bp WSL views to date. Transocean input important

20:02 End integrity test based on KL reading 0# but 1400# on DP. - Decided to move forward with sea water displacement

20:58 start staging pumps down for sheen test - DP pressure increasing (confirm SOBM gone) - Appears to be firs clear indication of flow

21:08 (10 min later) pumps fully shut down

- DP pressure continued building

- outflow meter indicate flow - 1.7 bbl/min

21:31 stop pumps abruptly - appear to detect problem

DP increases from 1240# to 1750 # in 6 minutes !!

Flow going overboard so could not meter

- 4 phone calls reported from witness statements (TP to Rig floor, AD to mud pits, Vidrine called by TP, Snr TP contacted by AD)

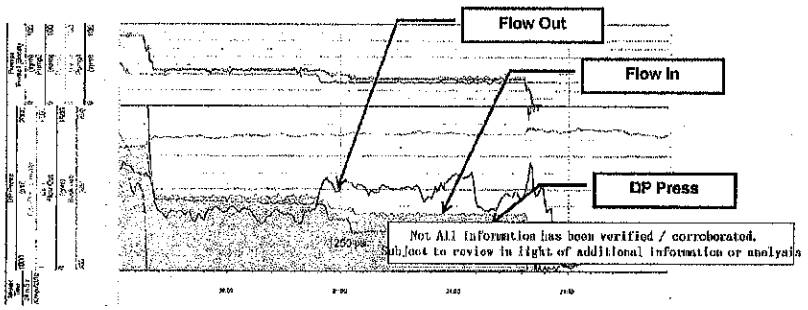
- Appear BOP activated late or not at all

21:49 Explosion

Critical Factor 2: Flow Indication #1
51 minutes before explosion

bp

- Following final integrity test of wellbore, BOP annular was opened and well displacement of mud to seawater began:
  - Flow-out volume of mud and drillpipe pressure showed expected correlation until about 20:58
  - At 20:58, pumps were slowed and the following abnormal results:
    - Drillpipe pressure increased from 1250 psi to 1350 psi
    - Flow-out volume increased instead of slowing
  - Flow-out vs flow-in shows gain of approx 57 bbls over 12 minute period
  - First indication of flow ~51 minutes before the explosion

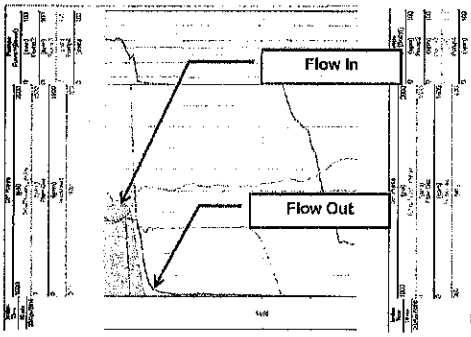


Critical Factor 2: Flow Indication #2
41 minutes before explosion

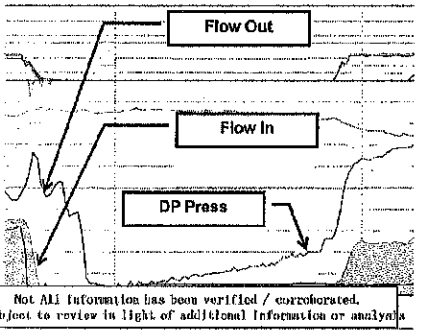
bp

- At 21:08 – pump shutdown as spacer observed at surface. Sheen test required.
  - Flow-out should be zero, but real-time data indicates well flowing after pump shut off
  - Drillpipe pressure increased from 1017 psi to 1263 psi over 5.5 minute period of sheen test

