Recommended Practice for Design of Control Systems for Drilling Well Control Equipment

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FOREWORD

Purpose:

This recommended practice was formulated to serve as a guide for the design and installation of control systems for well control equipment.

a. These recommended practices were prepared by the Subcommittee on Control Systems for Drilling Well Control Equipment. They represent a composite of practices employed by various operating, drilling, and equipment manufacturing companies. In some instances, reconciled composites of these practices are included in this publication. This publication is under jurisdiction of the American Petroleum Institute Production Department's Committee on Standardization of Drilling Well Control Systems.

b. The goal of these voluntary recommended practices is to assist the oil and gas industry in promoting personnel safety, public safety, integrity of the drilling rig and associated equipment, and preservation of the environment for land and marine drilling operations. These recommended practices are published to facilitate the broad availability of proven, sound engineering and operating practices. Recommendations presented herein are based on extensive and wide ranging industry experience. Practices set forth herein are considered acceptable for accomplishing the job as described, however, equivalent alternative installations and practices may be utilized to accomplish the same objectives. The formulation and publication of API recommended practices is not intended to, in any way, inhibit anyone from using other practices.

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Changes in the uses of these verbs *are not* to be effected without risk of changing the intent of recommendations set forth herein.

f. Suggestions for revisions or additions are invited and should be submitted to: Director, Production Department, American Petroleum Institute, 2535 One Main Place, Dallas, Texas 75202-3904.

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This is the first edition of API RP 16E. This document is under jurisdication of the API Committee on Standardization of Drilling Well Control Systems and was approved by letter ballot dated August 19, 1989.

SECTION 16E.1
GENERAL DESCRIPTION OF CONTROL SYSTEMS

16E.1 This recommended practice establishes design standards for systems, subsystems and components used to control BOP's (blowout preventers) and associated choke and kill valves that control well pressure during drilling operations. Although diverters are not considered well control devices, their controls are often incorporated as part of the BOP control system. Control systems for drilling well control equipment typically use stored energy in the form of pressurized hydraulic fluid (power fluid) to operate (open and close) the BOP stack components. Each operation of a BOP or other well control component is referred to as a control function. The control system equipment and circuitry varies generally in accordance with the application and environment. Thus, six control system categories are addressed.

These include:

16E.1.1 Control systems for surface mounted BOP stacks: These systems are typically simple closed hydraulic control systems consisting of a reservoir for storing hydraulic fluid, pump equipment for pressurizing the hydraulic fluid, accumulator banks for storing power fluid, manifolding, piping and control valves for transmission of control fluid to the BOP stack functions.

16E.1.2 Hydraulic control systems for subsea BOP stacks: In addition to the equipment required for surface mounted BOP stacks, subsea control systems use umbilical hose bundles for transmission of hydraulic pilot signals subsea. Also used are dual subsea control pods mounted on the LMRP (lower marine riser package), housing pilot operated control valves for directing power fluid to the BOP stack functions. Spent water-based hydraulic fluid is usually vented subsea. Hose reels are used for storage and deployment of the umbilical hose bundles. The use of dual subsea pods and umbilicals afford backup security.

16E.1.3 Electro-hydraulic/multiplex control systems for subsea BOP stacks: For deepwater operations, transmission subsea of electric (rather than hydraulic) signals permits short response times. Electro-hydraulic systems employ multi conductor cables, having an individual wire dedicated to each function to operate subsea solenoid valves which send hydraulic pilot signals to the valves that operate the BOP stack functions. Multiplex control systems employ serialized electronically coded messages transmitted over shared conductors. Electronic data processing and transmission are used to provide the security of codifying and confirming functional command signals so that a stray signal, cross talk or a short circuit should not execute a function.

16E.1.4 Diverter control systems: Direct hydraulic controls are commonly used for operation of the surface mounted diverter unit and any associated valves.

16E.1.5 Emergency Backup BOP Control Systems: When the subsea control system is inaccessible or nonfunctional, an independent control system may be used to operate critical well control and/or disconnect functions. These systems have their own supply of power fluid. They include acoustic control systems, ROV (Remotely Operated Vehicle) operated control systems and LMRP recovery systems. For surface control systems, a reserve supply of pressurized nitrogen gas can serve as a backup means to operate functions in the event that the pump system power supply is lost.

16E.1.6 Auxiliary equipment control systems and interfaces: For floating drilling operations, various auxiliary functions such as the telescopic joint packer, 30″ latch, etc., require operation by the control system.

SECTION 16E.2
CONTROL SYSTEM FOR SURFACE MOUNTED BOP STACKS

GENERAL

16E.2 BOP control systems for surface installations (land rigs, offshore jackups and platforms) normally supply hydraulic power fluid in a closed loop circuit as the actuating medium. The elements of the BOP control system normally include:

- Storage (reservoir) equipment for supplying ample control fluid to the pumping system.
- Pumping systems for pressurizing the control fluid.
- Accumulator bottles for storing pressurized control fluid.
- Hydraulic control manifold for regulating the control fluid pressure and directing the power fluid flow to operate the system functions (BOP's and choke and kill valves).
- Remote control panels for operating the hydraulic control manifold from remote locations.
- Hydraulic control fluid.

RESPONSE TIME

16E.2.1 Response time between activation and complete operation of a function is based on BOP or valve closure and seal off. For surface installations, the BOP control system should be capable of closing each ram BOP within 30 seconds. Closing time should not exceed 30 seconds for annular preventers smaller than 18¾ inches nominal bore and 45 seconds for annular preventers of 18¾ inches and larger. Response time for choke and kill valves (either open or close) should not exceed the minimum observed ram close response time. Measurement of closing response time begins at pushing the button or turning the control valve handle to operate the function and ends when the BOP or valve is closed effecting a seal. A BOP may be considered closed when the regulated operating pressure has recovered to its nominal setting. If confirmation of seal off is required, pressure testing below the BOP or across the valve is necessary.

HYDRAULIC FLUID AND STORAGE EQUIPMENT

16E.2.2 A suitable control fluid should be selected for the system operating medium based on the control system operating requirements, environmental requirements and user preference.

16E.2.2.1 Water-based hydraulic fluids are usually a mixture of portable water and a water soluble lubricant additive. When ambient temperatures at or below freezing are expected, sufficient volume of ethylene glycol or other additive acceptable to the control system manufacturer should be mixed with the water-based hydraulic fluid to prevent freezing.

The hydraulic fluid reservoir should have a capacity equal to at least twice the usable hydraulic fluid capacity of the accumulator system. (See Section 16E.2.4.3 for sizing capacity of accumulators). Air breather outlets should be installed of sufficient size to avoid pressurization of the tank during hydraulic fluid transfers or nitrogen transfers if a nitrogen backup system is installed (see Section 16E.6.4).

PUMP REQUIREMENTS

16E.2.3 A pump system consists of one or more pumps driven by a dedicated power source. Two (primary and secondary) or more pump systems should be employed having independent power sources. Each pump system should have sufficient quantity and sizes of pumps to satisfactorily perform the following: With the accumulators isolated from service, the pump system should be capable of closing each annular BOP (excluding the diverter) on the minimum size drill pipe being used, open the hydraulically operated choke valve(s) and provide the operating pressure level recommended by the annular BOP manufacturer to effect a seal on the annular space within 2 minutes.

The combined output of all pumps should be capable of charging the entire accumulator system from precharge pressure to the maximum rated control system working pressure within 15 minutes.

The same pump system(s) may be used to produce power fluid for control of both the BOP stack and the diverter system. Pump requirements relative to the diverter system are given in Section 16E.5.3 and 16E.5.3.1.

16E.2.3.1 Each pump system should provide a discharge pressure at least equivalent to the system working pressure. Air driven pump systems should require no more than 75 psig air supply pressure.

16E.2.3.2 Each pump system should be protected from over-pressurization by a minimum of 2 devices designed to limit the pump discharge pressure.

One device should limit the pump discharge pressure so that it will not exceed the design working pressure of the BOP control system (see Section 16E.2.3.3).

The second device, normally a relief valve, should be sized to relieve at a flow rate of at least equal to the design flow rate of the pump systems and should be set to relieve at not more than ten percent over the design working pressure.

