Vastar Resources, Inc.
Deepwater Horizon
Technical Position Paper
(Revision 5)

Issue: **EDS/DMS Disconnect Philosophy**

Date: September 13, 1999

Discipline: Engineering, Subsea, and Drilling Systems

Responsible: Mike L. Byrd, P.E.

Issue:
Initiation of either the **Emergency Disconnect Sequence** (EDS) or Deadman System (DMS) requires certain functions on the stack to execute within a certain amount of time. This paper describes the sequences, timing, and overall philosophy for these events. Based on this information, the vendor should be able to design the control system to accommodate these requirements.

Decision:
There will be three (3) possible modes of disconnecting the LMRP from the lower stack. They are initiated in the following priorities, depending on the nature of events driving the need for disconnect.

1. **Controlled Disconnect Sequence** (CDS) – This allows a manually controlled disconnect of the LRMP from the lower stack when adequate warning is provided and sufficient time exists to execute these functions. The functions are all operator controlled with no automation from the control system.
2. Emergency Disconnect Sequence (EDS) – This is a PLC driven disconnect sequence initiated from a Push-Hold button located on the Driller's Panel (located in the driller's work station), and the Toolpusher's Panel (located in the Bridge). This is to be used when the situation requiring disconnect has or is rapidly deteriorating. The rigid conduit system will close the SBR's and casing shears, depending on the mode selected. A manual mode selector for running pipe or casing, which is set prior to starting the respective operations, will determine the exact sequence of the EDS.
3. Deadman System Disconnect (DMS) – This is an automatic disconnect response in the event of catastrophic events requiring no manual intervention by rig personnel. The dedicated shear bottle circuit will drive SBR's.

The riser connector should be locked at 1,500 psi with 500 psi maintained on the lock side during operations. During both the EDS and DMS sequences, the connector should be unlocked with 3,000 psi. applied to both the primary and secondary unlock circuits. The hydraulic supply for the primary and secondary unlock function in the EDS mode will be supplied via two SPM valves down stream of the main supply source. In the DMS mode, due to limited quantity of accumulator bottles, there will be one supply to both the primary and secondary unlock function.

The primary goals for all disconnect sequences are:

1. Provide reliable ability to disconnect from the stack, hang-off the LMRP, and allow the rig to move off location.
2. Safety of all rig personnel.
3. Minimize or prevent discharge of hydrocarbons into the environment.
4. Minimize or prevent damage to capital equipment.
5. Limit pipe mode disconnect to no more than thirty (30) seconds.
6. Limit casing mode disconnect to as close to thirty (30) seconds as possible.

Discussion:

CLOSING SEQUENCES (for summary see Attachment 1)

Primary - CONTROLLED DISCONNECT SEQUENCE (CDS)
The controlled disconnect is the primary mode of disconnecting the LMRP from the lower stack. In this mode, the assumption is that there is adequate warning of deteriorating weather or current conditions. This would allow time to manually, as opposed to PLC or auto-sequence driven, initiate any hang-off and disconnect functions at the discretion of RBF/Operator's representatives.

Secondary - EMERGENCY DISCONNECT SEQUENCE (EDS)

4114
Exhibit No.
Worldwide Court Reporters, Inc.

- This is the secondary means of disconnecting the LMRP from the lower stack. This event could be driven by rapidly deteriorating weather or current conditions or fault with the rig power management or DP system causing the rig to rapidly drift off location to the point of requiring a disconnect.
- **The system shall have a mode selector for drilling and casing operations which is selected prior to beginning the respective operation.**
- Proper operational and tower change procedures will have to be in place to ensure that the correct mode is selected prior to running drill pipe or casing.

Drill Mode (Attachment 2)

- In the Drill mode, only the SBR's will close, shear, and provide a wellbore seal. Anything across the SBR's **which is 5-1/2", 24.7 ppf, S-135** or smaller, will be cut in this mode.
- Estimated time for this operation is approximately 27-30 seconds.

Casing Mode (Attachment 3 - W/O Auto-Shear, 4 - W/ Auto-Shear)

- In the casing mode, the casing shears will close first to enable shearing of the pipe, then the SBR's will close effecting the wellbore seal. This will minimize potential damage to the SBR's from closing on something on which they can not cut.
- The SBR's can be either powered by pressure from the rigid conduit or be activated by the auto-shear circuit. Utilizing the auto-shear circuit will minimize the time needed to execute the sequence by approximately 10 seconds. However, there is concern since this function takes place after the LMRP has disconnected. In the event of closing the SBR's with the rigid conduit supply, the estimated time for execution is 48 seconds. Using the auto-shear circuit reduces the time to approximately 37 seconds. The decision is to close the SBR's with the rigid conduit line. The preferred method of closing the SBR's is throught the rigid conduit system.
- The EDS will be operator initiated via push-hold buttons and will not be automatically initiated from the DP or Driltech systems.