Ex) Normal Flow Back @ 16:52

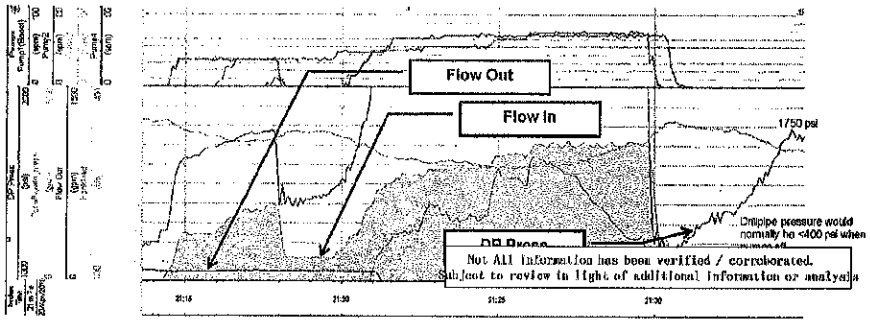


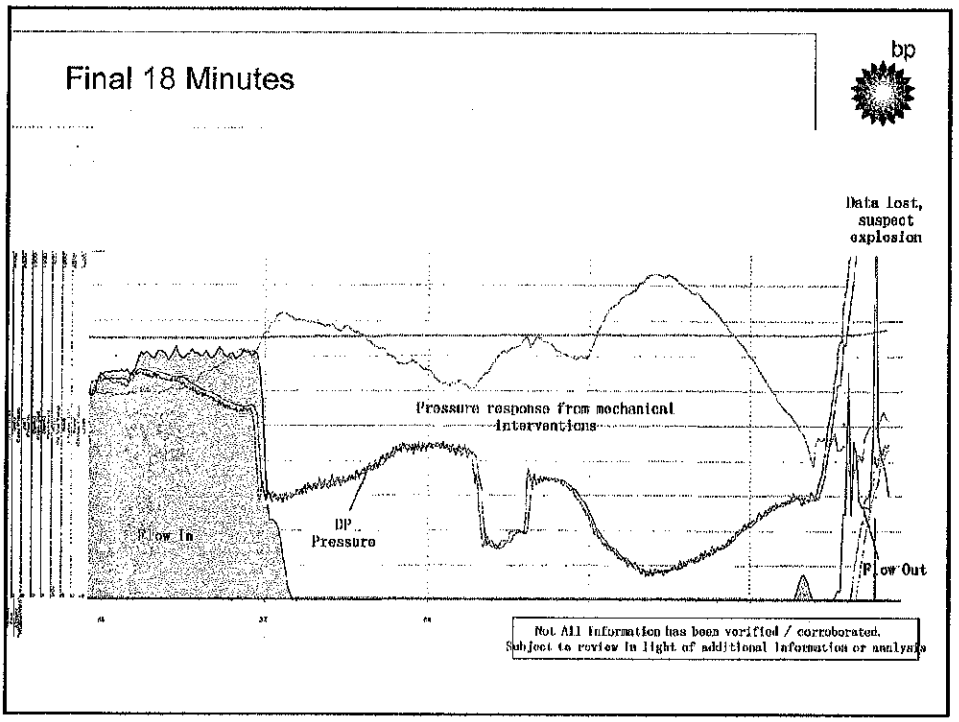
Flow Back @ 21:08

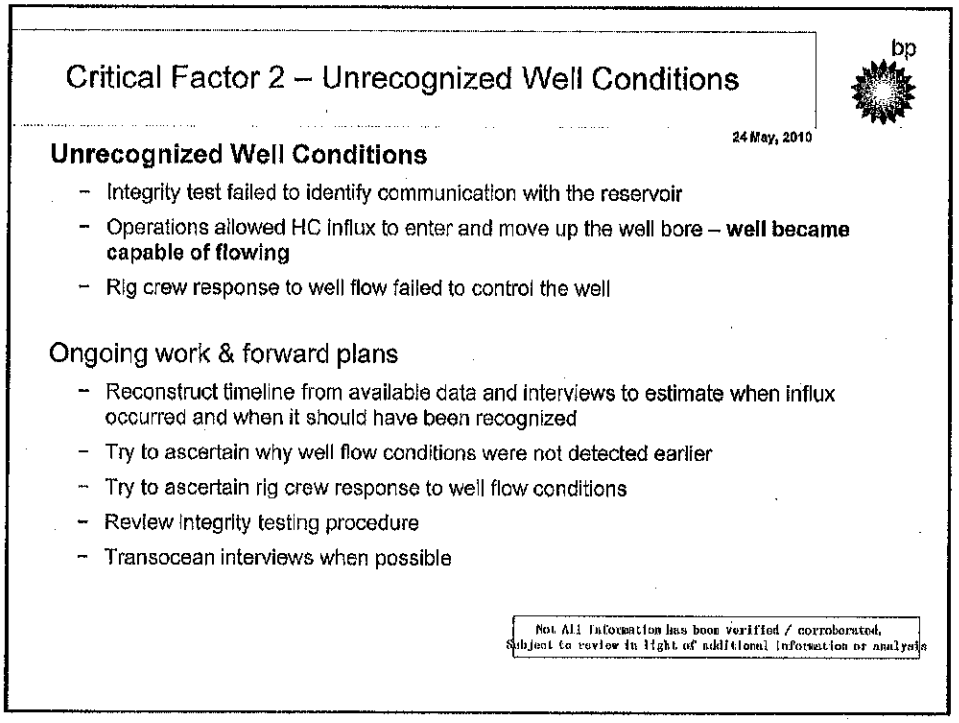


Critical Factor 2: Flow Indication #3
18 minutes before explosion

- Sheen test passed and approval granted to discharge overboard
- At 21:14, pumping resumed to continue displacement to seawater
- At 21:31, problem observed (e.g. mud returns, abnormal pressures)
  - Pump abruptly shutdown
  - Drillpipe pressure at time of shutdown was 1240 psi. Increased to 1750 psi over next 6 minutes.
  - Flow-out data not available due to fluids being discharged directly overboard (bypasses flow meter)




Final 18 Minutes
bp
Data lost, suspect explosion
Pressure response from mechanical interventions
Flow In
BP Pressure
Flow Out
Not All Information has been verified / corroborated. Subject to review in light of additional information or analysis



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DP increases from 1240# to 1750 # in 6 minutes !!

Flow going overboard so could not meter

- 4 phone calls reported from witness statements (TP to Rig floor, AD to mud pits, Vidrine called by TP, Snr TP contacted by AD)

- Appear BOP activated late or not at all

21:49 Explosion

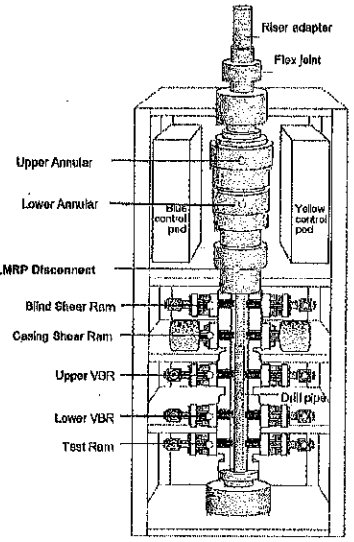
Critical Factor #2
Unrecognized Well Conditions

Immediate Cause	System Cause	Corrective Action
Negative Test Process Failed to Identify Loss of Casing Integrity	TBD	TBD
Poor Fluids Management as the well became Imbalanced	TBD	TBD
Delayed Response to Well Control Condition	TBD	TBD

Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

bp

Intended Purpose and Functions of BOP



- Upper Annular used in normal drilling operations for well shut-in rated to 10k psi.
- Lower Annular used in normal drilling operations with Casing Stripping Element. Rated to 5k psi.
- LMRP Disconnect - if EDS is activated and well sealed, LMRP disconnects rig from sealed well
- Blind Shear Rams - if EDS or AMF is activated, these cut the drill pipe and seal the well
- Casing Shear Rams primarily designed to cut casing in EDS; is not designed to seal the wellbore
- Variable Bore Rams (VBR) used in normal drilling operations. Ram packers can close on a range of drill pipe from 3 ½" OD to 6 5/8" OD and seal up to 15k psi wellbore pressure.
- Test Ram seals up to 15k psi pressure from above to enable functional testing of BOP

Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

EDS (Emergency Disconnect Sequence)

- The EDS function is activated from the surface (either the bridge or drill floor). Its function is to seal the well and disconnect the vessel from the well.
- The EDS sequence in drilling mode (per time of incident):-
  - Operator on rig pushes the EDS button
  - Blind shear rams close, cutting drill pipe and sealing the well
  - Choke and kill line valves are closed and lines unlatched
  - LMRP is unlatched and disconnects
  - The EDS sequence is complete and rig moves away from well.
- Witness accounts: EDS was activated from Bridge after explosion at 21:56.
- EDS failed to seal well and LMRP failed to disconnect.

Not All information has been verified / corroborated.
Subject to review in light of additional information or analysis

AMF (Deadman)

bp

- The AMF is activated automatically at the seabed if hydraulics, power and communications are lost from the surface. Its function is to seal the well in an emergency.
- The AMF sequence :-
  - The BOP senses the loss of hydraulics, power and communications from the surface (all three need to be lost), and arms the AMF.
  - The AMF activates the Blind shear rams cutting drill pipe and sealing the well.
  - Note that the AMF does not disconnect the LMRP.
- The AMF would have been expected to seal the well on loss of the three functions from the surface at some point between the explosion and the rig sinking.
- The AMF failed to seal the well.

Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

ROV Surveys conducted post incident

bp

- Post the explosion, numerous ROV surveys were conducted in an attempt to activate
  - Blind Shear rams
  - Pipe rams
  - LMRP Disconnect (ROV cut the Auto shear pin in attempt to activate the blind shear rams)
- ROV survey found:
  - A number of hydraulic leaks
  - Plumbing errors such that test rams were being activated instead of lower variable rams.
- Non destructive examination using ultra-sonics and radiography to try and detect position of rams and locks.

Not All information has been verified / corroborated.
Subject to review in light of additional information or analysis

bp

Need a Critical Factor 3 Chart Here

Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

Immediate Lines of Inquiry

- Maintenance
  - Was the BOP properly maintained?
- Testing
  - Was the BOP properly tested within regulation, what do tests tell us?
- Modifications
  - Could modifications conducted over life of BOP have impacted functionality?
- Leaks
  - Could hydraulic leaks found during ROV interventions and previously noted in Rig log have impacted functionality?

Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

Critical Factor #3
BOP Failed to Isolate the Source

bp

Immediate Cause	System Cause	Corrective Action
Direct control of BOP elements did not isolate the source	TBD	TBD
EDS did not isolate the source	TBD	TBD
AMF did not isolate the source		
ROV intervention did not isolate the source	TBD	TBD

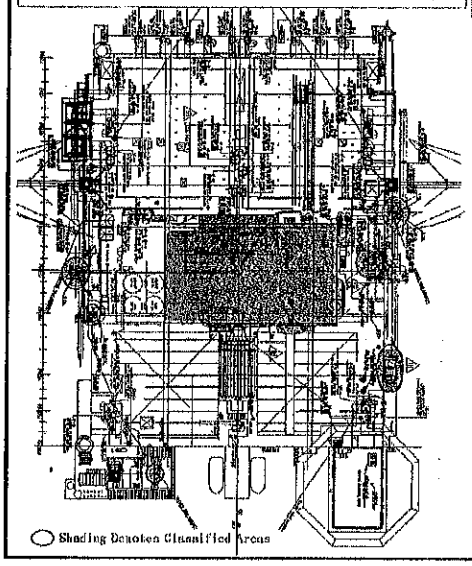
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

Critical Factor 4 – Ignition of Hydrocarbons

bp

24 May, 2010

Hazardous Area Classification - Main Deck



Shading Denotes Classified Areas

Ignition of Released Hydrocarbons

- Hydrocarbon gas detected by several gas detectors prior to explosion (two witness statements from bridge).
- Several potential scenarios of hydrocarbon release to atmosphere have been identified.
- Dynamic modeling estimates suggests that flammable gas mixtures could have reached non-electrically classified areas.

Ongoing work

- Fluid dynamic modeling being further developed in-line with most probable release scenarios.
  - Access to pit room / mud pumps
  - Access to derrick via degasser
  - Access to engine room
- Review of electrical area classification, fire and gas design and ventilation system design.