Devices used to prevent pump system over-pressurization should be installed directly in the control system supply line to the accumulators and should not have isolation valves or any other means that could defeat their intended purpose.

16E.2.3.3 Electrical and/or air (pneumatic) supply for powering pumps should be available at all times such that the pumps will automatically start when the system pressure has decreased to approximately ninety percent of the system working pressure and automatically stop within plus zero or minus 100 psi of the system design working pressure.

ACCUMULATOR BOTTLES AND MANIFOLDS

16E.2.4 Accumulators are pressure vessels designed to store power fluid. Accumulators should be compatible with control fluids, should meet ASME Section VIII Division 1 design requirements and should be documented with ASME UA-1 certificates.

ACCUMULATOR TYPES AND INTERCONNECT OF ACCUMULATOR BANKS:

16E.2.4.1 Accumulator designs include bladder, piston and float types. Selection of type may be based on user preference and manufacturer's recommendations considering the intended operating environment.

The accumulator system should be designed so that the loss of an individual accumulator and/or bank should not result in more than approximately twenty-five percent loss of the total accumulator system capacity.

Supply pressure isolation valves and bleed down valves should be provided on each accumulator bank to facilitate checking the precharge pressure or draining the accumulators back to the control fluid reservoir.

PRECHARGING ACCUMULATORS:

16E.2.4.2 The precharge pressure in the system accumulators serves to propel the hydraulic fluid stored in the accumulators for operation of the system functions. The amount of precharge pressure is a variable depending on specific operating requirements of the equipment to be operated and the operating environment.

The accumulator precharge pressure can be checked after bleeding off the control fluid. In the field, the precharge pressure should be checked and adjusted to within 100 psi of the recommended pressure at installation of the control system and at the start of drilling each well (intervals not to exceed sixty days).

Because of the presence of combustible components in hydraulic fluids, accumulators should be precharged only with nitrogen. Compressed air or oxygen should never be used to precharge accumulators since combining them with the oil could result in combustion.

16E.2.4.2.1 The recommended precharge pressures for the BOP components and conditions specified should be stated on a tag permanently attached to the accumulator banks. Precharge pressure should not exceed working pressure of the accumulator.

ACCUMULATOR VOLUMETRIC REQUIREMENTS:

16E.2.4.3 The BOP control system should have a minimum stored hydraulic fluid volume (VR), with pumps inoperative, to satisfy the greater of the two following requirements:

1. Close from a full open position at zero wellbore pressure, all of the BOP's in the BOP stack, plus fifty percent reserve.
2. The pressure of the remaining stored accumulator volume after closing all of the BOP's should exceed the minimum calculated (using the BOP closing ratio) operating pressure required to close any ram BOP (excluding the shear rams) at the maximum rated wellbore pressure of the stack.

VOLUMETRIC CAPACITY CALCULATIONS

16E.2.4.4 The equation for volumetric capacity calculation assumes isothermal conditions and $P_1 V_1 = P_2 V_2$ (Boyle's Law) where:

P_1 = Initial Pressure, (absolute)
V_1 = Initial Gas Volume
P_2 = Final Pressure, (absolute)
V_2 = Final Gas Volume

16E.2.4.5 Determine the accumulator system volumetric capacity as defined in Section 16E.2.4.3.

16E.2.4.3 Item 1 (nitrogen plus hydraulic fluid) by the following formula:

$$V_3 = \frac{VR}{P_n/P_{min} - P_n/P_{max}}$$

Where:

VR = Usable Fluid Required

$P_n/P_{min} - P_n/P_{max}$ = The Fraction of Usable Hydraulic Fluid Between P_{max} and P_{min}

P_{max} = Maximum pressure of the accumulator when fully charged, (absolute)

P_{min} = > Minimum operating pressure recommended by the manufacturer(s) of the component(s) being operated. Where these functions have different recommended minimum operating pressures, the highest value should apply.

P_n = Nitrogen Precharge Pressure (absolute)

VR = Usable hydraulic fluid volume required including safety factor.

V_3 = Total accumulator system volumetric capacity (nitrogen and hydraulic fluid)

16E.2.4.6 Determine the number of accumulator bottles required by dividing the total accumulator volumetric capacity (V_3) by the accumulator gas volume capacity. Round off to the next larger whole number.

NOTE: *The accumulator gas volume capacity should be determined by consulting the accumulator manufacturer's gas volume specifications.*

16E.2.4.7 The usable hydraulic fluid volume of the accumulator system should be used to determine pump system sizing and reservoir capacity. Usable hydraulic fluid volume is calculated by multiplying the actual number of accumulators determined in 16E.2.4.6 by the accumulator gas volume capacity, then multiplying by the percent of usable hydraulic fluid between P_1 and P_2 determined in 16E.2.4.5.

NOTE: *These calculations are for system design only and are* not *to be used as performance criteria aboard the rig. The calculations shown here are simplified examples for estimating minimum capacity requirements. More rigorous design calculations which account for parameters such as adiabatic gas expansion and specific volume of gas may be used.*

HYDRAULIC CONTROL MANIFOLD

16E.2.5 The hydraulic control manifold is the assemblage of hydraulic control valves, regulators and gages from which the system functions are directly operated. It allows manual regulation of the power fluid pressure to within the rating specified by the BOP manufacturer. The hydraulic control manifold provides direct pressure reading of the various supply and regulated pressures.

A suitable valve with porting sized at least equal to the control manifold supply piping size should be provided for supply of control hydraulic fluid from an alternate source. This valve should be plugged when not in use.

HYDRAULIC CONTROL MANIFOLD ANNULAR BOP CIRCUIT

16E.2.5.1 A dedicated control circuit on the hydraulic control manifold should operate the annular BOP(s). The components in this circuit should include a pressure regular to reduce upstream manifold pressure to the power fluid pressure level that meets the BOP manufacturer's recommendations. The regulator should respond to pressure changes on the downstream side with sensitivity sufficient to maintain the set pressure within plus or minus one hundred and fifty psi.

16E.2.5.1.1 The annular BOP pressure regulator should be remotely controllable. Direct manual valve and regulator operability should permit closing the annular BOP and/or maintaining the set regulated pressure in the event of loss of the remote control capability.

HYDRAULIC MANIFOLD CIRCUIT FOR COMMON PRESSURE FUNCTIONS

16E.2.5.1.2 The hydraulic control manifold includes a common power fluid circuit with pressure regulation and control valves for operation of the ram type BOP's and choke and kill valves. This curcuit may be provided with a manifold regulator bypass valve or other means to override the manifold regulator to permit switching from regulated pressure to direct accumulator pressure for operating functions.

HYDRAULIC CONTROL MANIFOLD VALVES

16E.2.5.2 Placing the control valve handle on the right side (while facing the valve) should close the BOP or choke or kill valve, the left position should open the BOP or choke or kill valve. The center position of the control valve is called the "block" position. In the block position, power fluid supply is shut off at the control valve. The other ports on the four-way valve may be either vented or blocked depending on the valve selected for the application. The hydraulic circuit schematics should clearly indicate the block position control valve port assignments for the particular control system.

Valves and gages should be clearly functionally labelled.

Protective covers or other means which do not interfere with remote operation should be installed on the blind/shear ram and other critical function control valves. Lifting of these covers is required to enable local function operation.

REMOTE CONTROL PANELS

GENERAL

16E.2.6 A minimum of one remote control panel should be furnished. This is to ensure that there are at least two locations from which all of the system functions can be operated. The remote panel should be accessible to the driller to operate functions during drilling operations. The driller's remote control panel display should be physically arranged as a graphic representation of the BOP stack. Its capability should include the following:

1. Control all the hydraulic functions which operate the BOP's and choke and kill valves.
2. Display the position of the control valves and indicate when the electric pump is running (offshore units only). (See Paragraph 16E.3.6.4.2).
3. Provide control of the annular BOP regulator pressure setting.
4. Provide control of the manifold regulator bypass valve or provide direct control of the manifold regulator pressure setting.
5. The driller's panel should be equipped with displays for readout of:

   Accumulator pressure
   Manifold regulated pressure
   Annular BOP regulated pressure
   Rig air pressure

6. Offshore rig driller's panels should have an audible and visible alarm to indicate the following:

   Low accumulator pressure
   Low rig air pressure
   Low hydraulic fluid reservoir level
   Panel on standby power (if applicable)

7. All panel control functions should require two handed operation. Regulator control may be excluded from this requirement.