Tertiary - DEADMAN SYSTEM (DMS) (Attachment 5)

The Deadman system is the final means of shutting in the well and effecting an environmental seal across the wellbore. It is anticipated that this would be an emergency measure only, initiated by events such as fire or explosion, parting of the riser, or any catastrophic event which shuts off hydraulic, power, and signal sources to the subsea control pods. The overall reliability philosophy of the DMS is to provide reliability through simplicity. This means that the fewer decisions the system has to make the more reliable it will be in executing its pre-programmed logic.

The DMS will activate upon loss of ALL of the following:

1. Communication between pods
2. Power and signal from the MUX cables
3. Hydraulic pressure from the rigid conduit

The DMS will close only the SBR's using the dedicated shear bottle circuit. The casing shears will not be closed due to accumulator volumetric constraints. This should cover approximately 95-97% of all drilling activities.

RISER CONNECTOR (Attachment 6)

The Cameron Type "HC" 18-3/4" 10M connector is used to connect and disconnect the LMRP from the lower stack. The HC connector:

- Has one lock circuit only.
- Has a primary and secondary unlock circuit.
- Unlock circuit provides approximately 1.24 times more unlocking force than locking force at a given pressure.

Function	Piston Area (in^2)	Lock Force (F_L) and Unlock Force (F_U) @ Operating Pressure (psi) of				
		1,500	1,500	2,000	2,500	3,000
Lock	549.0	823,500				
Unlock	679.9		1,019,850	1,359,800	1,699,750	2,039,700
Ratio = (F_U/F_L @ 1,500psi)			1.24	1.65	2.06	2.48

- The piston area was supplied by Cameron
- Is recommended by Cameron to have a locking pressure of 1,500 psi. and maintaining a locking pressure of 300-500 psi during drilling operations.
- Hydraulic circuitry is rated for 3,000 psi and is tested to 4,500 psi.

- Secondary unlock circuit provides no additional unlocking force above the primary unlock circuit at a given pressure. It does however, provide redundancy to the primary lock circuit in some conditions.

The fundamental operation of the connector is as follows:

- To lock, pressure is applied to the lock port, driving the locking piston down, which draws the collets around the mandrel hub, pre-loading the connector to the mandrel. Theoretically, the actuator ring is held in place with the 4° taper between the actuator ring and colletts. This however, is highly dependent on the coefficient of friction between the two parts. Too much friction requires higher locking and unlocking forces. Lower friction can cause the ring to back off without maintaining constant pressure. Using a pilot operated check valve (POCV) or maintaining 300-500 psi on the lock chamber normally controls the problem of actuator ring back-off. For this design, pressure will be used to maintain lock on the connector instead of a POCV.
- To unlock, pressure is applied to the primary unlock port. Normally, the secondary unlock piston remains seated against the stop on the outer body, which causes the actuator ring to be driven upward, releasing the colletts from the mandrel hub.
- In the event of failure of the seals used in the primary unlock between the actuator ring and the outer body, pressure can be applied to the secondary unlock port which will move the piston upward. It will then come in contact with the actuator ring driving the actuator ring upward, unlocking the connector.
- As seen in the drawing, the seal diameters between the primary and secondary unlock chambers are the same. This is why there is no additional unlock force generated when both the primary and secondary circuits are pressured.
- It can also be seen that if the source of the primary and secondary pressure is the same, failure of the primary unlock seals, will cause the pressure to bleed thereby never allowing pressure to build in the secondary unlock chamber.

There are several choices for plumbing the supply pressure to the connector. They are:

1. Single hydraulic supplies to either primary or secondary unlock port.
2. Single hydraulic supply to both the primary and secondary unlock port. (DMS)
3. Separate hydraulic supplies to each of the primary and secondary unlock ports (EDS)

The benefits and risks are shown in the table below:

Unlock Supply Method	Benefits	Risks
Single supply to secondary or primary unlock port.	• Piping is simple • Primary has held 500 psi prior to operating so confidence is high as to seal integrity	• Failure of upper seals between actuator ring and outer body may prevent connector from opening. • Single point failure mechanism
Single supply to both primary and secondary unlock ports. **(DMS Mode)**	• If the hydraulics are primarily hard piped, this will minimize the possibility of a leak in the supply. • Fewer accumulator bottles required.	• Piping is more complex • If upper seals between actuator ring and outer body leak, secondary unlock chamber will not build up pressure to drive secondary unlock piston upward. • If piping system leaks upstream of unlock ports, both primary and secondary ports are made ineffective
Discrete supplies to primary and secondary unlock ports **(EDS Mode)**	• If upper seals between actuator ring and outer body fail, the unlock piston will move upward until it is in full contact with actuator ring, driving the actuator ring upward to unlock • Failure to open the connector would require failure of both sets of seals between the actuator ring and outer body or failure of both supply circuits to the primary and secondary unlock ports • Secondary unlock port is truly redundant • Would require failure of entire supply circuit downstream of SMP valves.	• Piping is more complex • Additional shear seal valves are reqiured