Not All Information has been verified / corroborated. Subject to review in light of additional information or analysis

Critical Factor 4 – Ignition of Hydrocarbons

Immediate Cause	System Cause	Corrective Action
Hydrocarbon Released to Atmosphere	TBD	TBD
Ignition Occurred	TBD	TBD

Not All information has been verified / corroborated.
Subject to review in light of additional information or analysis

bp

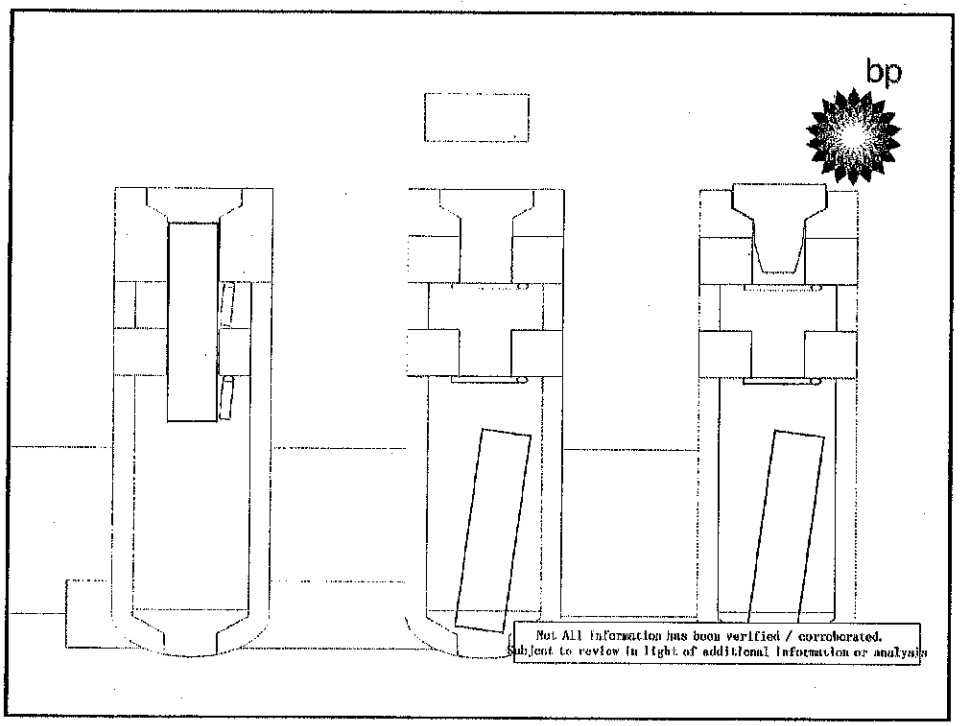
Possible Early Actions

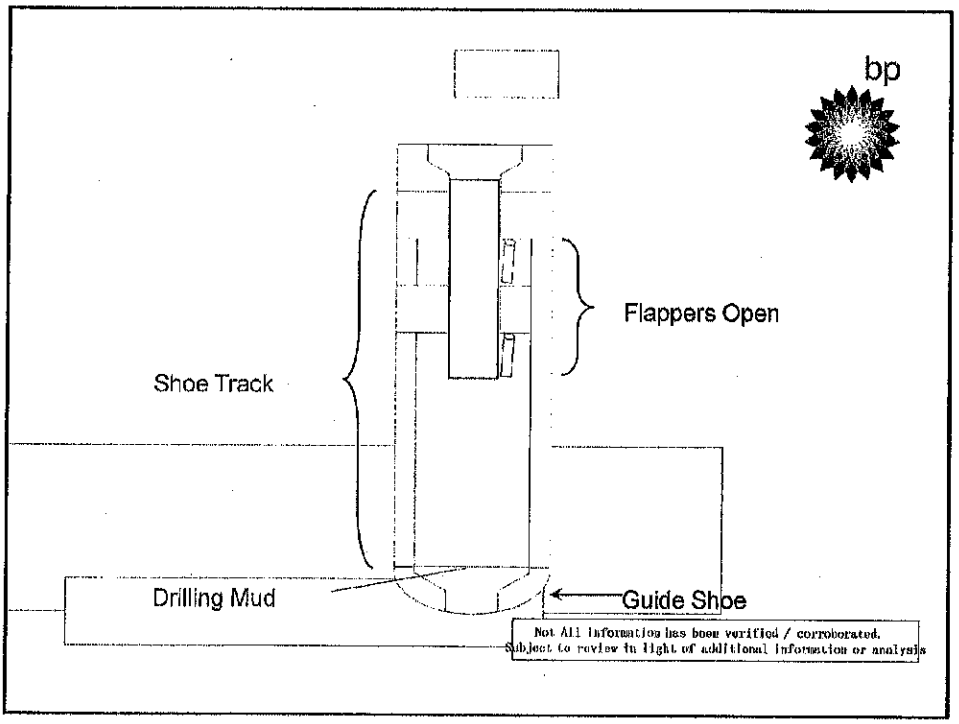
- Review integrity test procedure
  - Detailed procedures
  - Pass / fail criteria
  - Authority for acceptance
- Cause DW drilling contractors to:
  - Demonstrate modifications are reflected in "as-built" drawings
  - Demonstrate that pre-run BOP test procedures provide conformation that all functions are good to go
  - Demonstrate safety critical maintenance is up to date
  - Demonstrate that emergency systems have ongoing cycle of checks for effectiveness (including ROV, Dead-man & subsea)
- Reinforce expectations with contractor on wellbore and fluids management up to the point of BOP release from the well
- Cause Well Contractor to demonstrate well control competency

