OCS Report
MMS 2005-027

Investigation of Equipment Failure
Green Canyon Block 242, Well No. 1
OCS-G 21788
September 5, 2004

Gulf of Mexico
Off the Louisiana Coast

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U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Regional Office

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Glenn Woltman – Chair
Ronald Fowler
Freddie Mosely
David Nedorostek

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Gulf of Mexico OCS Regional Office

New Orleans
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Investigation and Report

Authority

On September 5, 2004, at approximately 2340 hours, an incident occurred involving equipment failure that resulted in the total loss of the surface casing. The casing was being deployed aboard Transocean Incorporated's (hereinafter referred to as "Contractor" or "Transocean Inc.") semi-submersible drilling unit *Marianas* (hereinafter referred to as the "Rig"). This incident occurred during the drilling of Well No. 1 for Nexen Petroleum U.S.A. Inc. (hereinafter referred to as "Operator" or "Nexen") on Lease OCS-G 21788, Green Canyon Block 242, in the Gulf of Mexico, offshore the State of Louisiana.

Pursuant to Section 208, Subsection 22 (d), (e), and (f), of the Outer Continental Shelf (OCS) Lands Act, as amended in 1978, and Department of the Interior Regulations 30 CFR 250, Minerals Management Service (MMS) has investigated and prepared a public report of this accident. By memorandum dated September 21, 2004, the following personnel were named to the investigative panel:

Glenn R. Woltman, Chairman – Office of Safety Management, GOM OCS Region
David Nedorostek – Accident Investigation Board, Office of Offshore Regulatory Programs, HQ
Ronald Lee Fowler – Lake Jackson District, Field Operations, GOM OCS Region
Freddie Mosely – Houma District, Field Operations, GOM OCS Region

Procedures

On the morning of September 6, 2004, District personnel from the Department of the Interior, Minerals Management Service (MMS) office in Houma, Louisiana, received preliminary statements on the incident from the Operator, along with the current status of recovery efforts. On September 9, 2004, District personnel traveled to the Rig and took written statements and pictures.

On September 23, 2004, members of the investigative panel received a written statement from the Operator as well as preliminary information gathered by the Houma District office. On September 28, 2004, panel members requested various kinds of information and data from the Operator to prepare the panel investigation report. A second request for data was sent to the Operator on November 1, 2004. Panel members held a telephone conversation on November 4, 2004, with Stress Engineering regarding the status of their metallurgical analysis report. Their report was forwarded to panel members by the Operator on November 9, 2004. A follow-up meeting with Stress Engineering was held on November 19, 2004, in Houston, Texas.

During the week of December 6, 2004, interviews were conducted with personnel from Nexen Petroleum USA in New Orleans, Louisiana; Offshore Energy Services at their office in Lafayette; and with XL Systems at their Beaumont, Texas, facility. Interviews were conducted with the *Marianas* personnel in New Orleans on December 14, 2004.

In addition to the interviews, other information was gathered at various times from a variety of sources. This information included the following reports, statements, and publications:

- Daily Contractor Drilling Reports, August 30, 2004 – September 9, 2004;
- Operator's Drilling Plan, OCS-G 21788 Well No. 1 and No. 2;
- Operator's written account of the incident, September 5, 2004;
- Operator's equipment and procedural changes to well plan after the incident;
- Pictures of equipment, layout, and casing;
- MMS interviews with Operator drilling management and engineering, and operational personnel, Contractor drilling management, operational supervisors, and operational personnel;
- Stress Engineering Structural Analysis Report;

- *Marianas* Daily Think plan;
- *Marianas* Task Specific Think Procedure for running casing;
- Offshore Energy Services (OES) Job Safety Analysis for rigging and running casing;
- XL Systems JSA for running 22-inch casing;
- Transocean's Marine and Technical Report for September 4-5, 2004;
- NOAA Gulf of Mexico Buoy Data;
- OTC Paper 14263, "New Revision of Drilling Riser Recommended Practice" (API RP 16Q);
- "Dynamic Loading of Drill Pipe During Tripping" *Journal of Petroleum Technology*, August 1988 by Arthur Lubinski;
- American Association of Drilling Engineers Paper 01-NC-HO-05 entitled "Deepwater Landing String Design" on March 27, 2001;
- "Evaluation of Heave-Induced Dynamic Loading on Deepwater Landing Strings" (IADC /SPE Paper No. 87152)
- MMS Technical Information Management System Well Data

The panel members met and discussed the evidence numerous times throughout the investigation and, after having considered all of the information available, produced this report.

Introduction

Background

Lease OCS-G 21788 covers approximately 5,760 acres and is located in Green Canyon Block 242 (GC 242), Gulf of Mexico, off the Louisiana Coast *(for lease location, see Attachment 1).* The lease was issued effective July 1, 2003. Nexen Petroleum Offshore U.S.A. Inc. is a 100-percent interest leaseholder and the Designated Operator to a depth of 25,000 feet true vertical depth (TVD), with British Petroleum Exploration and Production Company owning 100-percent interest below 25,000 feet TVD.

On November 25, 2003, the Application for Permit to Drill (APD) the exploratory well was approved by the Minerals Management Service (MMS); this application was subsequently modified and approved by MMS on July 15, 2004. Nexen Petroleum U.S.A. Inc. contracted Transocean Inc. to conduct the drilling operations of the Green Canyon 242 (OCS-G 21788) Well No. 1. The semi-submersible Rig *Marianas*, owned and operated by Transocean Inc., was moved and moored onto the well location on August 30, 2004. Exploratory drilling activities then commenced from the well's surface location at Lat 27 deg 44' 05.190" N and Long 90 deg 50' 14.043" W.

Brief Description, Equipment Failure on Drilling Rig

In September 2004, the Rig *Marianas* was conducting exploratory drilling operations on Green Canyon Block 242 Well No.1. The well had been spudded at 0930 hours on August 31, 2004. By September 5, 2004, the surface hole had been drilled riser-less, and 22-inch casing was run and stabbed into the wellhead. The operation at the ocean floor was monitored by a remote operated vessel (ROV). The casing tools were rigged down, an inner string of 6-5/8 inch (drill pipe) was run to 150 feet above the shoe of the 22-inch casing. The top stand of the 6-5/8 inch (drill pipe) landing string was picked up, along with the cross-over to the 5-1/2 inch pup joint on the top of the FMC running tool. The wellhead was lowered to the water line and the casing filled with seawater through the landing string by using the top drive. After getting seawater returns back through the 2-inch valve on top of the wellhead, the valve was closed and a bull plug was installed.