NOTE: The above table, when describing a seal failure, assumes a catastrophic failure in which all fluid pumped in is discharged through the seal interface. In actuality, that probability is very low. The most likely failure mechanism for a seal would be localized damage due to scoring or trash build-up on the sealing surfaces. In this case, the leak would tend to be slow. The hydraulic fluid input would likely exceed the fluid discharge through the damaged seal and just cause the connector to work more slowly rather than not work at all.

It can therefore be concluded that maximum redundancy to ensure unlocking of the connector can be achieved by using both the primary and secondary unlock circuits, each being supplied from independent sources. In addition, to account for connector wear, hydraulic frictional losses, actuator ring creep, etc. the unlock pressure should be greater than the lock pressure. The recommendation is 1,500-psi lock pressure and 3,000-psi unlock pressure for both the EDS and DMS sequences. This will give approximately 2-1/2 times additional unlock force than force used to lock the connector. This higher unlock pressure has two primary benefits;

1. It should allow the connector to open more quickly
2. It accounts for mechanical losses as described above.

In addition, 300-500 psi should be maintained on the lock circuit during operations after locking the connector. A POCV will not be used. It is felt that this creates a single point failure mechanism, which could prevent the connector from opening.

Both the lock, and primary and secondary unlock circuits should be tested as a regular part of the stack tests while the stack is on the surface. This should ensure the integrity of the piping systems supplying pressure as well as the internal seals on the connector.

REGULATORY ISSUES (Attachment 7 - ABS, 8 - MMS)

The table below summarizes the basic regulatory requirements relative to BOP, accumulator, and disconnect requirements.

Issue	ABS Certification of Drilling Systems 1990 (CDS +N refers to DNV regs issued in 1981 and has disclaimer B.1, para. 3)	MMS 30 CFR 250.406 June 1, 1998
Subsea BOP configuration	1 – Annular 1 – SBR w/locks 2 – Pipe rams w/locks CDS +N • Not specified	1 – Annular 1 – SBR w/locks 2 – Pipe rams w/locks
Subsea Precharge	Not specified	Precharge + 200 psi
Accumulator volume – Surface (for subsea stack)	Sec. 3.15.2.1 • 1.5 x volume required to close ram and annular preventers and close choke lines CDS +N (Appendix B.12) • Refers to NPD sections 2.6.3.3 and 2.6.4	1.5 x volume to operate BOP units (see above)
Accumulator volume – Subsea	Not specified	Not specified
Disconnect times	Not specified	".. fast closure.." 250.406
Redundant control system	CDS +N only Sec B.17	Not specified

***NOTE:** Although ABS, CDS (+N) is not required for Vastar Resources, certification for approval in Norwegian waters may include significant additions and/or changes to the above requirements. This is due to the fact that more recent NPD regulations exist than are mentioned in ABS Certification of Drilling Systems, 1990. RB Falcon should consult with ABS for specifying the exact requirements.*

SUBSEA ACCUMULATOR QUANITIES (Attachment 1)
Sizing for subsea accumulators should take into account adiabatic expansion of nitrogen at ambient vs. seabed temperatures in addition to any regulatory requirements.

Attachments:

1 - Description of EDS and DMS system
2 - Flow Chart, EDS - Drill Mode
3 - Flow Chart, EDS – Casing Mode, SBR's close w/ rigid conduit supply
4 - Flow Chart, EDS – Casing Mode, SBR's close w/ Auto-Shear Circuit
5 - Flow Chart, DMS
6 - Cameron Type "HC" Connector
7 - Regulatory Requirements – ABS, Certification of Drilling Systems, 1990
8 - Regulatory Requirements – MMS, 30 CFR 250

Prepared By:

Name	***Discipline***	***Signature***	***Date***
M. Byrd	Vastar, Subsea Consultant	M Byrd	9-13-99

Reviewed By:

Name	***Discipline***	***Signature***	***Date***
Kevin Wink	Deepwater Horizon, Rig Manager	K. Wink	01/05/00
Don Weisinger	Vastar, Project Manager	Don Weisinger	12/13/99