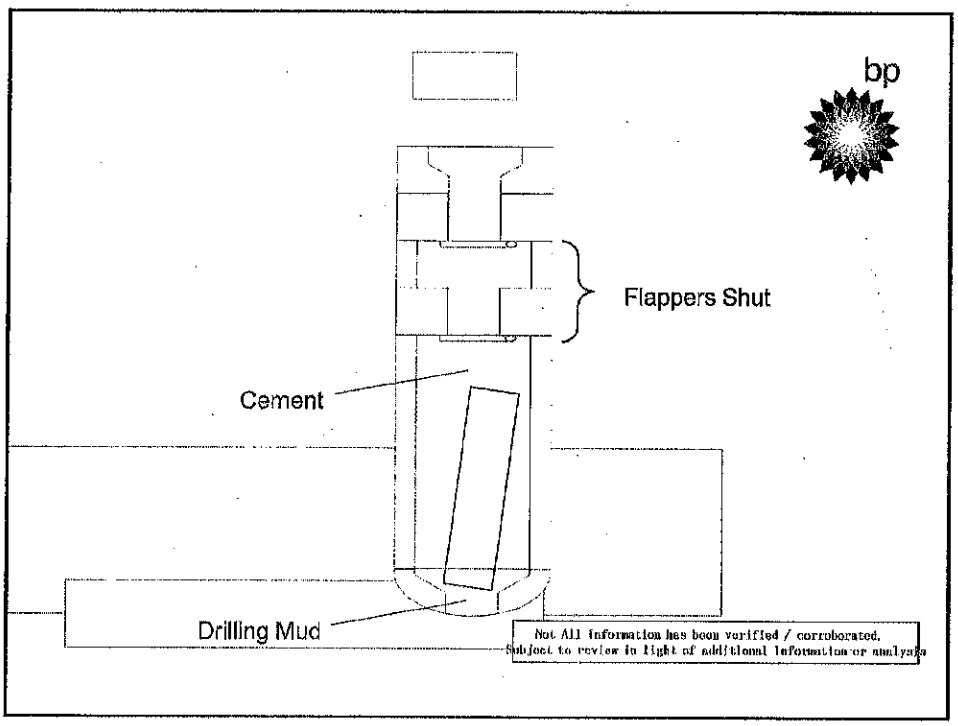
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

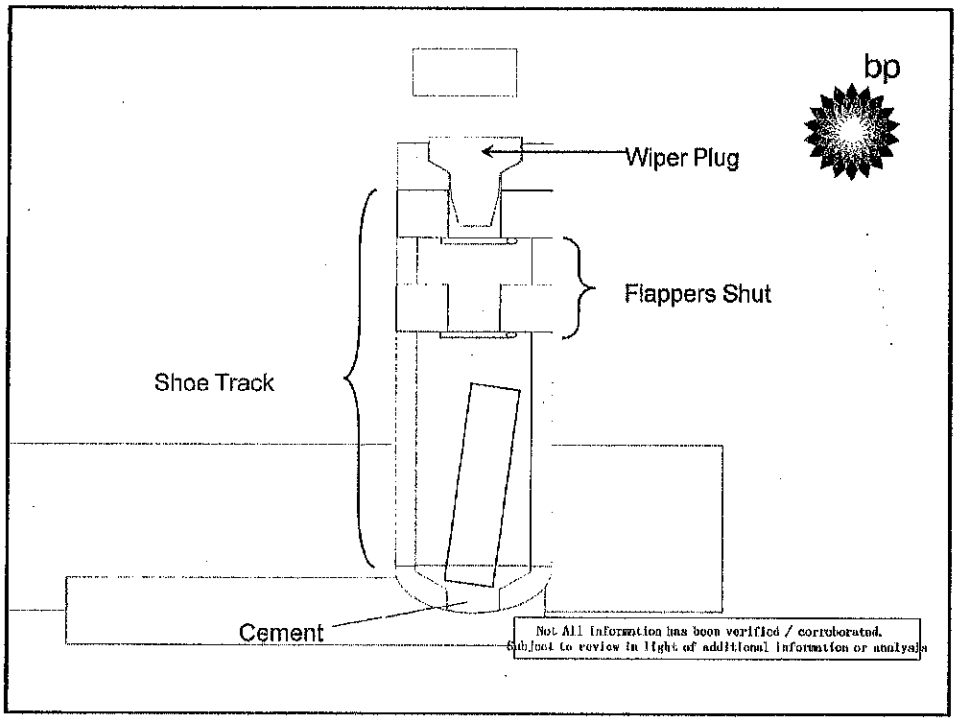
Back-up Slides

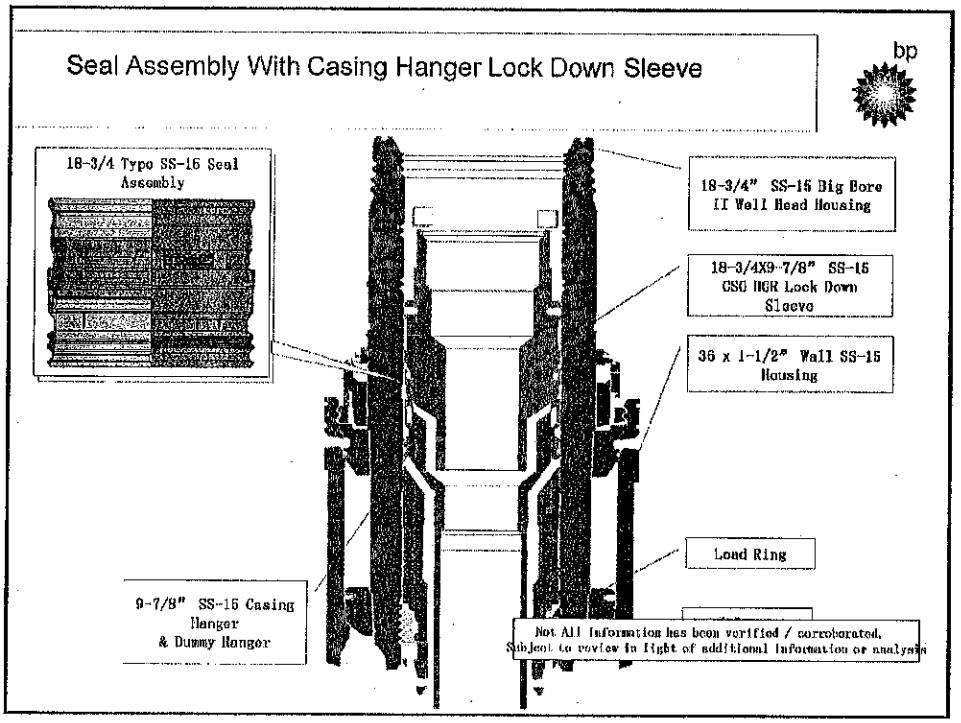
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