The casing volume between the cement stinger and the float shoe was displaced with 12.5 pounds-per-gallon (ppg) water-based drilling fluid. The inner string was then filled with fluid, the top drive was broken out, and the landing string was lowered to the rotary table. The pipe slips were set. The elevators were unlatched to pick up the second stand of pipe. At 2340 hours, the pipe and slips jumped in the rotary table some 3 feet. The slips released, and the top joint of the landing string passed the slips on the way down and fell through the rotary table. The entire casing/landing string assembly then fell unabated to the seafloor. Some of the casing/inner string fell onto the ROV. After the incident, the damaged ROV was recovered along with ten (10) pieces of pipe.

Findings

Preliminary Activities — Well Plan

The GC 242 Exploratory Well No. 1 location sits in 2,846 feet of water. In July 2004, the Operator's amended APD was approved by MMS, and the Contractor's Rig was towed and positioned over the proposed well location.

Exploration of this play of sands in the area commenced in late 2000. The initial well was drilled vertically to a deep sand and was plugged. Subsequent side-track drilling during 2001 defined the play and confirmed the oil/water contact depth; the fourth side-track well was drilled to develop productive sands in the area. Nexen had already drilled a directional development well designed to evaluate the western extent of the prospect. The well had been temporarily abandoned. The subject well, Well No. 1, was being drilled as a directional exploratory well designed to penetrate a number of deep sands to continue evaluation of these deep plays.

Drilling Activities — Spud to Time of Incident

(From drilling morning reports, interviews, and written statements)

30 August –03 September - Moved rig over new location. Picked up bottomhole assembly (BHA). Ran in hole with landing string (6-5/8 inch drill pipe) and tagged mudline at 2,934 feet. Jetted in for 36-inch casing. The 36-inch casing and wellhead were run. Drilled down. Ran and set the 26-inch casing at 4,025 feet. Continued to drill down to surface casing setting depth.

04 September –

0000 hrs-0350 hrs – Drilled to total depth of 6,090 feet.

0350 hrs-1430 hrs - Back reamed with drilling fluid to 26-inch shoe at 4,025 feet. Had excessive gumbo at wellhead while back reaming.

1430 **hrs-1530 hrs –** Pulled BHA out of wellhead. Washed around low-pressure wellhead (LPWH) and 36-inch casing with seawater through the 24-inch drill bit to disperse the excess gumbo accumulated on the seafloor.

***1530* hrs-2400 hrs –** Finished pulling out of hole with BHA. Laid down reamer. Rigged up to run 22-inch casing. Picked up 22-inch shoe joint.

05 September –

***0000* hrs-0600 hrs –** Ran 39 joints of 22-inch casing.

***0600* hrs-0700 hrs –** Held safety stand-down meeting. Apparently, the traveling block hit the basket door and broke the door. Because of safety concerns, the operation was suspended. Discussed near miss with all personnel involved in casing running operation.

***0700* hrs-1300 hrs –** Continuing to run 22-inch casing. Located 22-inch shoe with ROV, positioned 22-inch casing shoe above the 36-inch LPWH. String weight 590k. Stabbed 22-inch shoe into wellhead. Total casing run with FMC 18-3/4 inch wellhead is 3,070.08 feet. Planned casing shoe was to be set at 5,999.08 feet measured depth (MD).

***1300* hrs-1800 hrs –** Landed casing in slips and rigged down Offshore Energy casing equipment.

***1800-2030 hrs* -** Rigged up 6-5/8 inch handling tools and prepared rig floor to run inner cementing string. Ran 6-5/8 inch drill string. Finished tripping in hole with inner cement stinger (diverter tool, 15-foot pup, and 30 stands of 6-5/8 inch drill pipe). Rigged down inner string running equipment.

***2030-2130 hrs* –** Picked-up 18-¾ inch well head joint. Made up a 5-1/2 inch by 6-5/8 inch full hole crossover. Made up the drill pipe stinger to the inner string. Made up the 18-¾ inch wellhead connection to the 22-inch string in the rotary.

***2130-2230 hrs* –** Rig down casing tools from rig floor and made up the first stand of 6-5/8 inch landing string and cross-over to the 5-1/2-inch pup joint in the top of the FMC running tool.

***2230- 2330 hrs* -** Lowered wellhead to the water line and filled casing with seawater by using the top drive. After getting water returns back through the 2-inch valve on top of the wellhead, closed the valve and installed the bull plug. Lined the pump up on 12.5-ppg water-base drilling fluid and displaced with approximately 175 barrels in the inner string and the 22-inch casing from the bottom of the cement stringer to the float shoe.

***2330-0000 hrs* -** After displacing drilling fluid, broke out the top drive. Lowered the landing string down 15 feet to the rotary and set slips. Unlatched the elevators and started after the second stand. At 2340 hours, the pipe and slips jumped in the rotary table 3 feet. The top joint of the landing string passed through the slips on the way down and fell through the rotary. The slips fell back in the rotary.

Note: The ROV was monitoring the casing and the 36-inch wellhead prior to and when the above occurred, and Oceaneering International Inc. recorded the operation on video tape. After a review of the Oceaneering tape, metallurgical experts working for the Operator surmised that the 22-inch casing parted as it was falling to the seafloor. The top section of casing/wellhead fell over, disabling the ROV.

06 September -

00:15 hrs - 06:45 hrs - Nexen Petroleum USA Inc. management was notified of incident. Discussed options available with Oceaneering to send out another Intervention unit. Decided to release to shore all service personnel from the Rig not needed for fishing operation. Discussed plans to recover ROV, FMC running tool, and to fish casing out of wellbore. Planned to get materials and tools ready for fishing 6-5/8 inch drill pipe in 26-inch hole and fishing 22-inch casing in 26-inch hole.

The Incident

At the time of the incident, the casing string and the internal "stinger" had just been made up and the lower end of the assembly had been lowered into the 36-inch wellhead housing that stood up approximately 10 feet above the mudline. The upper end of the 22-inch casing was reportedly 10 feet below the water line at that time. Approximately 244 feet of the 22-inch casing was thus below the wellhead housing. Weld-on bow type centralizers had been placed over the bottom few joints of casing. After personnel made up the 22-inch casing and the inner cementing string, filled both strings with seawater and displaced weighted drilling fluid, the assembly was lowered into the well with the first stand of 6-5/8 inch drill pipe. The first stand had originally been set with the box of the top joint approximately 15 feet above the rig floor, while the casing assembly was filled with seawater and the 12.5-ppg drilling fluid. The stand was then lowered and set in the slips, with the upper box approximately 3 feet above the drill floor. There was no continuous recording of data from the weight indicator on the rig; however, according to testimony from the Contractor's driller, the Martin Decker load on the "hook" (inclusive of the casing and landing string, and wellhead assembly) was about 660,000 pounds just prior to the incident. The elevators were unlatched to pick up the second stand of pipe. The traveling block was being raised to latch the second stand of drill pipe. During this operation, the slips rattled and, suddenly, the upper end of the first stand of drill pipe and the slips jumped 3 feet. When the slips released, the first stand of 6-5/8 inch drill pipe passed the slips on the way down and fell through the rotary table. The casing, inner cementing string, and first stand fell to the ocean floor. Most of the casing (approximately 2,400 feet of casing) was scattered around the wellhead in various lengths on the ocean floor, with approximately 650 feet (15 joints) in the wellbore. The well had 12.5-ppg drilling fluid in the hole, holding back a pore pressure of 9.5 ppg. Thus, the well did not flow back fluids. *(See casing configuration schematic, Attachment No. 2.)* The falling casing damaged and pinned the ROV on bottom. An intervention vessel with an ROV was located and mobilized to the location. This ROV verified that the well was not flowing. Recovery options and well salvage activities were discussed.

