UNITED STATES DEPARTMENT OF THE INTERIOR
MINERALS MANAGEMENT SERVICE
GULF OF MEXICO REGION

ACCIDENT INVESTIGATION REPORT

1. OCCURRED
   DATE: **21-MAY-2003** TIME: **0400** HOURS

2. OPERATOR: **BP Exploration & Production Inc.**
   REPRESENTATIVE: **Anne Renee Laplante**
   TELEPHONE: **(713) 685-2011**
   CONTRACTOR: **Transocean Offshore**
   REPRESENTATIVE: **Don Hulseberg**
   TELEPHONE: **(815) 777-0652**

3. OPERATOR/CONTRACTOR REPRESENTATIVE/SUPERVISOR ON SITE AT TIME OF INCIDENT:
   Cecil Cheshier

4. LEASE: **G14658**
   AREA: **MC** LATITUDE: **28.19040988**
   BLOCK: **822** LONGITUDE: **-88.49525617**

5. PLATFORM:
   RIG NAME: **T.O. DISCOVERER ENTERPRISE**

6. ACTIVITY:
   - [ ] EXPLORATION(POE)
   - [X] DEVELOPMENT/PRODUCTION (DOCD/POD)

7. TYPE:
   - [ ] HISTORIC INJURY
     - [ ] REQUIRED EVACUATION
     - [ ] LTA (1-3 days)
     - [ ] LTA (>3 days
     - [ ] RW/JT (1-3 days)
     - [ ] RW/JT (>3 days)
     - [ ] Other Injury
   - [ ] FATALITY
   - [X] POLLUTION
   - [ ] FIRE
   - [ ] EXPLOSION
   - LWC
     - [ ] HISTORIC BLOWOUT
     - [ ] UNDERGROUND
     - [ ] SURFACE
     - [ ] DEVERTER
     - [ ] SURFACE EQUIPMENT FAILURE OR PROCEDURES
   - COLLISION [ ] HISTORIC [ ] >$25K [ ] <=$25K
   - [ ] STRUCTURAL DAMAGE
   - [ ] CRANE
   - [ ] OTHER LIFTING DEVICE
   - [ ] DAMAGED/DISABLED SAFETY SYS.
   - [ ] INCIDENT >$25K
   - [ ] H2S/15MIN./20PPM
   - [ ] REQUIRED MUSTER
   - [ ] SHUTDOWN FROM GAS RELEASE
   - [ ] OTHER

6. OPERATION:
   - [ ] PRODUCTION
   - [X] DRILLING
   - [ ] WORKOVER
   - [ ] COMPLETION
   - [ ] HELICOPTER
   - [ ] MOTOR VESSEL
   - [ ] PIPELINE SEGMENT NO.
   - [ ] OTHER

8. CAUSE:
   - [X] EQUIPMENT FAILURE
   - [ ] HUMAN ERROR
   - [ ] EXTERNAL DAMAGE
   - [ ] SLIP/TRIP/FALL
   - [ ] WEATHER RELATED
   - [ ] LEAK
   - [ ] UPSET H2O TREATING
   - [ ] OVERBOARD DRILLING FLUID
   - [X] OTHER **Riser Parted**

9. WATER DEPTH: **6040** FT.

10. DISTANCE FROM SHORE: **75** MI.

11. WIND DIRECTION: **ESE**
    SPEED: **12** M.P.H.

12. CURRENT DIRECTION: **S**
    SPEED: **2** M.P.H.

13. SEA STATE: **2** FT.

17. INVESTIGATION FINDINGS:

Well No. 6 was TD'd at KB. Rig on the main rotary was in the process of pulling out of hole with drill pipe at ' KB when the rig experienced a heave followed by a jarring action at 4:00 a.m. It was believed that riser had become unlatched or parted. The remote operated vehicle (ROV), which was observing 20" casing (from MC 778 No. 9) being run on the aft rotary, was sent to observe the riser. It was determined that the riser had parted in at least two places. The riser was parted at 3200' KB and one foot above the lower marine riser package (LMRP). The ROV observed several joints of riser on the seafloor. The remainder of the riser was located with one end penetrating the seafloor and the top at 5087' KB. The casing shear ram and the lower blind shear ram closed via the deadman sequence providing an effective seal on the wellbore. The drill string appeared to be intact from the rig floor down to and into the riser that penetrated the seafloor. The ROV was used to activate an upper set of blind shear rams at 8:53 a.m. A worst case scenario (if all mud u-tubed out) of the discharge is 2450 bbls (pollutant volume 1421 bbls - 58% of 2450 bbls) of ppg synthetic mud. No sheen was observed. USCG and NRC were notified. BP sent a helicopter to observe for possible sheen. Sea conditions at the time of the incident were 2' seas with a 1.9 kt current to the South. The 20" casing was pulled from the aft rotary and laid down.