The BOP stack functions should also be operable from the main hydraulic control manifold. This unit should be installed in a location remote from the drill floor and easily accessible to rig personnel in an emergency.

OPTIONAL REMOTE CONTROL METHODS

16E.2.6.1 Remote control from the remote panels of the hydraulic control manifold valves may be actuated by pneumatic (air), hydraulic, electro-pneumatic, or electro-hydraulic remote control systems. The remote control system should be designed such that manual operation of the control valves at the hydraulic control unit will override the position previously set by the remote controls.

PNEUMATIC REMOTE CONTROL

16E.2.6.1.1 Pneumatic remote controls employ compressed air as the medium to operate actuators for control of the hydraulic control valves. Response time between the actuation of the pneumatic valve at the remote panel and the actuation of the control valve is generally a linear function of the length of the interconnecting hose. Therefore, pneumatic controls are not recommended where hose lengths exceed 150 feet. Pneumatic remote controls are not recommended for use in freezing temperatures because condensate in a control line may solidify and plug the line.

HYDRAULIC REMOTE CONTROL

16E.2.6.1.2 Hydraulic remote control is a method to interface with the hydraulic control manifold. This method can be used in the absence of electrical power and can function in sub-freezing temperatures. Pilot pressure for remote control should be supplied from a hydraulic power source separate or suitably isolated from the main hydraulic power source so that failure of the remote control will not affect manual operation of the BOP control system.

ELECTRO-PNEUMATIC REMOTE CONTROL

16E.2.6.1.3 Electro-pneumatic controls employ electric circuits to operate pneumatic solenoid valves that control the pneumatic actuators which operate the hydraulic control valves. Electro-pneumatic controls have the advantage of fast response and ease of running electrical cables compared to hose bundles of pneumatic remote controls.

Electro-pneumatic controls should not be used in sub-freezing temperatures.

ELECTRO-HYDRAULIC REMOTE CONTROL

16E.2.6.1.4 Electro-hydraulic controls employ electric circuits to operate the hydraulic control valves. Electro-hyraulic controls have the advantages of fast response, ease of running electrical cables and are functional in sub-freezing temperatures. The hydraulic power supply for the remote controls should be isolated from the main hydraulic system so that a failure in the remote control circuit will not affect the manual operation of the control valves.

16E.2.6.2 Electric remote control panels and equipment should be designed to meet the requirements of API RP 14F Sections 2, 4, 5, 6, 8, 10.1 and 10.2. All electrical equipment is to be designed so as to be suitable for use in the atmosphere in which it is installed as defined by API RP 500B.

REQUIREMENTS FOR BOP CONTROL SYSTEM VALVES, FITTINGS, LINES AND MANIFOLD

REQUIRED PRESSURE RATING

16E.2.7 All valves, fittings and other components such as pressure switches, transducers, transmitters, etc., should have a working pressure at least equal to the working pressure of the control system. BOP control system working pressure rating is usually 3000 psi. Other working pressure ratings may be preferred based on function operating requirements.

CONFORMITY OF PIPING SYSTEMS

16E.2.7.1 All piping components and all threaded pipe connections should conform to the design and tolerance specifications for American National Standard Taper Pipe Threads as specified in ANSI B2.1. Pipe and pipe fittings should conform to specifications of ANSI B31.3. If weld fittings are used, the welder should be certified for the applicable procedure required. All rigid or flexible lines between the control system and BOP stack should be fire-resistant including end connections, and should have a working pressure equal to the design working pressure of the BOP control system.

All control system interconnect piping, tubing, hose, linkages, etc., should be protected from damage from drilling operations, drilling equipment movement and day-to-day personnel operations.

ELECTRICAL POWER SUPPLIES

16E.2.8 The electrical power supply to electro-pneumatic and electro-hydraulic panels should automatically switch to an alternate source of electric supply when primary power is interrupted. The alternate source of electric power supply should be capable of maintaining operation of the remote functions for a minimum of two hours if primary source should fail.

SECTION 16E.3
HYDRAULIC CONTROL SYSTEMS FOR SUBSEA BOP STACKS

GENERAL REQUIREMENTS

16E.3 Floating drilling rigs such as drillships and semisubmersibles experience vessel motion which necessitates placement of the BOP stack on the sea floor. The control systems used on floating rigs are usually open ended hydraulic systems (spent hydraulic fluid vents to sea) and therefore employ water-based hydraulic control fluids. In addition to the conventional components used on surface BOP control systems, subsea hydraulic control systems require hydraulic umbilical hose bundles deployed from storage reels to carry function pilot signals and power fluid from the surface to the subsea BOP stack. Pilot operated valves, controlled from the surface, are usually mounted in control pods on the LMRP and direct hydraulic power fluid to the annular and ram type BOP's, choke and kill valves and hydraulic connectors.

Because the subsea BOP stack is not easily accessible for maintenance and repair, redundant (backup) subsea pods and umbilicals are provided. The redundant components include the following:

1. Two complete sets of pilot operated control valves with each set mounted in one of two control pods located on the LMRP.
2. Two control hose bundle umbilicals, each stored on and deployed from an umbilical reel, to connect the two subsea pods to the surface control equipment.
3. Two jumper hose umbilicals to connect the reel mounted umbilicals to the surface controls.

RESPONSE TIME

16E.3.1 The control system for a subsea BOP stack should be capable of closing each ram BOP in 45 seconds or less. Closing response time should not exceed 60 seconds for annular BOP's. Operating response time for choke and kill valves (either open or close) should not exceed the minimum observed ram close response time. Time to unlatch the LMRP should not exceed 45 seconds. Measurement of response time begins at pushing the button or turning the control valve handle to operate the function and ends when the BOP or choke or kill valve is closed effecting a seal, or when the hydraulic connector(s) is fully unlatched.

A BOP may be considered closed when the regulated pressure has recovered to its nominal setting. If confirmation of seal off is required, pressure testing below the BOP or across the valve is necessary.

MIXING AND STORAGE EQUIPMENT

16E.3.2 A solution of potable water and a suitable soluble lubricant should be used as the subsea control system operating hydraulic fluid. Appropriate proportions of ethylene glycol antifreeze should be added to control fluids containing water if ambient temperature at or below 32°F is anticipated. Additives which may be used to impede bacterial growth should not adversely affect performance. The hydraulic fluid reservoir should consist of two or more storage tanks. The large main tank should contain the control system fluid to be be used in the operation of the BOP and valves. Another tank should contain the concentrated water soluble hydraulic fluid to be mixed with water to constitute the control system fluid. A third optional tank may contain ethylene glycol to be used when it is required to operate at temperatures close to, or below, 32°F. A fourth optional tank may contain a dedicated supply of pilot fluid mixture.

16E.3.2.1 The usable control system fluid reservoir capacity should be at least equal to the total accumulator storage capacity as determined in 16E.3.4.1. There should be sufficient space in the reservoir above the upper hydraulic fluid fill valve shut off level to permit draining the largest bank of accumulators back into the tank without overflow.

The lubricant/additive reservoir should be sized using the maximum anticipated ratio for mixing the control system's hydraulic fluid. The reservoir should contain sufficient lubricant/additive to mix at least ten times the total accumulator storage capacity of control system fluid as determined in 16E.3.4.1.

The antifreeze reservoir if required, should be sized using the maximum anticipated ethylene glycol/water ratio for the minimum anticipated ambient temperature to which the control fluid will be exposed. The reservoir should contain sufficient antifreeze to mix the accumulator storage capacity of control system fluid as determined in 16E.3.4.1.

16E.3.2.2 An audible and visible alarm should be provided to indicate low fluid level in each of the individual reservoirs. The alarm control should be set to activate after 75% of the reservoir usable volume has been drained. The alarm should sound and illuminate at the master, driller's and auxiliary remote panels.