Testimony indicated that the casing crew had rigged down their equipment and departed the rig floor. The *Marianas* crew was in the process of picking up and running the landing string. Two of the Contractor's floor hands were near the rotary table, making up the drill pipe *(Attachment No. 3)*. The driller was at his console, operating the draw works and monitoring the load indicator. The Operator's representative was standing near the driller's console.

According to testimony provided by the Operator's representative and the Contractor's individuals on the drill floor, two (2) distinct audible sounds were heard, corresponding to two (2) above-the-rotary pipe and slip movements that were noted. The first audible sound was consistent with a movement in the drill pipe (which had been set in the slips) and with the rattling of the rotary slip handles. The next audible sound was consistent with the cessation of the downward motion of the drill pipe, as the slips re-engaged momentarily and then "kicked" out of the master rotary bushing, allowing the drill pipe and casing to fall unabated to the seafloor.

Testimony from the Contractor's roustabout located on a work boat suggested that, simultaneously to running and landing the surface casing, the Contractor was in the process of off-loading three (3) joints of riser pipe (total weight approximately 200,000 pounds). This riser pipe was being off-loaded on the port side to the riser bays. The third joint of pipe was being prepared to be off-loaded. Spreader bars with slings attached were in a slack-off position (3-5 feet of slack). The Pedestal Crane Operator was prepared to hoist the riser to the Rig. According to testimony, all slack was suddenly and temporarily lost, with all slings in a tension position. Almost immediately thereafter, the slings returned to the previous slack-off position. According to testimony, the Contractor's roustabout glanced over to the Rig after the slings returned to their initial position, and reported that he witnessed the drill pipe falling into the sea from the rig floor.

Weather Conditions

At the time of the incident, the air temperature was about 80 degrees Fahrenheit. The barometric pressure was 1009 m Bars. The wind direction and speed were north-northeast (approximately 30 degrees) at approximately 10-12 knots. The seas were relatively calm, running out of the north-northeast with a wave height of 1 foot. Swells were running at 2 feet. The wave period at the time of the incident was 5 seconds. Wave height is the measurement from mean sea level (MSL) to either the crest (top) of the wave or trough (bottom) of the wave. Under these weather conditions, the Rig was experiencing a pitch of 0.20 degrees and a roll of 0.20 degrees and a heave of 0.20 feet. Pitch is the pivotal movement up and down of the rig along the centerline axis from the bow to the stern. (When the bow goes up, the stern goes down). Roll is the pivotal movement up and down of the rig along the centerline axis from port to starboard sides. (When the port side is up, the starboard side is down). The Rig also had a heave of approximately 2.4 inches. Heave is the vertical movement up or down of the rig along the surface of the water. Doppler water current speed data were not available, as the meter was not functioning.

Buoy data obtained from the National Oceanic and Atmospheric Administration some 180 nautical miles south of Southwest Pass, Louisiana, the closest station to the block upon which the incident occurred, confirmed the above information provided by the Rig.

Post-incident Events

An Oceaneering intervention vessel was dispatched to the location the following day. The seafloor debris field was mapped. Casing was extending some 120 feet above the mudline. The casing was cut off 10 feet above the mudline, and laid down on the seabed. One joint of casing and a torn piece of casing were recovered from the wellhead, and the drill pipe attached to the FMC running tool was recovered. The recovered material was delivered to the Stress Engineering Services (SES) Office in Houston, Texas, for metallurgical analysis. The FMC wellhead housing was not recovered. Futile attempts were made to salvage the well and recover the pipe inside the wellbore. Subsequently, the well was plugged and abandoned, and the Rig was moved to drill an offset well. The replacement well was some 400 feet to the east and just south of the initial well. The twin well was drilled in similar water depths.

Computer models have been run by the Contractor on the basis of the semi-submersible *Marianas'* draft requirements at various topsides loading conditions. A sudden loss of 660,000 pounds of load (which represents the total loss of the landing string and casing assembly) would have changed the draft of the vessel approximately 1 foot. The resulting motion on the vessel would be a "spring effect" in the upward direction. As the vessel moved up from this loss of load, additional axial loads (to exceed the yield of the pipe) could have been achieved with only 8.7 inches of stretch in the drill pipe, according to SES personnel. On the basis of studies conducted by SES, audible sounds (accompanying the initiation of plastic deformation) would have likely been heard with about 870,000 pounds of load. Considering the buoyed weight of the casing and assembly prior to the incident, any extraneous dynamic load of only 200,000 - 300,000 pounds would have initiated deformation and the ultimate slip crushing of the drill pipe.

Operator Changes to Subsequent Drilling Project

The Operator successfully re-spudded and ran and cemented 22-inch casing on Well No. 2, which was intended as the twin replacement well to Well No. 1. Several recommendations resulting from the Operator's initial investigation of the failed casing incident had been incorporated in the well plans for the replacement well, including

> (1) upgrading the casing wall thickness from 0.75 inch by 1.00-inch mixed string to a full string of 1.00-inch wall thickness casing, thereby eliminating the cross-over joints, and
> (2) shortening the 22-inch surface casing length by some 250 feet, resulting in the 22-inch casing hanging above rather than below the 26-inch housing at the mudline, and
> (3) changing the casing connection from a threaded to a weld-on connector, and
> (4) changing the running string for the 22-inch casing from a nominal 6-5/8 inch, 27.7 pound-per-foot drill pipe to a 6-5/8 inch, 34 pound-per-foot drill pipe, and
> (5) using a set of slips with a longer contact length, thereby reducing the possibility of slip-crushing the pipe.

Stress Engineering Report

After receipt of pieces of the retrieved assembly , Stress Engineering Services commenced examination and testing of the samples in hopes of determining the cause(s) of the observed failure. A total of 10 pieces of drill pipe and casing were made available to SES. Specifically, SES was retained to (a) evaluate the properties of the casing and drill pipe, (b) use industry equations to predict the crushing load of the drill pipe, (c) perform visual inspection of the casing box and pin connections, (d) perform a bending test on the casing to predict the bending moments that would have been generated in the casing assembly by water currents of various magnitudes, and to (e) perform dimensional checks of the master bushing, split bowl, and slips involved in the incident.