The lower riser section was latched with slings on drill pipe from aft rotary and secured at approximately 1000' above seafloor. Slips were set on drill pipe at rig floor. ROV seafloor survey indicated only minor damage to nearby wells. Louisiana Responder vessel arrived on location.

Performed minor repair on drawworks. Top drive system checked out fine. Pulled drill pipe from forward rotary. Re-ran drill pipe through upper riser section on forward rotary. Attached second sling to lower riser section with ROV. Released drill pipe sling from aft rotary and attached to drill pipe on forward rotary. POOH with drill pipe on aft rotary. Picked up and ran hydraulic riser pulling tool on aft rotary. Stabbed and latched into lower riser section. Rotated rig to position lower riser section away from wells in vicinity. No pollution observed.

Pick up on riser. Pull riser joints 26, 25, and 24 out of mud while positioning rig south of drill center. Riser joints on seafloor appear to be connected. Jet mud from beneath riser joint 23. Cut boost and choke line on riser joint 23 with rig ROV chop saw.

Jumped ROV to make cut on riser with diamond band saw. Cut riser along with choke, kill, boost, and rigid conduit lines. Picked up riser off bottom. Cleared Mux line around bottom of lower riser section while slowly moving off location.

Lower riser section retrieved on aft rotary. Top joint (#39) of lower riser section sent to Stress Engineering in Houston for analysis. Retrieved last joint (#40) of upper riser section on forward rotary. Joint #40 also sent to Houston for analysis.

Lower Marine Riser Package was retrieved and repaired on rig for reuse. It will be rerun to latch to BOP stack to begin fishing operations. All bolts and inserts from the 3200 feet of upper riser to go through full inspection (including magnetic particle inspection). Riser tubes to be analyzed for damage. BP team planning for re-entry and well control plan. BP riser recovery team reviewing procedures for recovering remaining riser on seafloor. Magnetometer survey indicated parts of riser located 40' below mud line. MMS Accident Investigation Team (Lars Herbst, David Trocquet, Fred Hefren) met with BP, Transocean, and Stress Engineering to discuss incident and get update of their investigation.

17. INVESTIGATION FINDINGS (See 20. ADDITIONAL INFORMATION)

18. LIST THE PROBABLE CAUSE(S) OF ACCIDENT:

The failure originated in one of six inserts (nut) in the female connector of joint 39. The failure of the first insert transferred additional loads to the adjacent inserts and bolts, which subsequently failed.

The high tensile loads from normal operation produced high stresses which were magnified by the design of the insert. Cracks were either initiated in the inside shoulder area from the high stresses or were created in the manufacturing process. These cracks provided a means for the initiation and propagation of hydrogen embrittlement, leading to environmentally assisted cracking (EAC) and ultimate failure.

After the first insert failed, the load it was holding was transferred to the adjacent bolts and inserts, increasing their tensile loads and stresses. These additional loading stresses made the adjacent inserts more susceptible to EAC. Consequently, four of the five remaining inserts failed in a similar manner and the last bolt failed under tension.

19. LIST THE CONTRIBUTING CAUSE(S) OF ACCIDENT:

Three conditions must exist for EAC to propagate: 1) the material must be stressed; 2) it must be susceptible to EAC; 3) it must be in an environment that has some means of transferring hydrogen atoms to the material. The potential for EAC increases as the potentials of these circumstances increase.

1) STRESS

- The inserts were designed with an inherent stress riser (stress concentration area) in the inside corner. This design increases the surface tensile loads in that area.

- It was determined that cracks initiated in the inside shoulder of the inserts. They were either formed in the manufacturing process or they were caused by extreme tensile stresses due to the stress riser.

2) MATERIALS

- The insert material was hardened steel. Hardened steel lends itself to hydrogen embrittlement and EAC.

3) HYDROGEN SOURCE

- Seawater can be considered a corrosive environment and could possibly have been the source of hydrogen.

- Thermally sprayed aluminum (TSA) was used to coat the body of marine riser joints for corrosion protection. The contractor has performed tests that show when TSA is in the presence of hydraulic control fluid, it becomes cathodic to steel, creating an electro-chemical reaction. This would provide a transfer of electrons to the insert and cause hydrogen embrittlement. Evidence suggests that a reaction such as this may have taken place on the first insert that failed.