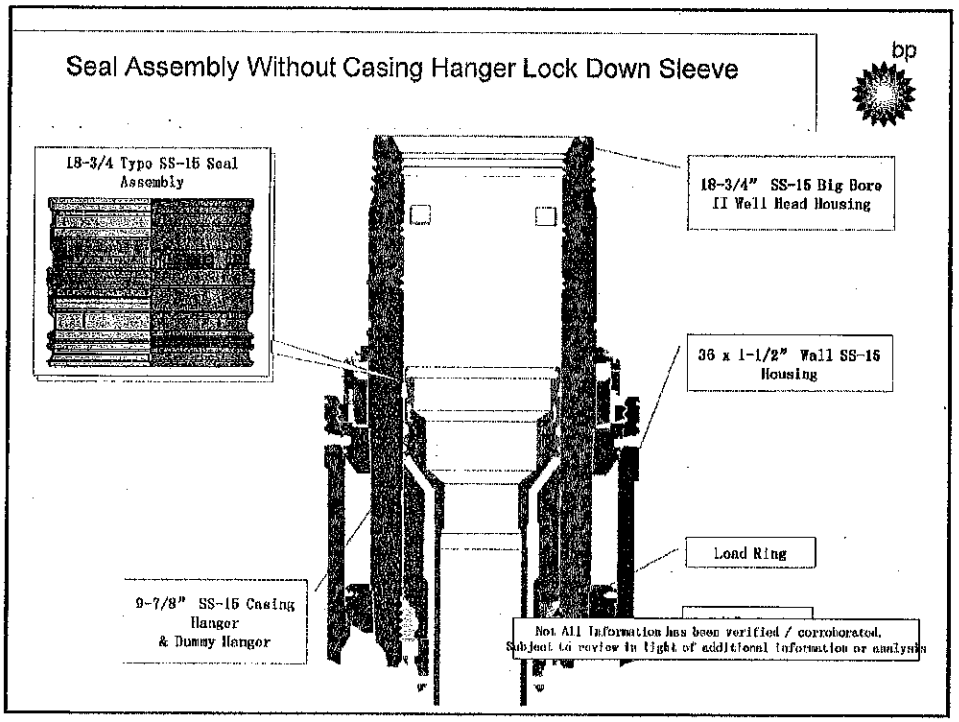

bp
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis


bp
Flappers Open
Shoe Track
Drilling Mud
Guide Shoe
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

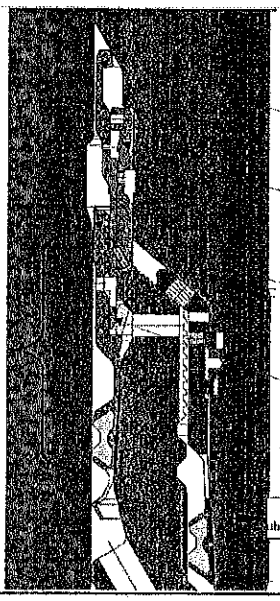

bp
Flappers Shut
Cement
Drilling Mud
Not All information has been verified / corroborated.
Subject to review in light of additional information or analysis


bp
Wiper Plug
Flappers Shut
Shoe Track
Cement
Not All information has been verified / corroborated.
Subject to review in light of additional information or analysis


Seal Assembly With Casing Hanger Lock Down Sleeve
bp
18-3/4 Type SS-16 Seal Assembly
18-3/4" SS-16 Big Bore II Well Head Housing
18-3/4X9-7/8" SS-16 CSG HGR Lock Down Sleeve
36 x 1-1/2" Wall SS-16 Housing
Load Ring
9-7/8" SS-16 Casing Hanger & Dummy Hanger
Not All Information has been verified / corroborated. Subject to review in light of additional information or analysis


Seal Assembly Without Casing Hanger Lock Down Sleeve
bp
18-3/4 Type SS-15 Seal Assembly
18-3/4" SS-15 Big Bore II Well Head Housing
36 x 1-1/2" Wall SS-15 Housing
Load Ring
9-7/8" SS-15 Casing Hanger & Dummy Hangor
Not All Information has been verified / corroborated. Subject to review in light of additional information or analysis