The results of the analyses, from static current loading conditions alone, would indicate that the largest equivalent stresses occur in the region below the rotary in the drill pipe. These stresses are a consequence of the tension from the weight of the string and the induced bending moment from the static current profiles. The current profile was assumed to have a constant velocity through the water depth, with the vessel assumed to be directly over the wellhead and with no dynamic motion of the drilling vessel included. No sea state was defined. Testing and analyses by SES offered the following findings:

- Visual inspection of the top joint of drill pipe from the first stand *(Attachment 4)* contained an area of "*severe crushing damage, obviously caused by the action of the slips on the pipe.*" The crushing damage, with deep, slip teeth marks, was approximately 16 inches long and extended outward from 41-1/2 inches to 57-1/2 inches from the outer end of the box. Another area of deformation (about 9-1/2 inches in length) extended from 32 inches to 41-1/2 inches from the end of the box, apparently caused by the slips sliding along the pipe. A second set of slip teeth marks on the crushed pipe was found at a location approximately 10.9 feet below the heavily damaged area of pipe. SES personnel concluded that the pipe had been plastically deformed at the level of the second set of slip marks.

  Note: Testimony revealed that the Rig floor crew did initially set the first stand of the drill pipe in the slips, placing the outer box end of this stand about 10-15 feet above the rotary to allow personnel to "break-out" the top drive. Elevators were then attached, and the pipe picked up to pull the slips and to lower the drill pipe nearer the end of the outer box. Slips were again set and the elevator released to go after the second stand of drill pipe.

- Although the ROV was damaged in the incident, video recordings taken by the ROV at the time of the incident were still intact. Real-time detailed examination of the ROV video revealed that (a) the final few feet of casing assembly that entered the well appeared to have been run at a velocity of less than 1 foot per second, (b) the casing assembly appeared to be fully stopped for more than 30 seconds at the time of the final failure, and (c) at the end of the 30-second pause, the casing assembly suddenly fell approximately 6 inches and then stopped momentarily before the final failure of the entire assembly.

- A visual inspection of the slip bowl and master rotary bushing indicated that the master bushing was in good shape, with dimensions that were within allowable tolerances. However, the angle of the taper area of the slip bowls had been worn, suggesting that some loss of support for the slips in the contact area could have been realized. A "crush test" performed on a section from the same joint of drill pipe *(Attachments 5 & 6)* that had been damaged in the incident (using the master bushing and slip bowl from the rig) suggested that 870,000 pounds of load would initiate plastic deformation. The final failure of the drill pipe was noted to have occurred at 884,000 pounds.

- *Little to no damage was found on the cross-over sub* that supported the casing assembly at the time of the incident. *No evidence of metallurgical or manufacturing defects was noted on the hinge pins on the slips or on the slip dies.*

- Observations of field samples appeared to show that the casing and drill pipe failures likely took place primarily by bending as the casing assembly was falling downward (*Attachment 7*) after being released by the slips. Visual evidence showed that a joint of 22-inch by 0.75-inch casing had suffered significant deformation by bending *(Attachment 8).* Three joints of drill pipe that were found inside one field sample had clearly failed by bending at both their upper and lower ends. Further, the box connection at the upper end of the field sample was found to contain the pin end of the next higher casing joint. With the estimated total buoyed weight only 53 percent of the measured axial yield load of the drill pipe body, and only 17 percent of the yield load of the XLF connection in the 1-inch thick casing, and only 34 percent of the minimum yield load of the drill pipe tool joints, SES personnel suggest that equipment failure on Well No. 1 "*was not likely due to axial tensile loads.*"

Note: Nevertheless, this statement by SES does not fully explain the fact that equipment failure did occur, and that certain extraneous sources of dynamic loads longitudinally or laterally must have existed to cause pipe failure.

- Given the acceptable material property values of the failed drill pipe, the high calculated values of the slip-crushing force, the acceptable dimensional measurement of the master bushing and slip bowl, the results of the slip-crushing test, and the fact that the equipment failed, the axial tensile force required to crush the drill pipe in the field must have been as large as the crush force (884,000 pounds) measured in the lab test. The static weight of the casing and drill pipe stinger assembly alone was too low to account for the damage seen in the drill pipe.

- SES experts did evaluate other sources of dynamic axial loads, above those caused by the static hanging weight, which could have initiated the failure.

  a. These loads could have been *dynamically induced and generated by sudden starts or stops of the casing assembly, such as "kicking-in" the slips while the casing is still in motion."* SES experts determined that these loading conditions could have been achieved from suddenly stopping the casing assembly from a velocity of 1 foot per second. ROV video recording, however, of the operation just prior to the failure does not support evidence of a resulting increase or decrease in the apparent running velocity of the casing assembly.

  b. An obstruction within the wellhead housing could have supported a significant portion of the weight of the casing assembly for a brief period. Any subsequent sudden release of this assembly from such an obstruction could have produced dynamic loads sufficient to have caused the failure. Calculations of pipe stretch necessary to induce axial loads necessary to exceed the yield on the landing string would be 8.7 inches.

c. Dynamic loads resulting from a sudden failure of a defective XLF connection could account for the sudden upward movement of the drill pipe and its release from the slips that were observed. The failure of a casing connection, however, would not account for the slip crushing damage seen in the drill pipe.

- *Side loading may have played a role in the observed failure, which would have resulted in bending stresses in the casing assembly generated by water current .* Unfortunately, no acoustic Doppler current profile (ADCP) monitoring system was available to confirm the speed of the water currents, since the meter on the Rig was malfunctioning at the time of the incident. Stress Engineering did set up a test to assess potential effects of current-induced bending forces on the casing utilized, and a sample of casing was exposed to a bending moment of 1,500,000 foot-pounds. Plots were made of pipe body strain versus bending moment and of the connection displacement versus bending moment. Very little permanent deformation of either the pipe body or connection was produced at these levels. Calculations do suggest that the average water current of 1.8 knots would have been required to produce a bending moment of 1,500,000 foot-pounds in the casing. Only 1.4 knots of current would have been necessary to produce the yield stress of the drill pipe at the top of the first stand of drill pipe. Reports from work boats in the area suggest that the currents at the time of the incident were much less than 1 knot. Regardless of the current speed, it is reasonable to assume that the top of the first stand of drill pipe would have failed preferentially ahead of any failure of the casing.

Technical Challenges in Open Water Drilling Operations

Technical reference material has been sourced to understand more fully the challenges in open water drilling operations. Three recent publications are referenced in this panel report.