16E.3.2.3 Adequate cleanout ports/hatches should be provided for each reservoir to facilitate cleaning. To prevent overpressurization, each reservoir should have suitable vents that have flow capacity in excess of the incoming flow capacity (including flow from accumulators for the mixed fluid reservoir). These vents should not lend themselves to being mechanically plugged, or capped.

16E.3.2.4 The hydraulic fluid mixing system should be designed for automatic operation. The system should automatically stop when the mixed fluid reservoir reaches the upper hydraulic fluid fill valve shut off level. (Ref. 16E.3.2.1). The mixing system should automatically restart when the fluid level decreases not more than ten percent (10%) below the fill valve shut off level.

The mixing system should be capable of mixing the fluids at a mixture ratio suitable to combat freezing at anticipated ambient temperature and supply an output flow rate at least equal to the combined discharge flow rate of the pump systems.

The automatic mixing system should be manually adjustable over the ranges recommended by the manufacturer of the water soluble lubricant additive including proper proportioning of ethylene glycol.

PUMP SYSTEMS

16E.3.3 The subsea BOP control system should have a minimum of two pump systems (primary and secondary), ref. 16E.2.3. The combination of all pumps should be capable of charging the entire accumulator system from the established minimum working pressure (P_{min} defined in Section 16E.2.4.5) to the maximum rated system pressure in fifteen minutes or less. See Section 16E.3.4.3.6.

16E.3.3.1 Isolated accumulators may be provided for the pilot control system which may be supplied by a separate pump. The dedicated pump, if used, can be either air powered or electric powered. Air pumps should be capable of charging the accumulators to the system working pressure with 75 psi minimum air pressure supply. Provision should be made to supply hydraulic fluid to the pilot accumulators from the main accumulator system if the pilot pump becomes inoperative.

PUMP SYSTEM CONTROLS

16E.3.3.2 The pump systems should have controls for automatic operation.

The primary pump system's controls should be set so that the pump(s) will automatically stop at the maximum design working pressure of the BOP control system. The primary pump system control should start the pump(s) automatically if the control system accumulator pressure decreases to ninety percent of the design working pressure.

The secondary pump system's controls should provide operation similar to the primary system except that the set point to start the pump may be adjusted slightly lower so that both pump systems do not start simultaneously. The secondary pump control should not stop the pump at less than ninety-five percent of the BOP control system design working pressure and should start the pump automatically prior to the system pressure decreasing below eight-five percent of the design working pressure.

See Section 16E.2.3.2 for information regarding over-pressurization protection.

ACCUMULATORS AND MANIFOLDS

16E.3.4 Accumulators and manifolds for hydraulic control systems for subsea BOP stacks should meet the guidelines of Section 16E.2.4 as well as Sections 16E.3.4.1 through 16E3.4.2.2 below.

ACCUMULATOR VOLUMETRIC CAPACITY CALCULATION

16E.3.4.1 The hydraulic control system for a subsea BOP stack should have a minimum total stored hydraulic fluid volume (TVR), with the pumps inoperative, to satisfy the greater of the two following requirements:

1. Open and close, at zero wellbore pressure, all of the ram type BOP's and one annular BOP in the BOP stack, with a fifty percent reserve.
2. The pressure of the remaining stored accumulator volume after opening and closing all of the ram BOP's and one annular BOP, should exceed the calculated minimum system operating pressure. The calculated minimum system operating pressure should exceed the greater of the following minimum stack component operating pressures:
    1. The minimum calculated operating pressure required (using the closing ratio) to close any ram BOP (excluding shearing pipe) at the maximum rated wellbore pressure of the stack.
    2. The minimum calculated operating pressure required to open and hold open any choke or kill valve in the stack at the maximum rated wellbore pressure of the stack.

16E.3.4.2 Accumulators may be mounted on the subsea BOP stack to reduce response time and/or to serve as a backup supply of power fluid. The stored capacity should be protected from discharge through the supply lines by suitable devices such as pilot operated check valves. (See Section 16E.3.7.5).

16E.3.4.2.1 The subsea accumulator capacity calculations should compensate for subsea hydrostatic pressure gradient at the rate of .445 psi per foot of true vertical water depth. (For example the hydrostatic head at 500 foot water depth is 222.5 psi). This requires that all pressure values in the calculations be increased by this amount.

VOLUMETRIC CAPACITY CALCULATIONS

16E.3.4.3 Determine the total stored hydraulic fluid volume required (TVR) to accomplish the recommendations of Section 16E.3.4.1.

16E.3.4.3.1 Determine the stored subsea hydraulic fluid volume (SSVR) to be provided by the subsea mounted accumulators.

16E.3.4.3.2 Calculate the subsea accumulator capacity (nitrogen plus hydraulic fluid) required (SSV_3) compensated for the subsea hydrostatic pressure gradient.

$$SSV_3 = \frac{SSVR}{\frac{P_n+(.445\times TVD)}{P_{min}+(.445\times TVD)} - \frac{P_n+(.445\times TVD)}{P_{max}+(.445\times TVD)}} = \frac{\text{Usable Fluid Required}}{\text{Fraction of usable hyd. fluid between } P_{max} \text{ and } P_{min}}$$

See Section 16E.2.4.5 for definition of terms.

16E.3.4.3.3 Determine the number of subsea accumulator bottles required by dividing the subsea accumulator capacity (SSV_3) by the accumulator gas volume capacity. Round off any fraction resulting to the next higher whole number.

NOTE: *The accumulator gas volume capacity should be determined from the accumulator manufacturer's specification for the accumulator size to be used.*

16E.3.4.3.5 Determine the stored surface hydraulic fluid volume required (SVR) by subtracting the actual subsea stored hydraulic fluid volume (SSVR) from the total stored hydraulic fluid volume required (TVR) determined in Section 16E.3.4.1.

16E.3.4.3.6 Calculate the surface accumulator volumetric capacity required (V_3) (nitrogen plus hydraulic fluid) substituting SVR for VR using the equation in Section 16E.2.4.5.

16E.3.4.3.7 Determine the number of surface mounted accumulators required per Section 16E.2.4.6 and the actual surface accumulator capacity per Section 16E.2.4.7.

16E.3.4.3.8 The actual total system accumulator storage capacity is then the sum of the actual stored accumulator volumes surface and subsea. The actual total system accumulator storage capacity is then used to size the pumping system's capacity and reservoir storage volumes.

SUBSEA ACCUMULATOR CONTROLS

16E.3.4.4 Accumulators mounted subsea should have a subsea mounted, surface controlled valve to allow blocking the supply pressure to the accumulators so that the pump system pressure may be directed straight through to a selected BOP stack function.

16E.3.4.4.1 When a fully charged subsea accumulator is retrieved to the surface unvented, its internal pressure could exceed the maximum operating pressure rating of the accumulator. A means should be provided to allow venting or equalizing the subsea accumulator pressure prior to or during retrieval of the accumulators to the surface. When precharging subsea accumulators on the surface, the precharge pressure should not exceed the design working pressure of the accumulator.

16E.3.4.4.2 When the actual stored subsea accumulator volume is used to meet the minimum total stored hydraulic fluid volume (Reference Paragraph 16E.3.4.1), the surface controlled valve to allow blocking the supply pressure should not be operated as a routine basis. This valve should be operated only to direct fluid from the surface for a specific purpose.

CONTROL MANIFOLD

16E.3.5 The control manifold is an assemblage of valves, gages, regulators, and a flow meter for operating and monitoring all of the system functions. The manifold has a power fluid supply pod selector valve and a separate pilot fluid manifold for operating subsea control valves. The pilot manifold should contain the necessary valves to send pilot signals to all of the subsea pilot operated valves. When a valve on the control manifold is operated, a pilot signal is sent to a subsea control valve which, when operated, allows flow of power fluid to operate the BOP's or other stack functions.

16E.3.5.1 The pilot manifold contains hydraulic pressure regulators to pilot the subsea pressure regulators. Provisions should be made so that any rig service failures to the remote controls for the surface regulators should not cause loss of subsea pressure regulator setting or control. Provisions should be made for manual intervention and control of the surface regulators at the control manifold.