Seal Assembly Cross Sectional View



6" Seal Area

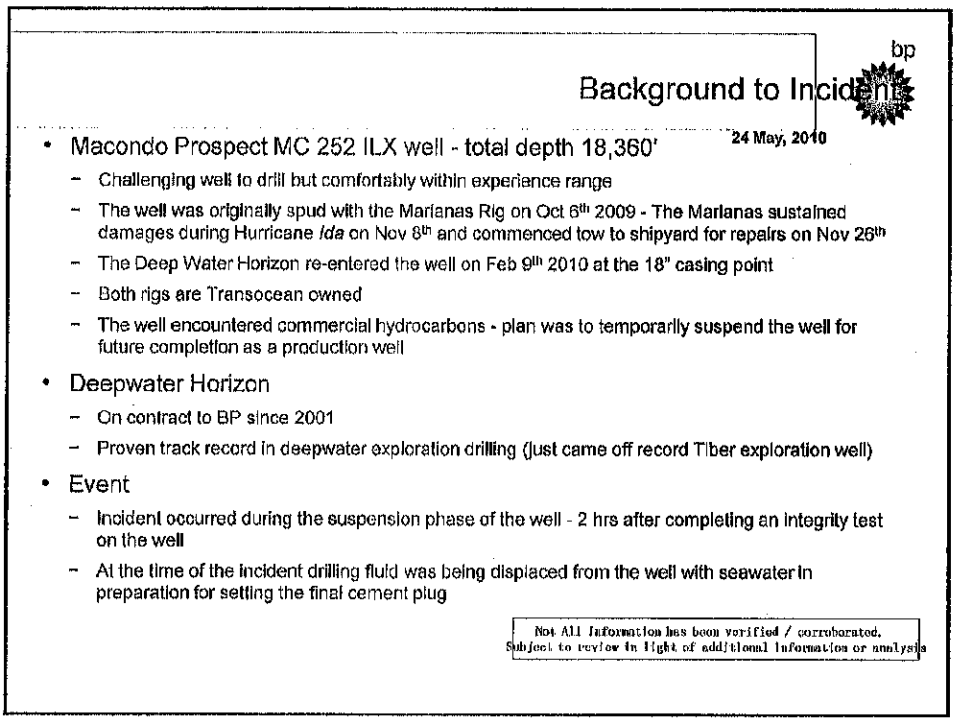
Lockdown Sleeve

Upper Housing

Lower Housing

Snap Lock Ring

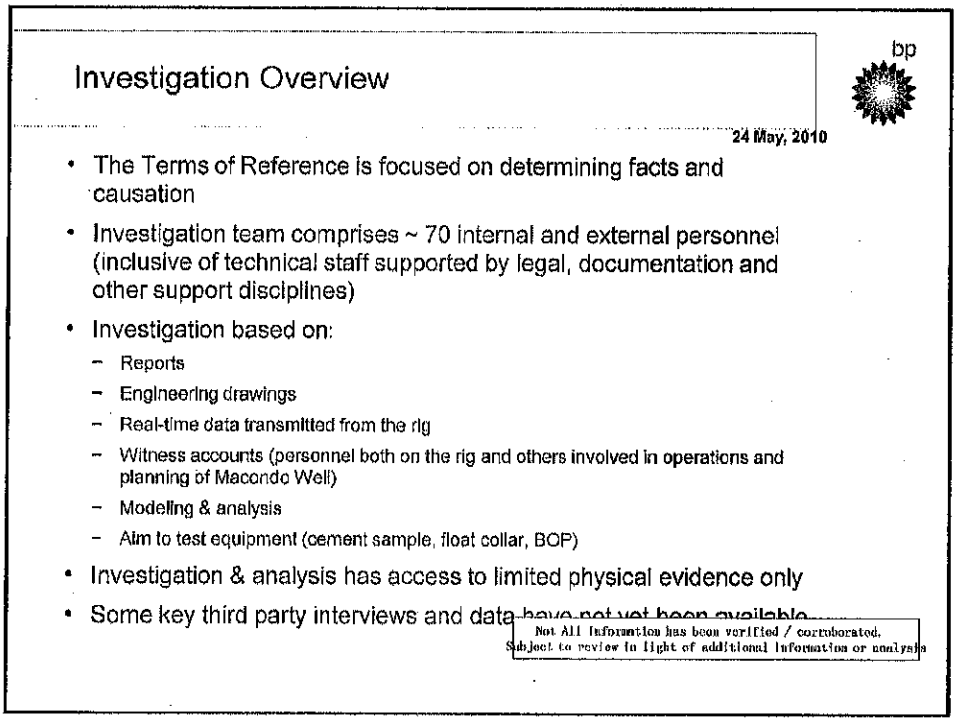
Not All Information has been verified / corroborated, subject to review in light of additional information or analysis



Event

Horizon primarily an Exploration Rig

At the time of the incident there were a few remaining steps to secure the well and depart i.e. final cement plug & lock ring



Team Composition

Several bp & Industry SME' s (SETA' s) engaged,

Good team in place, still building on the BOP side of inquiry

External consultants engaged - Arnold & Porter, Add Energy, Baker Risk, Boots & Coots, CSI, Ex-PRO Soft, HOSE, Stress Engineering, Subsea Ventures Marine, Well Control Systems, Academic Support (MIT and/or Manchester

•Full-Time: 46

•BP Part Time: 8

•Consultants: 17

Important to understand the context in which the investigation is happening

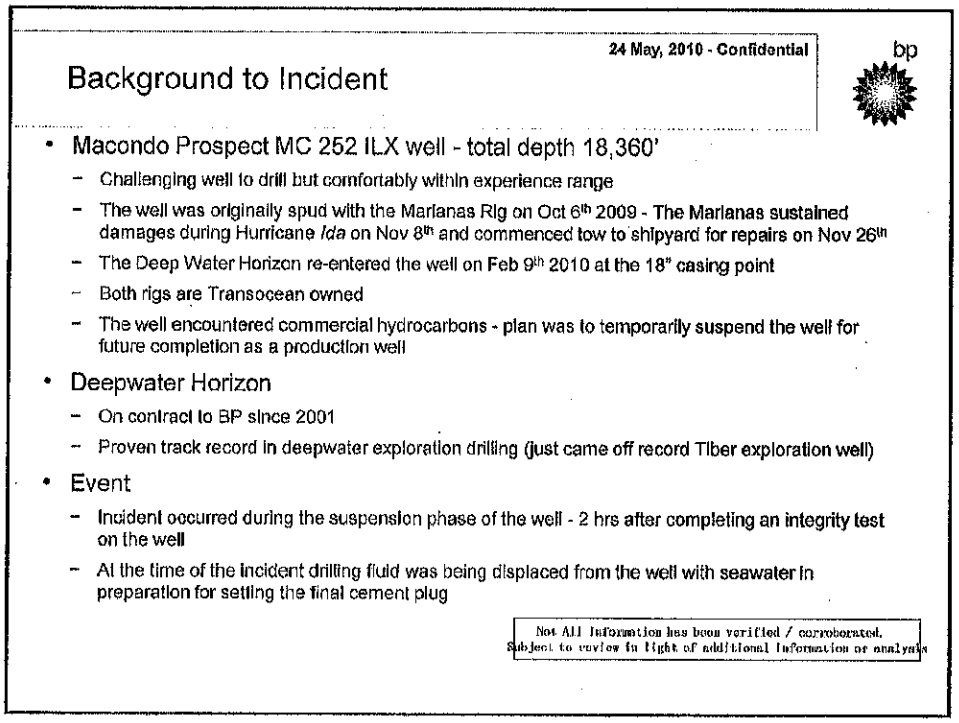
Access to 3rd parties has been challenging - Transocean (no interviews to date - 12 requested)