1) Reference is made to a paper presented at the International Association of Drilling Contractors (IADC) and Society of Petroleum Engineers (SPE) Conference in Dallas during March 2004, “Evaluation of Heave-Induced Dynamic Loading on Deepwater Landing Strings,” which explores static tensile loads approaching the capacity of today’s landing strings. As reviewed in the paper, dynamic loads caused by vessel heave are imparted to the drill string when it is sitting stationary in the slips and when suspended from the elevators at loads greater than what the motion compensator can absorb. This

phenomenon, as explained, is similar to the dynamic loading experienced by drill pipe during tripping, as investigated by Arthur Lubinski, per the article “Dynamic Loading of Drill Pipe During Tripping,” *Journal of Petroleum Technology*, August 1988. Mr. Lubinski considered impulse excitation caused by adding a stand of drill pipe and then setting the slips. He indicates that dynamic loading from slip operation can easily reach as high as 100,000 pounds, as the top of the drill string experiences a sudden change in velocity within a short period of time before reaching constant tripping speed. The heave-induced drill string vibration considered in deepwater landing strings is mainly low-frequency persistent excitation as is the nature of ocean swells.

2) The issue of slip-crushing capacity caused by large loads is discussed in findings presented in American Association of Drilling Engineers Paper 01-NC-HO-05, “Deepwater Landing String Design,” on March 27, 2001. In this paper, the author explains that tension is the primary design consideration for landing string design. Increased minimum tube wall thickness is required to provide sufficient slip-crushing capacity because of large loads. However, make-up torque is a significant issue because of combined loading. The ability of slips to transfer an axial load to a transverse load is the premise behind slip crushing. There are three verifiable factors affecting the slip-crushing calculation and one variable factor. Drill pipe dimensions, slips dimensions, and hook load are the verifiable factors affecting slip crushing. The coefficient of friction between the slips and the bowl is the variable factor. Normally, a slip with a longer contact length to increase slip-crushing capacity is desired. Additionally, the slips and bowl should be inspected for wear in accordance with API Spec 8A to ensure that the slip crushing load is distributed over the contact length. An effort should be made to minimize the number of cross-overs in the landing string, since the weak point of a cross-over is often the connection. Handling tools, such as bails, slips, master bushings, elevators, spiders, and top drive stem assemblies, encounter the highest loads. Often they are not “purpose qualified.” Visual, dimensional, and flaw-detecting inspections should be performed to verify load capacity and detect flaws. Elevators, spiders, and bails should be pull tested to the maximum anticipated load, if these components will be subjected to loads exceeding 75 percent of their rated capacity.

3) Per findings in the Offshore Technology Conference Paper 14263, “New Revision of Drilling Riser Recommended Practice” (API RP 16Q), operational difficulties can be

experienced in the use of a marine drilling riser and/or in running casing with currents exceeding about two knots. These problems include high drag and the potential that the riser or casing might experience high bending stresses and vortex-induced vibrations. Large displacements with possible moon pool clashing and bending stresses can result during this operation, especially when the casing is rigidly hung in the slips. The author suggested that the limiting current and wave environments should be identified.

Review of Pre-Job Safety Analysis – Safety Meeting

A Job Safety Analysis (JSA) was completed prior to the task. This report identified potential hazards, slips, and falls. The JSA, however, did not address various environmental parameters, such as the water current speed versus bending moment loading, and other open water conditions that would prevent the running of casing. Stand down conditions were not reviewed.

Note: Albeit, even if the stand down conditions had been noted and discussed prior to running the casing, acoustical water current meter information was not available because of the malfunction of the current meter at the time that casing was run.

Testimony from the casing vendor indicated that many major oil and gas companies will perform front-end stress analysis at various water current conditions as a pre-requisite in open water drilling operations. Furthermore, testimony from the casing vendor suggested that most operators did not run more casing than the water depth. Review of MMS data would suggest that on 530 wells where water depths exceeded 1,500 feet, operators did run more casing than the water depth. (This corresponds to 37% of the 1,416 open water projects where water depths exceeded 1,500 feet.)

Conclusions

The Accident

After a review of the information obtained during the investigation, it is the conclusion of this panel that on September 5, 2004, at approximately 2340 hours, while picking up the second stand of the 6-5/8 inch (drill pipe) landing string during the deployment process to run surface casing in open waters, with the upper end of the first stand of drill pipe hanging in the rotary slips, and the full weight of the entire string of 22-inch casing and subsea wellhead below, the slips suddenly jumped twice. The second jump was nearly 3 feet, thereby releasing the drill pipe from the slips and allowing the pipe with inner string (and casing below) to fall through the rotary to the seafloor.

The panel's review of the failure sequence as observed on the drill floor involved the two (2) distinct audible sounds heard, corresponding to the two (2) above-the-rotary pipe and slip movements noted.

The first audible sound was consistent with a movement in the drill pipe (which had been set in the slips), and with the rattling of the rotary slip handles. This noise could have been caused by the pipe wall splitting longitudinally (slip crushing of drill pipe). Audible sounds (per laboratory tests conducted by SES accompanying the initiation of plastic deformation) would have likely been heard with about 870,000 pounds of load. Loss of contact between the slips and the drill pipe caused by the initiation of plastic deformation would have allowed the drill pipe to move downward (as revealed with real-time analysis of the ROV video). In this incident, the length of the second area of plastic deformation on the outer end of the drill pipe near the box end was approximately 9-1/2 inches. The slips apparently did re-engage an area of larger diameter drill pipe (in dynamic fashion) after the initial movement downward, as the next audible sound was heard. This second noise is likely consistent with the secondary failure resulting in the loss of the casing assembly.

Cause of Incident

No definitive root cause(s) can be confirmed to explain the observed failure. Peripheral data such as weight indicator information were not available, and weight loss or gains on the "hook" cannot be assessed for induced dynamic loading. Loop current information at the time of the incident was not measured. The acoustic doppler current profiler (ADCP) monitoring system was not functioning. These two pieces of data would have provided insight on the nature of the failure.

Probable Cause

The failure of the drill pipe at the rotary slips is believed to be the probable cause of this incident. Initiation of plastic deformation leading to the pipe collapse, coupled with the worn angle of the taper area of the slip bowls, likely lessened the competence of the slips to maintain their contact with the drill pipe. This loss of contact would have allowed the drill pipe to move downward. When the downward motion of the drill pipe suddenly stopped as the slips re-engaged, induced loads would have been exerted dynamically in an upward direction to the rotary. These upward forces could have "kicked" the slips upward and out of the master rotary bushing, which allowed the drill pipe to fall unabated to the seafloor.

Possible lateral deflection on the casing string and/or induced longitudinal forces on the landing string at the time of the incident are not known. Environmental factors certainly could have imparted forces on the assembly leading to the initiation of the slip crushing incident. The casing assembly was hanging in the slips and motion compensation was not functional. The landing string/casing assembly was laterally pinned top and bottom. *(Attachment 9 shows the parted and pinned casing below the LPWH housing at the mudline.)*

Possible Contributing Causes

It is possible that other factors contributed to the accident.