An isolated pilot supply (pneumatic or hydraulic) should be provided for the remote operation of the manifold mounted control valves. Loss of pilot supply should not affect the manual operation of the control system.

The remote control system should permit operation of all the surface control valves at least two times after the loss of rig air and/or electric power.

16E.3.5.2 The pilot system should include components to indicate the selected position of the BOP's at the remote panels by sensing the presence of pilot signals. Refer to Section 16E.3.6.5.2.

16E.3.5.3 The hydraulic control manifold should be equipped with a flowmeter which measures the volume of flow supplied subsea from the pumps and surface accumulators. The hydraulic fluid volume measured when a particular function is operated may be used as an indication of the proper operation of that function.

16E.3.5.4 The hydraulic control manifold should include pressure gages to indicate the accumulator pressure, pilot system pressure, main hydraulic subsea supply pressure, subsea manifold regulator pilot pressure, subsea manifold regulated (readback) pressure, subsea annular BOP regulator pilot pressure, subsea annular BOP regulated (readback) pressures and rig air pressure.

16E.3.5.5 The hydraulic control manifold should contain a visible and audible alarm for low accumulator pressure, low rig air pressure and loss of primary electrical power supply.

16E.3.5.6 The hydraulic control manifold should be installed in a location remote from the rig floor. The hydraulic manifold should be easily accessible in case of emergency. All functions on the hydraulic control manifold should be remotely operable from the rig floor (driller's panel).

16E.3.5.7 The control manifold interface should be designed so that all control signals and power fluid supplies have redundant access (two separate jumpers, umbilical hose bundles, reels and control pods) to the shuttle valves on the BOP stack functions. Retrievable pods should be individually retrievable to the surface without loss of operability of any of the BOP stack functions through the other pod.

16E.3.5.8 The valve handles or push buttons to control critical functions such as shear rams, wellhead and riser connector and connector secondaries should be provided with hinged covers or other means to prevent inadvertent operation. The covers should not interfere with remote operating capability. All valves, regulators and gages should be clearly labelled to indicate function and position status.

16E.3.5.9 Subsea blind/shear ram control circuits may be designed to permit the option of either closing as a blind ram at regulated pressure or shearing at a higher pressure.

16E.3.5.10 The main hydraulic power fluid supply and hydraulic pilot supply to the control manifold should be filtered in accordance with the control system manufacturer's recommendations. Filtering devices should be marked to indicate restriction size. A dual filter parallel arrangement with isolation valves for independent fluid routing should be used. Filters should permit bypassing clogged elements rather than interrupting system operation and should have a bypassing indicator.

HYDRAULIC MANIFOLD ELECTRIC REMOTE PANEL INTERFACES

16E.3.5.11 The control manifold functions should be indicated at, and operable from, one or more remote control panels connected in parallel. This typically requires that the manifold control unit contain solenoid valves to convert the electric command signals coming from the remote panels to control function hydraulic power fluid signals and readback transducers to convert function actuations and measurements to electrical signals for status monitoring.

16E.3.5.11.1 Electrical power for the remote controls and indicators should be provided from an uninterruptible power supply. The uninterruptible power supply should provide sufficient battery storage capacity to operate the remote controls and indicators for a minimum of two hours after the loss of primary electrical power. The automatic transfer from primary to secondary power should be bumpless and not affect any memory circuit operation.

16E.3.5.11.2 If the hydraulic manifold is installed in a hazardous area as defined in API RP 500B; all electrical enclosures, exposed electrical components and their installation should be certified as suitable for use in the hazardous location in which it is installed. All such electrical equipment should meet the requirements of API RP 14F Sections 2, 4, 5, 6, 8, 10.1 and 10.2.

16E.3.5.11.3 Electro-hydraulic or electro-pneumatic devices mounted inside junction enclosures should be vented to the outside of the enclosure. Consideration should be taken in manifolding multiple vents and sizing vent lines to avoid back pressure to other components.

16E.3.5.11.4 Failure of a remote control circuit component, including a conductor/cable, should not cause any function to be unintentionally operated.

16E.3.5.11.5 All electrical circuits and/or components common to the entire control system (i.e., control circuits, memory circuits, alarm circuits, cables, etc.) should be located at the central control point at or near the control manifold so that disabling of one of the remote panels will not affect the other panels. Therefore, all remote panels should be connected in parallel.

16E.3.5.11.6 Hydraulic interfaces should be maintained outside of the electrical enclosure where possible. If hydraulic interfaces are present inside the enclosure, an internal hydraulic fluid leak should not affect the operation of the electrical system.

REMOTE CONTROL AND MONITORING PANELS

GENERAL

16E.3.6 The subsea BOP control system should have capability to control all of the BOP stack functions including pressure regulation and monitoring of all system pressures from at least two separate locations. One location should be in a non-classified (non-hazardous) area as defined in API RP 500B. This may be accomplished by placing the main hydraulic control unit in a non-hazardous area remote from the rig floor (refer to 16E.3.5.6) and a full function remote control panel (driller's panel) accessible to the driller on the rig floor.

16E.3.6.1 In addition to the driller's panel and main hydraulic control unit at least one remote control panel should be provided for BOP stack functions.

16E.3.6.2 Remote panels should have visible and audible alarms. A means to silence the audible alarm may be provided. Alarm conditions arising after executing an alarm silence should again activate the audible alarm. All alarm monitors should automatically reset after the condition that caused the alarm has been corrected.

16E.3.6.2.1 The following visual and audible alarms should be included on the driller's panel and may be included on other panels.

1. Low control system (rig) air supply pressure
2. Low accumulator pressure
3. Low mixed hydraulic fluid level
4. Low glycol level (if applicable)
5. Low soluble lubricant level
6. Power loss alarm (indicating loss of remote control supply, on backup power)
7. Low air purge pressure, (if applicable) a separate indicator lamp should be provided for each purged enclosure
8. Loss of pump system electric power supply
9. Pumps running (visual indicator only).

16E.3.6.2.2 Alarm set points should be established within the limits of safe operation. Alarms should be activated prior to reaching unsafe levels.

16E.3.6.3 The BOP stack configuration and function status should be graphically displayed on the faces of all remote panels.

16E.3.6.4 Remote panels should have status indicating lights to show the position of the control valves they operate (or monitor) and related function positions. Circuits should retain memory in the event of momentary primary power interruptions.

16E.3.6.4.1 All panels should have means for illumination testing all lamps. They may be tested individually or as a panel set. A panel or individual lamp test should not affect any other panel in the control system.

16E.3.6.4.2 Panel lamps used to indicate function status should track the position of the hydraulic control valves. Red, amber and green should be used as standard colors for control panel indicator lights. Illumination of the green light should indicate that the function is in its normal drilling position. The red light should indicate that the function is in an abnormal position. The amber light (when used) should indicate that the 3-position control valve is in its vent or block position. The red or green light should be on whenever the block (amber) light is on, and thereby indicate the function's last selected position.

Other indicator light colors may be used for information display on particular functions such as selection of yellow or blue subsea control pods.

16E.3.6.5 Panel displays (lamps, meters, etc.) should be sufficiently luminous to be readily discernible in all conditions of ambient light in which the panel will be operated.

16E.3.6.6 A transparent safety cover or grille should be provided on the following function pushbutton controls:

1. Riser connector unlock
2. Riser connector secondary unlock
3. Shear rams close and high pressure shear rams close (if applicable)
4. Wellhead connector unlock
5. Wellhead connector secondary unlock
6. Emergency disconnect sequence activate (if applicable)
7. Any other function which could adversely affect normal operation if inadvertently operated.

16E.3.6.7 All panel control functions should require two handed operation. Regulator control may be excluded from this requirement if inadvertent operation does not adversely affect normal operation.

16E.3.6.8 Panel pushbuttons should be spaced to avoid two buttons being inadvertently pressed simultaneously.

16E.3.6.9 All analog circular mechanical meter movements should have a movement of 120° or greater. All analog displays should have a minimum resolution of 5%. System accuracy should be within ± 2.5% of full scale.