The average safety factor in the design of the insert at the inside shoulder area was around 2.0. This is acceptable provided the service environment is considered, there are no flaws in the manufacturing process and it sustains no damage throughout its life. A better design would have a much higher safety factor to overcome the effects of the environment and to negate flaws that are not discovered.

20. LIST THE ADDITIONAL INFORMATION:

17. (Cont.) INVESTIGATION FINDINGS:

1. EAC was confirmed as a failure mechanism.

2. Stress analysis showed stresses alone were not sufficient to explain failure.

a. Tension in flange at time of incident - 1.7 MM lb
b. Rating of flange - 2.5 MM lb
c. Flanges above failed location subject to higher tension.
d. All five failed inserts exhibited low-energy fracture surfaces versus 100% ductile, which would be associated with an overload failure.

3. No evidence was found to support fatigue as the primary mode of failure, based on metallurgical findings and analysis of recorded current data.

4. Investigation supports unzipping hypothesis of cracking initiated in insert 39-6 and progressing to adjacent inserts until final failure of the riser connection.

5. Metallurgical analysis points to hydrogen charging as most probable root cause with work ongoing to determine source of hydrogen.

6. Deadman sequence began approximately 24 seconds after the riser parted with the casing shear ram closed approximately 29 seconds after the start of the sequence and the wellbore secured via the lower blind shear ram approximately 30 seconds later. It is believed that the drill pipe had parted when the riser collapsed just above the LMRP and fallen into the wellbore before the casing shear ram closed.

22. (Cont.) RECOMMENDATIONS TO PREVENT RECURRENCE NARRATIVE:

1. Course of Action for MMS (Cont.)

According to API RP 16Q (a non-referenced document) all riser systems should be inspected yearly with liquid penetrant or magnetic particle inspection performed in all critical areas, unless there is evidence that the inspections are not needed that frequently as determined by the manufacturer and contractor. The Safety Alert should cite ABB Vetco's Product Advisory of October 24, 2003 recommending a 6-month inspection frequency for their HMF Type F, G, and H riser systems. There is a general consensus that risk of failure is low and complacency is now the norm. Operators should also be encouraged to create and follow QA procedures for inspection and installation practices.

NOTE: Transocean has met these requirements on the Discoverer Enterprise. All other vessels with suspect riser (Transocean's Discoverer Deep Seas, Discoverer Spirit, Deepwater Millennium, and Deepwater Pathfinder) have had visual inspection, dimensional inspection, hardness testing, stress relieving and TSA removed on all risers in service. Magnetic particle inspection was not an in-house requirement to return to service.

New Orleans District inspected Discoverer Enterprise more often (in accordance with MOC policy). During inspections, verify that operations are being conducted in accordance with newly implemented riser operating procedures.

2. Course of Action for Industry

a) Reduce the susceptibility of suspect riser to EAC through replacement of the bolts and inserts with new design as follows:

i) Reduce the stress in the insert shoulder to an acceptable level. Possible redesign considerations are changing the thread engagement, thus placing the shoulder in compression instead of tension; increasing insert length; increasing bolt diameter; stress relieving.

ii) Reduce the hardness of the insert and bolt material to eliminate crack propagation. The original maximum hardness criteria set by the insert manufacturer was 40 HRC. The average hardness measured for 103 inserts after the incident was 37.5 HRC with 99 inserts harder than 35 HRC. Transocean has reduced the hardness criteria for its Class F riser inserts to a Rockwell Hardness below 35 HRC.

iii) Remove all TSA from insert and bolt areas and modify procedures to eliminate overspray from the manufacturing process.

iv) Increase quality assurance to eliminate cracked inserts and bolts from entering service.

NOTE: ABB Vetco has redesigned the insert and bolt combination to achieve the requirements above. Transocean is in the process of repacing all existing inserts and bolts with the new design. Replacement will begin in the 4th quarter of 2003 and will continue until all suspect risers have been modified with an estimated completion in the 4th quarter of 2004. All new risers on order will be outfitted with the new design. Once all original design HMF Type F bolts and inserts are replaced with the new design, inspection frequencies can be increased.

b) It has been suggested that the combination of subsea control fluid (hydraulic fluid) and TSA was the source of hydrogen atoms transferred to the inserts; studies are still ongoing to determine if this is the case. An investigation into a recent incident involving the failure of a kill line has produced recommendations to reduce the potential of recurrence. It is recommended that additional steps be taken to decrease the likelihood of hydraulic line leaks as follows:

i) Operator/Contractor to develop detailed inspection program of riser seals and stabs.

ii) Operator should review policies regarding operational limits and sea currents for running riser. Durations should be established for leaving riser hanging beneath vessel unlatched from wellhead.

iii) Encourage BP and other operators to participate with contractors and manufacturers to improve choke, kill and hydraulic line seal design for VIV condition.