(1) Casing Hanging Below Mudline Housing -

It is possible that running the 22-inch casing below the mudline, thus pinning the casing below the 26-inch housing while the cement stinger was run, may have contributed to the cause of this incident. With the end of the 22-inch casing setting below the 26-inch housing, and the top section of the first stand of the landing string set in the slips at the rotary table, a no-free end boundary condition could have introduced

- dynamic side load from loop currents that could have caused failure at one or more casing connectors;
- dynamic longitudinal loads from the sudden release of the assembly, which may have hung on any obstruction in the wellhead housing that could have supported a significant portion of the weight of the casing assembly for a brief period of time; and
- axial loads required to exceed the yield of the pipe, such as would have been the case if an unusual heave had occurred, impacting the semi-submersible rig.

(2) Marginal Conditions During Casing Landing –

It is possible that the nominal 6-5/8 inch, 27.7 pound-per-foot drill pipe used to land the 22-inch casing was marginal, given expected sea states at the time and that the rotary slips were somewhat worn.

- Visual inspection of the top joint of drill pipe from the first stand contained an area of severe crushing damage, obviously caused by the action of the slips.
- Inspection of the master rotary bushing and slip bowl after the incident indicated that the angle of the taper area of the slip bowls had been worn, and that some loss of support for the slips in the contact area could have been realized.
- The slips and bowl apparently were not pre-use inspected for wear in accordance with API Spec 8A to ensure that the slip-crushing load was distributed over the contact length. No record of visual, dimensional, and flaw-detecting inspections were available to verify load capacity or detect flaws. No record of pull testing of the elevators, spiders, and bails was available.

(3) Unspecified Stand-down Conditions–

Stand-down conditions for aborting the running of casing were not pre-identified. Limiting current and wave environments for the casing and landing string design were not noted on the well plan. The ADCP monitoring system was not functional at the time of the incident. Load indicator information was not graphically recorded on the rig during the deployment of casing, possibly obscuring sudden or unexpected conditions that would have alerted personnel. The drillers' console only revealed real-time information.

The "Change Analysis" technique was used in this panel review to support our evaluation and to determine possible root cause(s). The panel believes that the changes implemented by the Operator on the replacement well positively influenced the success of the tasks that had previously failed. Three changes specifically addressed possible marginal conditions during the deepwater casing landing operations (whether a defined configuration of drill pipe and casing can be successfully landed, given the expected sea states), and these three changes provided additional design margins so that the Operator could go forth with confidence:

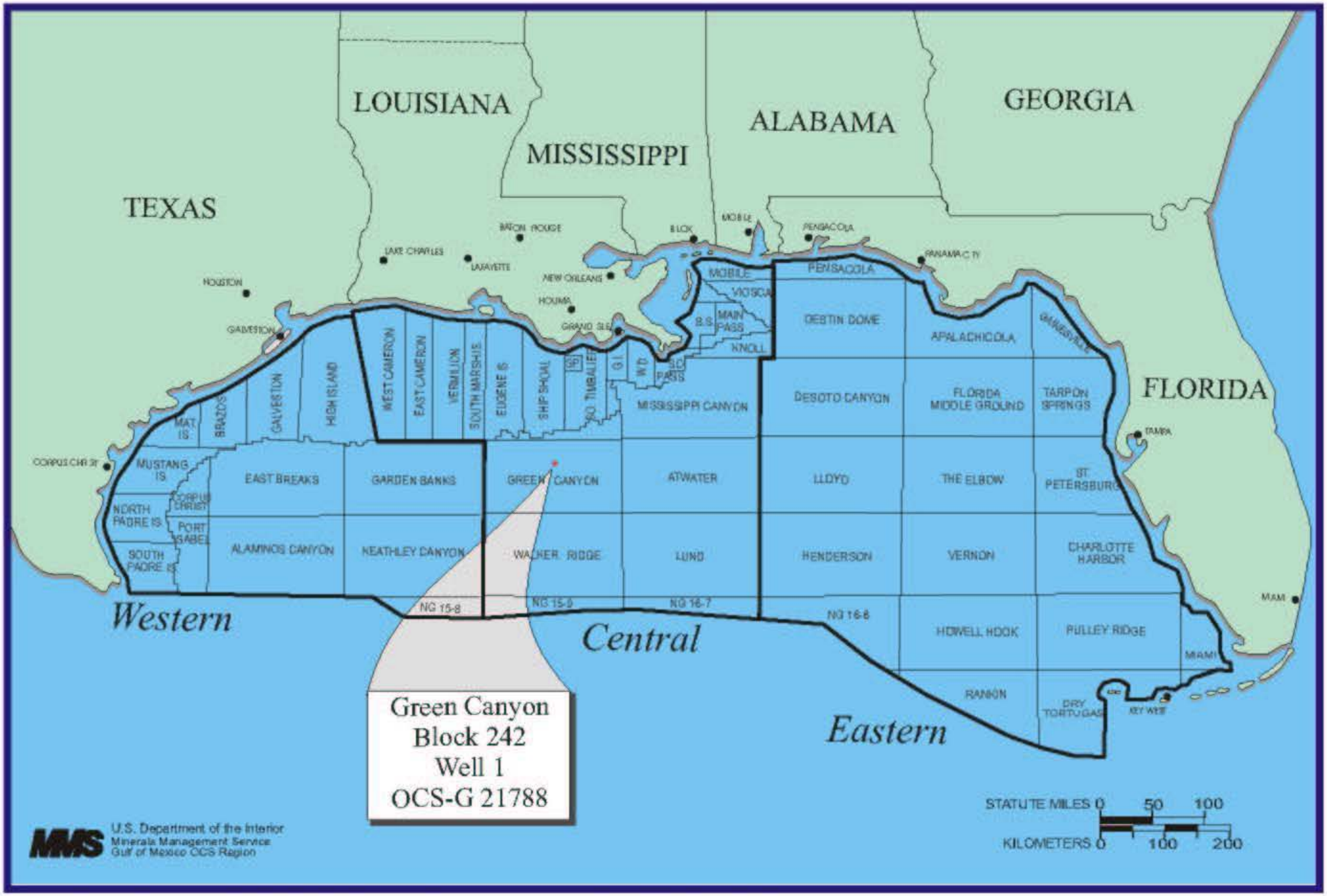
1. Shortening the 22-inch surface casing length, resulting in the 22-inch casing hanging above rather than below the 26- inch housing at the mudline, and
2. Changing the running string for the 22-inch casing from a nominal 6-5/8 inch, 27.7 pound-per-foot drill pipe to a 6-5/8 inch, 34 pound-per-foot drill pipe, and
3. Using a set of slips with a longer contact length, thereby increasing the slip-crushing capacity of the drill pipe.