16E.3.6.10 All pressure readings should be displayed in psi. Additional units of measure are optional.

16E.3.6.11 Keyboards, CRTs, alphanumeric displays etc., may be used as appropriate provided the requirements of 16.E.3.6.4, 16E.3.6.5, and API RP 14F, Sections 2, 4, 5, 6, 8, 10.1 and 10.2 are met. In addition, if such equipment is being used as one of the control stations required by this document, the entire BOP stack and diverter status should be displayed simultaneously and the capability to operate any function using a single entry should be included. The use of menu driven controls or paging should be avoided in this application.

16E.3.6.12 No more than 150V RMS should be connected to any control system component mounted in a control panel face or any component requiring routine adjustment.

Any voltage higher than 150V RMS should be confined inside an enclosure requiring tools to gain access. Appropriate high voltage warning signs should be mounted on the enclosure.

16E.3.6.13 Any enclosure door with electrical components mounted on it should have a ground strap connecting the door to the main enclosure.

16E.3.6.14 No hydraulic lines or components containing hydraulic fluid should be mounted inside of any control panel in such a way that a hydraulic leak would render all or part of the system electrical controls inoperative. Electro-hydraulic components may be mounted in a dedicated junction box provided that any hydraulic leak will not migrate to other parts of the control system, or cause a loss of system power from short circuits or otherwise render the remainder of the control system inoperative.

16E.3.6.15 In addition to the above requirements, all electrical components, panels, etc., exposed to a hazardous atmosphere as defined in API RP 500B, should conform to the requirements of API 14F, Sections 2, 4, 5, 6, 8, 10.2 and 10.3.

DRILLER'S PANEL (RIG FLOOR PANEL)

16E.3.6.16 The following BOP control system pressures should be displayed on the driller's panel:

1. Annular BOP regulated pressure (readback)
2. Annular BOP regulator pilot pressure
3. Manifold regulated pressure (readback)
4. Manifold regulator pilot pressure
5. Control system (rig) air supply pressure
6. Accumulator pressure
7. Pilot supply pressure
8. Main hydraulic supply pressure

16E.3.6.17 A resettable readout indicating the transferred volumes of subsea control fluid in suitable fractions of a gallon should be provided on the Driller's Panel. Additional units of measure are optional.

16E.3.6.18 Driller's panels should be designed to meet the recommendations of API 14F, Sections 2, 4, 6, 8, 10.1 and 10.2.

16E.3.6.19 If an air purge system is used, a loss of air purge in any junction box or control panel should activate an alarm at the affected panel and at the driller's panel. The driller should have the means to electrically disconnect or totally isolate the panel or junction box if the condition is considered hazardous.

UMBILICAL CONTROL HOSE BUNDLES, RIGID CONDUIT AND SUBSEA ACCUMULATORS

16E.3.7 Umbilical control hose bundles are used to provide the main supply of power fluid and pilot signals from the surface hydraulic control manifold to the subsea control pods mounted on the BOP stack. The surface jumper hose bundle is a fixture on the rig that extends from the manifold to the hose reel. The subsea umbilical is run, retrieved and stored on the hose reel.

The pilot signals are routed to the hose reels through the appropriate length of surface umbilical jumper hose bundle from the hydraulic junction boxes located on the control manifold.

The main hydraulic power fluid supply is normally carried by a steel pipe run communicating through a swivel fitting on the hose reel through a 1" nominal size supply hose in the hose bundle to the subsea control pod.

16E.3.7.1 Two separate and independent sets of surface and subsea umbilicals should be employed; one dedicated to each control pod.

16E.3.7.2 Design requirements for umbilical hose bundles include:

1. Umbilical hose bundles should consist of sufficient numbers and sizes of hydraulic fluid conductors to pilot the operation of all of the subsea BOP stack functions and provide readback pressures to the surface. Spare conductors should be available to add functions or replace faulty fluid conductors.
2. Fluid conductors should be rated for the maximum pressure of the hydraulic circuit in which they are used.
3. Fluid conductor cores should be designed to withstand continuous exposure to control fluid.
4. Fluid conductors, where possible, should be continuous end to end without splices or restrictions. Where splices are necessary they should not appreciably affect pressure integrity or

response times. Splices should be tested in accordance with item 8. Each splice location should be identified on the outer sheath of the umbilical.

5. Permanently attached stainless steel end fittings rated for the design working pressure and hose application should be fitted on both ends of each hydraulic fluid conductor.

6. Fluid conductors should be sufficiently reinforced and enclosed in a durable oil resistant outer sheath with inner filler material to prevent collapse or kinking if proper minimum bend radius is maintained.

7. Fluid conductors in multi-conductor assemblies should have discrete identification, at least every 18 inches throughout the entire length.

8. Fluid conductors complete with end fittings should be hydrostatically tested to one and one-half times the design working pressure for a minimum of one hour without showing signs of leak, blister or permanent deformation.

9. The umblical assembly should be capable of operating at the rated working pressure and bend radius within the anticipated service temperature range.

10. Design and materials used in the manufacture of subsea umbilicals should take into account the affect of the configuration of the pilot hoses on the response time and recommendations of 16E.3.1.

11. The length of the subsea umbilical should allow proper routing from the hose reel and a minimum of three wraps of umbilical on the hose reel drum when the hose is deployed at the rig's maximum planned water depth.

16E.3.7.3 Subsea hose umbilicals for retrievable control pods are usually supported by wire lines running to the pods with clamps on the wire lines spaced at least one per riser joint. Umbilicals for non-retrievable pods are usually clamped to the riser. All clamps should be corrosion resistant or suitably coated for long term immersion in salt water and designed for quick installation and removal when running or retrieving the subsea umbilical. The umbilical hose bundle should not be used to pull or support weight.

16E.3.7.4 Power fluid may be conducted subsea through a large diameter (commonly 1″ nominal) hose included in each of the umbilical hose bundles. Optionally, a large diameter rigid conduit auxiliary line integral to the marine riser affords enhanced flow capacity to offset high frictional losses. Supply means should have adequate flow capacity to meet the response time limits recommended in Paragraph 16E.3.1. For backup capability, two independent supply means (two rigid conduits, two dedicated hoses or one of each), should be employed. Another option is to use a single rigid conduit or a single dedicated hose with BOP stack mounted, rechargeable accumulators as a backup.

Accordingly, when accumulators are employed on the BOP stack as a backup power fluid supply, the usable stored hydraulic fluid volume should be sufficient to close one annular BOP, three ram type BOP's plus fifty percent reserve without resupply from the surface. The pressure remaining after closures should comply with the recommendations stated in 16E.3.4.1. The stored capacity should be protected from inadvertent discharge through the supply lines by suitable devices such as pilot operated check valves.

ELECTRIC POWER SUPPLY AND DISTRIBUTION

16E.3.8 The electrical remote control panels and associated components necessary to operate the BOP control manifold from a remote location should receive power from a minimum of two electrical power sources, the primary supply and the backup supply. In the event of the loss of primary power, the backup supply should be capable of sustaining full system normal operational capabilities for a minimum of two hours.

16E.3.8.1 All over-current protection devices should be sized to protect the smallest conductor wire in the control circuit. Series over-current protection devices should be progressively smaller as required.

16E.3.8.2 Resettable over-current protection devices should be used between the system backup power supply and the control system. Any over-current protection device which will disable the system should be of the resettable type.

16E.3.8.3 Each control panel or point should be protected by an over-current protection device in each main power connection.

16E.3.8.4 The condition of any over-current device should be discernible by visual inspection.

16E.3.8.5 An alarm circuit should indicate failure of the primary power source. The alarm should be indicated on the driller's panel audibly and by a flashing red light.

16E.3.8.6 In the event of a transfer of load from the primary to the secondary power supply the control system should be unaffected (i.e., a "bumpless transfer").

16E.3.8.7 Any battery pack capable of generating flammable or toxic gases should be properly ventilated and the gases exhausted away from personnel, sensitive equipment and sources of ignition.