21. PROPERTY DAMAGED:

Top drive, riser with associated lines (choke, kill, boost, hydraulic, MUX), BOP/LMRP, SBM.

NATURE OF DAMAGE:

Top drive and BOP/LMRP damaged; riser with associated lines and SBM lost.

ESTIMATED AMOUNT (TOTAL): **$8,161,008**

22. RECOMMENDATIONS TO PREVENT RECURRANCE NARRATIVE:

The riser design can be made safe by reducing any or all of the three conditions that cause EAC.

1. Course of Action for MMS

a) Send instructional memo from RSFO to Districts that requires:

- For drilling rigs with the original suspect riser design (ABB Vetco HMF Type F), the MMS District Drilling Engineer will confirm that appropriate measures are being or have been taken to mitigate EAC potential. Operators using the suspect riser would be required to satisfy the following conditions prior to approval of the APD:

- The operator will supply evidence that all inserts and bolts have been removed and inspected to the minimum criteria as follows:

i) Magnetic particle inspection of the inserts by a qualified inspector show no indications of inclusions or cracking in the inside shoulder area.

ii) Dimensional checks of threads on bolts and inserts meet manufacturer's tolerances.

iii) Average hardness test by a qualified inspector not exceed Rockwell HRC 35 or equivalent.

iv) Stress concentration areas relieved by some means to prevent surface crack initiation.

v) All TSA removed from insert area on riser flange.

- Magnetic particle inspections and dimensional checks to the abovementioned standards should be repeated at least every 6 months.

b) MMS should consider sea current data and time on bottom when considering future subsea BOP "stack hopping" departures. Risers should be pulled at least every 6 months to reduce any ongoing EAC effects.

c) Promote more frequent inspections of all riser systems via an MMS safety alert, reminding the contractors of the importance of inspecting newer riser systems (ABB Vetco HMF Type F, G, and H) more frequently. Presently, most contractors only inspect inserts/bolts on a 5-year basis.

See 20. ADDITIONAL INFORMATION for continuation of 22. RECOMMENDATIONS TO PREVENT RECURRENCE NARRATIVE

23. POSSIBLE OCS VIOLATIONS RELATED TO ACCIDENT: **YES**

24. SPECIFY VIOLATIONS DIRECTLY OR INDIRECTLY CONTRIBUTING. NARRATIVE:

E-100 - Pollutant released to the Gulf of Mexico.
G-111 - Operator/contractor failed to follow their riser inspection program contributing to the riser failure.

25. DATE OF ONSITE INVESTIGATION:

21-MAY-2003

26. ONSITE TEAM MEMBERS:

Lars Herbst / Fred Hefren / David Trocquet / Dave Emilien /

27. OPERATOR REPORT ON FILE: **YES**

28. ACCIDENT CLASSIFICATION:

MAJOR

29. ACCIDENT INVESTIGATION PANEL FORMED: **NO**

OCS REPORT:

30. DISTRICT SUPERVISOR:

Lars Herbst

APPROVED

DATE: **09-JAN-2004**

POLLUTION ATTACHMENT

1. VOLUME: GAL **1421** BBL

   YARDS LONG X YARDS WIDE

   APPEARANCE:

2. TYPE OF HYDROCARBON RELEASED:
   - [ ] OIL
   - [ ] DIESEL
   - [ ] CONDENSATE
   - [ ] HYDRAULIC
   - [ ] NATURAL GAS
   - [X] OTHER **synthetic based mud**

3. SOURCE OF HYDROCARBON RELEASED: **rig mud contained within riser and aux. lines**

4. WERE SAMPLES TAKEN? **NO**

5. WAS CLEANUP EQUIPMENT ACTIVATED? **NO**

   IF SO, TYPE:
   - [ ] SKIMMER
   - [ ] CONTAINMENT BOOM
   - [ ] ABSORPTION EQUIPMENT
   - [ ] DISPERSANTS
   - [ ] OTHER ______________________

6. ESTIMATED RECOVERY: GAL BBL

7. RESPONSE TIME: HOURS

8. IS THE POLLUTION IN THE PROXIMITY OF AN ENVIRONMENTALLY SENSITIVE AREA (CLASS I)? **NO**

9. HAS REGION OIL SPILL TASK FORCE BEEN NOTIFIED? **NO**

10. CONTACTED SHORE: **NO** IF YES, WHERE:

11. WERE ANY LIVE ANIMALS OBSERVED NEAR: **NO**

12. WERE ANY OILED OR DEAD ANIMALS OBSERVED NEAR SPILL: **NO**