Recommendations

It is recommended that MMS issue a Safety Alert to describe the incident briefly. As related to running and landing casing in open water operations, the industry should be aware of (1) special considerations to predict dynamic loading conditions, and (2) limiting current and wave environments prior to running and landing casing.

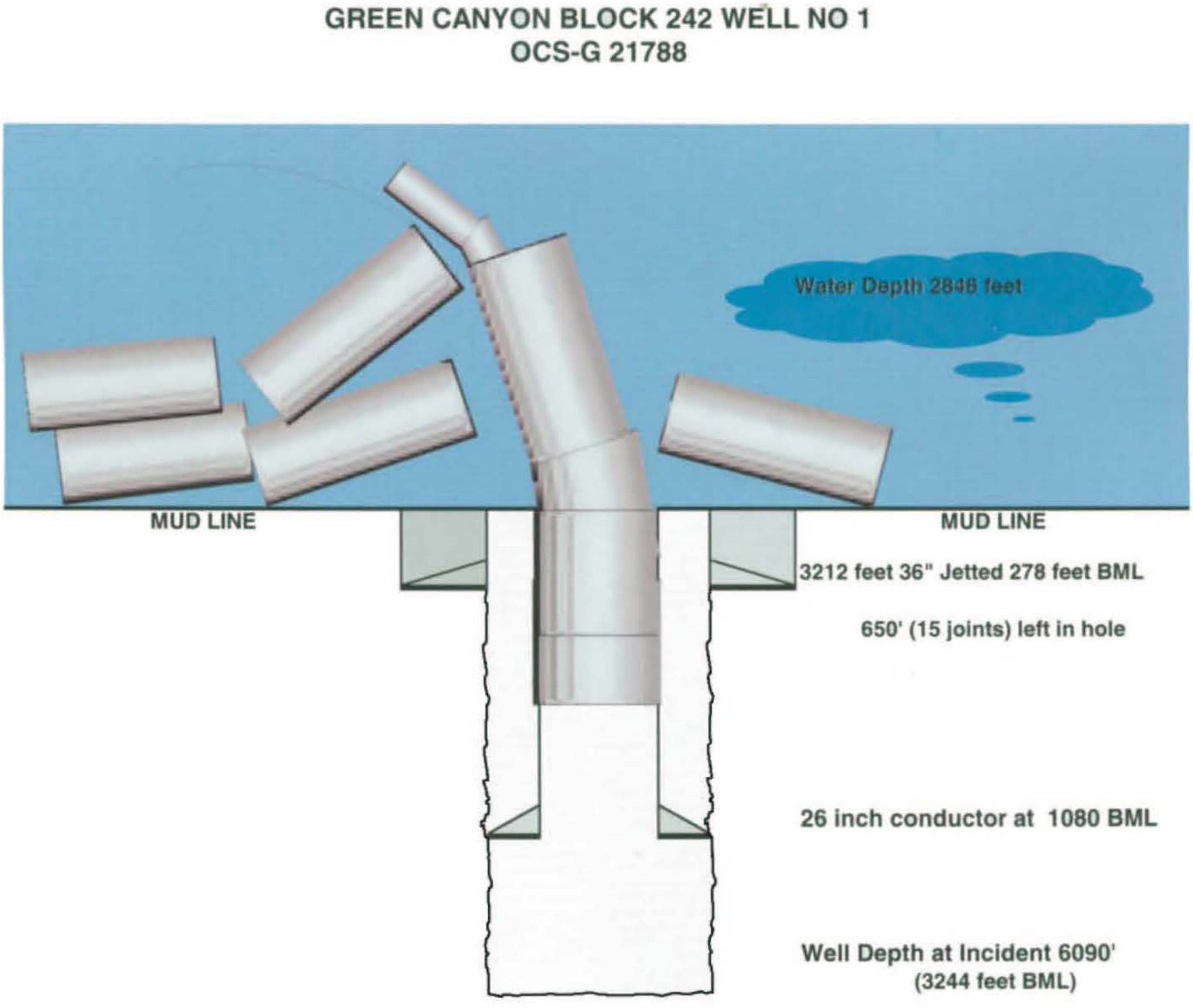
Critical action items should include the following:

1) Stress analysis considerations at varying sea states, with a thorough analysis of all dynamic loads, including tripping loads and slip-crushing loads.
2) Graphical load indicator data for trending analysis during all open water operations.
3) Functional ADCP monitoring to ensure real time measurement and comparison to the safe operating envelope as determined in Item 1 above. Per MMS NTL 2005-G02, which will be effective March 31, 2005, "Ocean Current Monitoring on Floating Facilities," operators of deepwater production facilities and drilling rigs in water depths greater than 400 meters must monitor the ocean currents near the installation.
4) Slips and bowl inspections for wear in accordance with API Spec 8A to ensure that the slip crushing load is distributed over the contact length.
5) Visual, dimensional, and flaw detecting inspections and/or pull testing of handling tools, such as bails, slips, master bushings, elevators, spiders, and top drive stem assemblies, in accordance with API Spec 8B / ISO 13534:2000. Suggested guidelines for inspection category and frequency are shown in Table 1 of the API Spec 8B. Inspections should be noted on the daily report. Reference is made to API Spec 8C, *Specification for Drilling and Production Hoisting Equipment (PSL 1 and PSL 2), third edition Addendum 1*, and to the ASTM E4-03, *Standard Practices for Force Verification of Testing Machines*.



Location of Lease OCS-G 21788, Green Canyon Block 242, Well 1.

Attachment 1



Well configuration, Post-Incident

View of drill pipe in rotary slips.

DAMAGED CASING AND DRILL PIPE

Upper damaged end of the 22-inch casing, showing the upper end of the drill pipe as delivered to lab.

Upper end of the section of the drill pipe, after removal from the 22-inch casing.

SLIPS AND PIPE BEFORE AND AFTER LAB TEST

View of the slips and pipe before test at lab.

Pipe in slips after test at lab.