HOSE REELS

16E.3.9 Hose reels are used to store, run and retrieve the umbilical hose bundles which communicate the main hydraulic power fluid supply and command pilot signals to the subsea mounted BOP control pods. The hose reels are equipped with hose reel manifolds having valves, regulators and gages for maintaining control through the subsea umbilical of selected functions during running and retrieving of the pod or LMRP and/or the BOP stack. Additional hose handling equipment includes hose sheaves used to support and change direction of the subsea umbilical while maintaining the specified minimum bend radius recommended by the umbilical manufacturer.

16E.3.9.1 The hose reel drum diameter should be a minimum of two times the minimum bend radius recommended by the manufacturer of the subsea umbilical.

16E.3.9.2 The hose reel drive should have a minimum torque capacity of 1.5 times the maximum anticipated torsional load.

16E.3.9.3 The hose reel should be powered by either an air or hydraulic motor controlled by a valve on the reel frame or mounted at a remote location. The hose reel control station should be located to give the operator an unobstructed view of the moonpool area and routing of the subsea umbilical.

16E.3.9.4 The hose reel control valve should be equipped with a device that prevents operation of the hose reel motor or locks the drum when the jumper hose assembly is connected at the reel.

16E.3.9.5 The hose reel drum should be equipped with a brake capable of overriding and stalling the motor. The brake should be capable of supporting the weight of the fully deployed subsea umbilical when it is suspended in water.

16E.3.9.6 The hose reel drum should have a mechanical locking device that positions the hose reel manifola and junction box in an accessible position.

16E.3.9.7 The hose reel assembly should be especially prepared and coated to withstand direct exposure to salt water spray.

16E.3.9.8 Two independent hose reels should be provided. Each reel should be clearly identified regarding which subsea control pod it services. Standard practice is to color code the reels or the hose reel manifolds one blue and one yellow corresponding to the color of the associated pod.

HOSE REEL MANIFOLD

16E.3.9.9 The hose reel manifold provides control of selected functions through the pilot lines when the hydraulic jumper hose to the control manifold has been removed to permit rotation of the hose reel drum.

16E.3.9.9.1 All functions required to land and retrieve the LMRP and/or the BOP stack should remain fully active during landing and retrieval.

16E.3.9.9.2 All hydraulic fluid components used in the hose reel manifold system should have a rated working pressure at least equal to the design working pressure of the control system.

HOSE SHEAVES

16E.3.9.10 Hose sheaves should facilitate running and retrieving the subsea umbilical from the hose reel through the moonpool and support the moonpool loop which is deployed to compensate for vessel heave.

16E.3.9.10.1 Hose sheaves should be mounted to permit three-axis freedom of movement. The design should prohibit damage to the umbilical in normal ranges of anticipated movement.

16E.3.9.10.2 The hose sheave design should permit installation of the umbilical without disconnecting from the hydraulic junction box assemblies to which the umbilical may be terminated.

16E.3.9.10.3 Wheels or rollers which support a bend in the subsea umbilical should have a minimum arc of one hundred seventy degrees of load bearing support and provide a bend radius greater than the minimum bend radius recommended by umbilical manufacturer.

16E.3.9.10.4 All components of the hose sheave assembly should be constructed from corrosion resistant materials or be properly coated to withstand exposure to salt water spray.

SUBSEA CONTROL PODS

16E.3.10 Each control pod should contain all the pressure regulators, valves and straight-through functions required to operate all subsea functions.

16E.3.10.1 Two control pods should be used to provide redundant control of all subsea functions. The surface control manifold should direct pilot commend signals to operate the pressure regulators, control valves, and straight-through functions in the pod.

16E.3.10.2 An umbilical strain relief/radius guard should be employed at the pod/umbilical interface to prevent the umbilical from being bent on a radius less than the umbilical manufacturer's minimum recommended bend radius.

16E.3.10.3 Isolation means should be provided so that, if one pod is disabled, it should not affect the operation of the other pod or the subsea functions.

16E.3.10.4 There are currently two basic designs for hydraulic control pods for subsea systems. They are those designed to permit retrieving the pods (retrievable) to the surface independently of the LMRP (lower marine riser package) and those designed to be attached to the LMRP (non-retrievable pods).

16E.3.10.5 The subsea pressure regulators in each pod should provide regulated pressures to ensure proper operation of the designated function(s). The valves and regulators should be sized to supply the volume required to operate each function within its specified response time in accordance with Section 16E.3.1.

16E.3.10.6 The retrievable pods should consist of:

1. The Pod Assembly — The pod assembly should include the hydraulic regulators, hydraulic pilot operated subsea function valves, interfacing port seals and all mechanical apparatus to operate the BOP stack which may require maintenance during the drilling operation.

   NOTE: *Redundancy of the subsea control equipment is mandatory. This allows one pod to be retrieved for repair while maintaining control with the other pod.*

2. LMRP Receiver Blocks — These blocks are mounted on the LMRP and are designed for landing and locking the pod assembly. Porting in the LMRP receiver blocks direct control fluid from the pod to appropriate outlet connections to operate the riser connector and other hydraulic actuated riser functions.

3. Pod Locks — Surface controlled locking devices are required to latch retrievable hydraulic control pods to the LMRP receiver blocks. The pod locks are normally hydraulically activated. A manual means to unlock in the event hydraulic lines are severed is recommended in addition to the hydraulic lock.

4. Stack Receiver Blocks — These blocks are mounted on a spring housing which is mounted on the BOP stack frame. The blocks are ported to direct control fluid from the pod to the appropriate outlet connections to operate BOP stack functions. The spring housing assembly should be designed to maintain proper alignment and provided proper preload against the pod seals. When the LMRP is landed and locked, communication paths between the stack hydraulic control function connections and the surface control equipment is established. Since the pod is not latched to the stack receiver blocks, but engagement is matintained by spring force alone, this provides a quick disconnect means permiting the LMRP to be retrieved independently of the BOP stack.

   16E.3.11.6.1 Careful consideration should be employed in the design of all subsea components to minimize the corrosive effect of salt water to the materials. Sacrificial anodes are recommended at dissimilar metal junctures.

   16E.3.11.6.2 Pods should be color coded, striped or otherwise distinguished so that identification by subsea cameras is easily discernible.

   16E.3.11.6.3 Pod seals should be designed to be captive in the pod assembly and to prevent seal damage should the pod be separated from the receiver blocks under pressure.

16E.3.11.7 Non-retrievable pods should be designed employed the same considerations as retrievable pods except that the pod assembly is mounted to the LMRP. This eliminates the need for pod locks as the pod can only be retrieved with the LMRP. The stack block is still required to interface between the pod assembly and the BOP stack function control lines.

SECTION 16E.4
ELECTRO-HYDRAULIC AND MULTIPLEX CONTROL SYSTEMS FOR SUBSEA BOP STACKS

16E.4 Electro-hydraulic and multiplex control systems are used in deep water where response times of hydraulic signals would be too lengthy. Hydraulic signal transmission time is lengthened by physical expansion of the fluid conductor hose as the internal pressure surges. Electrical command signals transmitted over lengthy subsea umbilical cables have shorter response times than hydraulic pilot signals transmitted over hose bundles of equal length.

Electrical command signals operate subsea solenoid valves which, in turn, provide hydraulic pilot signals directly to operate the pod valves that direct power fluid to the subsea functions.

Electro-hydraulic control systems have parallel capability to execute and receive commands whereas multiplex control systems process multiple signals on each conductor set. Electro-hydraulic systems have conductor wires in the subsea umbilical cable dedicated to each function.

Multiplex (MUX) systems serialize and code the command signals which are then sent subsea via shared conductors in the umbilical cable. Multiplex control system logic may incorporate additional security by requiring transmission of a coded message to the subsea pod, return of the message to the surface by the pod electronics package for verification, and re-transmitting the verified command before execution of the function. Subsea data are electrically transmitted to the surface.

RESPONSE TIME

16E.4.1 Refer to 16E.3.1

MIXING AND STORAGE EQUIPMENT

16E.4.2 Refer to 16E.3.2

PUMP REQUIREMENTS

16E.4.3 Refer to 16E.3.3

ACCUMULATOR BOTTLES AND MANIFOLDS

16E.4.4 Refer to 16E.3.4

ELECTRICAL CONTROL UNIT

16E.4.5 The electrical control unit is the central control point (corresponding to the hydraulic control manifold of a hydraulic control system).