No access to Cameron

Lack of physical evidence - yet to secure from Halliburton cement sample used in cement job

Yet to secure cement samples (of boat) from Coast Guard

Access to BOP with ongoing Government/MBI proceedings?



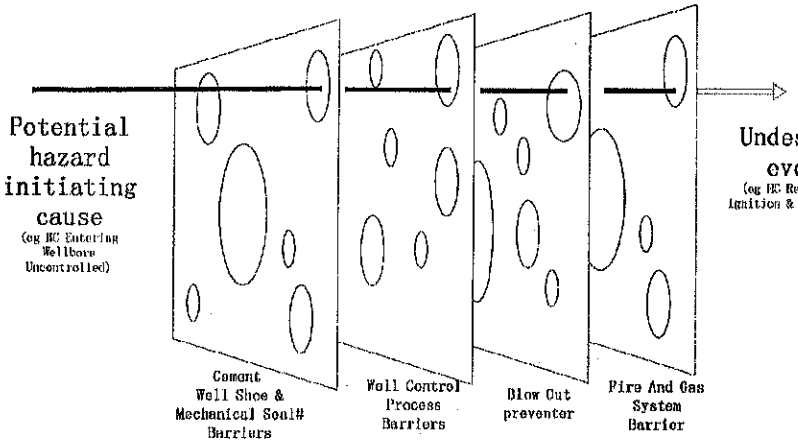
Event

Horizon primarily an Exploration Rig

At the time of the incident there were a few remaining steps to secure the well and depart i.e. final cement plug & lock ring

Independent Protection Layers – Swiss Cheese Model

24 May, 2010 - Confidential



Protection layers represent that protection layer's probability of failing to mitigate the hazard)

Not All Information has been verified / corroborated, subject to review in light of additional information or analysis

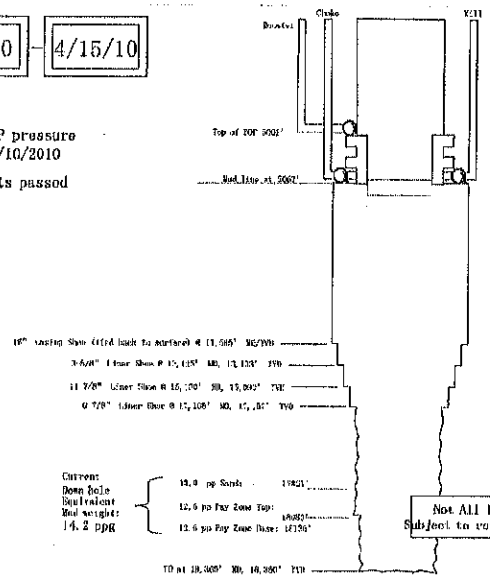
Finish Drilling and Complete Logging

bp

4/9/10 – 4/15/10

Last BOP pressure test: 4/10/2010

All tests passed



Data

- Finish drilling
  - 9-7/8" x 8-1/2" open hole
  - 14.0 ppg mud inside and out
- Trip out with drilling assembly
- Wire line log for 4 days

Interpretation

- Hole stable

Not All Information has been verified / corroborated. Subject to review in light of additional information or analysis

Wiper Trip

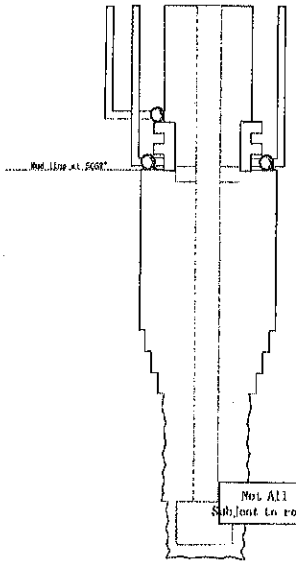
bp

14:00 — 12:00

4/16/10
4/17/10

Function test BOP:
4/17/10 at 01:00

Function test diverter: 4/17/10 at 01:30



Data

- Run in hole for wiper trip
  - Circulate bottoms up at TD
  - Pump high vis sweep
  - Monitor for gains or losses - none
  - 14.6 ppg clean mud throughout before trip out
- Pump out from 18360', - 14750'
  - 4 flow checks during trip out - no flow

Interpretation

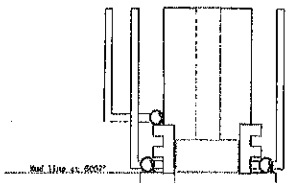
Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis

Retrieve Wear Sleeve

bp

12:00 – 00:30
4/17/10
4/18/10

- Function test BSR
  4/17/10 23:00



Data

- Make trip to retrieve wear sleeve
  - Retrieval successful

Interpretation

Not All Information has been verified / corroborated.
Subject to review in light of additional information or analysis