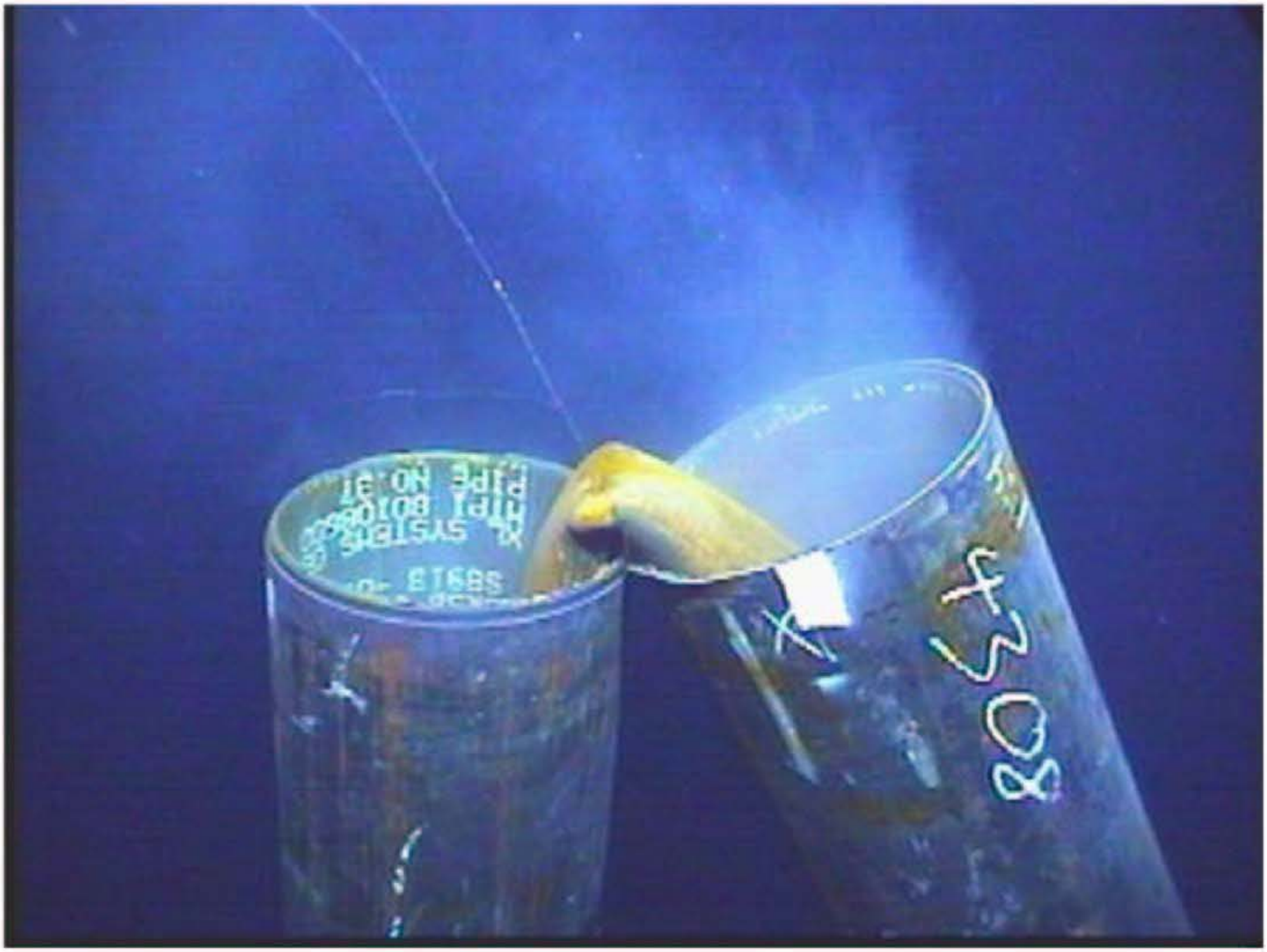
COMPARISON OF CRUSHED TEST PIPE TO DAMAGED DRILL PIPE FROM FIELD

View of the crushed test pipe, following removal of the slips at lab.

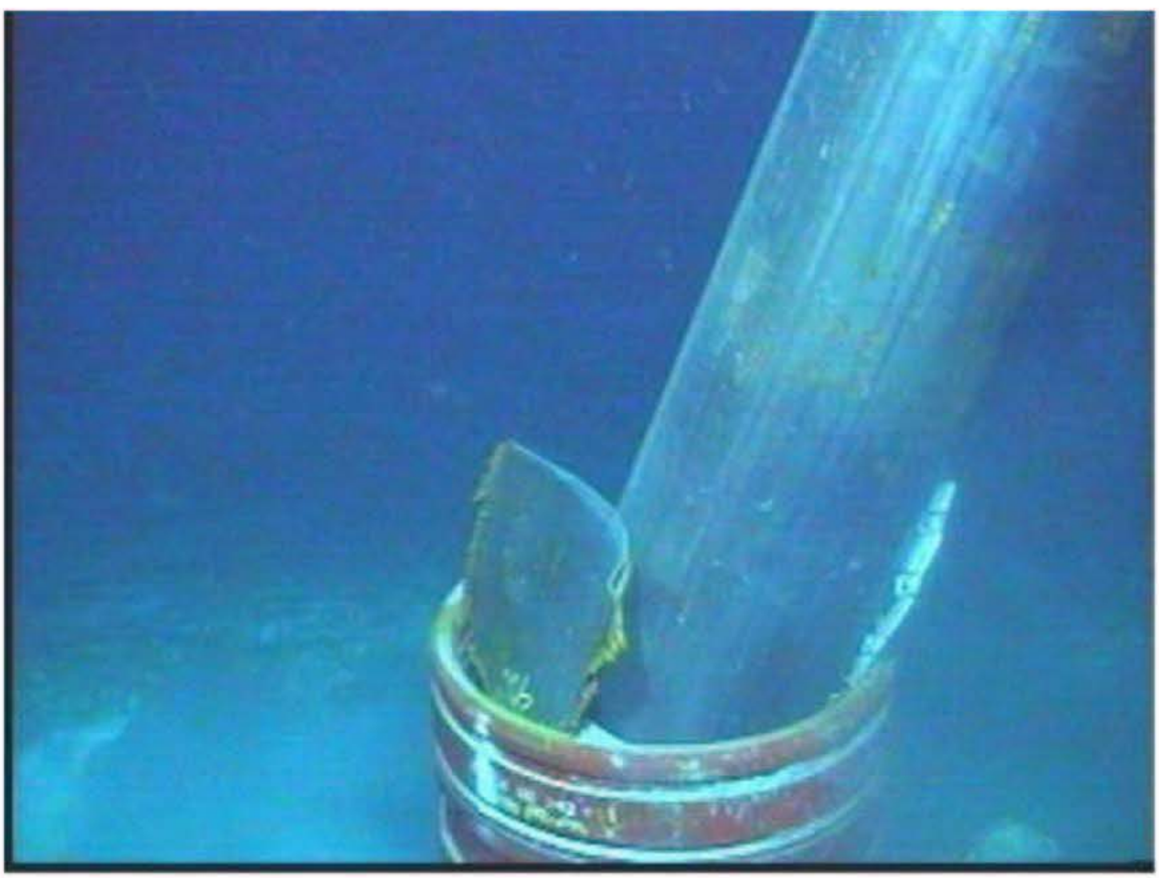
Damage in the drill pipe as received from the field.

Drill pipe bending below running tool.

Attachment 8



Pipe failure by bending.



Parted and pinned casing on seafloor.

MMS Securing Ocean Energy & Economic Value for America

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.