16E.4.5.1 The electrical control unit should be supplied electrical power from an uninterruptible power supply. Refer to the Section 16E.3.8.

16E.4.5.2 The electrical control unit should be located in a safe, dry area. All functions should be operable from and monitored from a remote control panel located on the rig floor interfacing with the central control unit. Refer to Section 16E.3.6 for construction recommendations.

16E.4.5.3 The electrical control unit should maintain function status memory in the event of power interruption. Upon restoration of power, the system should display the status of all functions as they were prior to the loss of power.

CONTROL PANELS

16E.4.6 Refer to Section 16E.3.6

CONTROL HOSES

16E.4.7 Refer to Section 16E.2.7

CONTROL FLUIDS

16E.4.8 Refer to Section 16E.3.2

ELECTRICAL POWER SUPPLIES

16E.4.9 Refer to Section 16E.3.8

SUBSEA UMBILICAL CABLES AND CONNECTORS

16E.4.10 The subsea umbilical cable is run, retrieved and stored on a cable reel. The subsea umbilical electrical cable supplies power, communications, and control of the subsea control pods. The electrical cable may be integral to the hydraulic fluid supply hose or, more commonly, be a stand alone assembly. If the cable is a component part of the hose and reel assembly, the recommendations outlined in this section apply as well as the recommendations for hose reels in Section 16E.3.10.

16E.4.10.1 Two complete independent cables should be used. The severing, opening, or shorting of one cable assembly should not disable the surface equipment and the pod connected to the other cable should remain fully functional.

16E.4.10.2 The umbilical cables to be routed from the reels to the pods should be routed and secured in a manner that will minimize the chances of kinking, twisting, birdcaging, or otherwise damaging the cable. The cables should also be routed separately to minimize the possibility of both cables being severed simultaneously.

16E.4.10.3 Each elelctrical cable should contain all communications and/or power conductors required to control all the subsea functions through one pod.

16E.4.10.4 The cable should be torque balanced to prevent kinking and twisting. The cable should be designed to be capable of supporting at any point along its drum length, two times the weight of the full cable length in water. The electrical conductors and electrical insulation should not be used as load bearing components in the cable assembly.

16E.4.10.5 All underwater electrical umbilical cable terminations should be water blocked to prevent water migration up the cable in the event of connector failure or leakage and to prevent water migration from the cable into the subsea connector termination in the event of water intrusion into the cable. Individual conductor terminations should be physically isolated so that seawater intrusion does not cause electrical shorting. A pressure compensated junction box containing dielectric fluid may be used to accomplish this.

CABLE REELS

16E.4.11 The cable reels should be designed to run and retrieve the cable without damaging or kinking.

16E.4.11.1 All functions required to run, land and retrieve the LMRP and/or the stack should remain fully active during running, landing and retrieval.

16E.4.11.2 The cable reel brake should have sufficient capacity to stall the cable reel at full torque output.

16E.4.11.3 A mechanical locking mechanism should be used to lock the drum in position.

16E.4.11.4 All cable reel components should have an environmental rating suitable for the area in which the reel is installed.

16E.4.11.5 The cable reel may have payout and take up controls located on the reel or at a remote location. If a remote control station is used, there should also be controls at the reel capable of overriding the remote controls.

16E.4.11.6 All electrical terminations, slip rings, etc., should be protected against moisture.

16E.4.11.7 Slip ring contact assemblies should be of a non-oxidizing material suitable for the surrounding atmosphere. Contacts should be designed to minimize the possibility of flash over between the contacts.

16E.4.11.8 Slip ring contact material should be designed to minimize wear and the formation of resulting conductive dust which could cause signal degradation and short circuits.

16E.4.11.9 If the slip rings are located in a hazardous area they should be rendered safe by one of the approved means outlined in NEC and ISA specifications.

UMBILICAL HOSES AND RIGID CONDUITS (AS REQUIRED)

16E.4.12 Refer to Section 16E.3.7.

HOSE REELS (AS REQUIRED)

16E.4.13 Refer to applicable paragraphs in Section 16E.3.9.

SUBSEA CONTROL PODS/MANIFOLDS AND ELECTRICAL EQUIPMENT

16E.4.14 The control pod serves as the subsea control valve manifold and contains all the pressure regulators and valves required to operate the subsea functions.

16E.4.14.1 Two control pods/manifolds should be used to provide backup control of all subsea functions.

16E.4.14.2 The surface electrical control point should direct function commands through the umbilical cables to operate the pressure regulators, valves and straight-through functions installed in the pod.

16E.4.14.3 A cable strain relief/radius guard should be employed at the cable/pod interface.

16E.4.14.4 In the event of failure of one pod/manifold, the disabled pod should not affect the operation of the other pod/manifold or the subsea functions.

16E.4.14.5 The subsea pressure regulators in each pod/manifold should provide regulated pressures to ensure proper operation of the designated function. The valves and regulators should be sized to supply the volume required to operate each function within the specified response time.

16E.4.14.6 The pods may or may not be retrieved independently of the LMRP. A retrievable control pod assembly should be comprised of the retrievable control pod and at least two pod receivers (single receiver assembly or multiple stab type). One receiver should be mounted on the LMRP to provide the landing and seal interface between the pod and LMRP functions (LMRP receiver). The second receiver should be mounted on the BOP stack to provide the landing and seal interface between the pod or LMRP and the BOP stack functions (BOP stack receiver). Proper alignment between the control pod and receivers should be maintained to ensure fluid seal integrity. Usually, one elastomeric/steel seal assembly is dedicated to each function interface.

16E.4.14.7 A retrievable control pod should be equipped with a remote controlled locking mechanism to lock the control pod to the LMRP or receiver. If conditions dictate, the control pod locking mechanism may be capable of being unlocked by means of a mechanical override operable from the vessel.

16E.4.14.8 Non-retrievable control pods/manifolds are usually fixed to the LMRP and may require only the BOP stack receiver to provide the landing and fluid seal interface for the control pod to the BOP stack.

16E.4.4.14.9 Corrosion in the subsea control equipment should be minimized by implementing measures such as anticorrosive coating selection, corrosion resistant material selection, cathodic protection, etc.

SUBSEA ELECTRICAL EQUIPMENT

16E.4.14.11 All electrical connections which may be exposed to seawater should be protected from over current to prevent overloading the subsea electrical supply system in the event of water intrusion into the connection.

16E.4.14.11.1 All electrical apparatus to be used subsea is to be temperature rated to be fully operational on a continuous basis while exposed to surface ambient conditions without the use of auxiliary cooling or heating.

16E.4.14.11.2 All subsea electrical equipment should be designed to be suitable for use subsea with particular attention paid to mechanical vibration and shock induced while drilling. Plug-in devices should be mechanically secured.

16E.4.14.11.3 Auxiliary subsea electrical equipment which is not directly related to the BOP control system should be connected in such a manner to avoid disabling the BOP control system in the event of a failure in the auxiliary equipment.

16E.4.14.11.4 All subsea electrical equipment should be galvanically isolated from any surface exposed to seawater.

16E.4.14.11.5 All electrical and electronic chambers should be double sealed at all areas exposed to seawater or hydrostatic pressure with a provision for a test port. A chamber containing electrical components which is filled with dielectric fluid and pressure compensated to the ambient pressure surrounding the stack may be sealed using a single seal.

SECTION 16E.5
DIVERTER CONTROL SYSTEMS GENERAL

GENERAL

16E.5 The diverter control system should be designed to preclude closing-in the well with the diverter. This requires opening one or more vent lines prior to closing the diverter as well as closing normally open mud system valves.

Hydraulic control systems for subsea diverter stacks, if used, should be designed in accordance with the guidelines of Section 16E.3.

RESPONSE TIME

16E.5.1 A diverter control system should be capable of operating the vent line and flow line valves (if any) and closing the annular packing element on pipe or open hole within thirty seconds of actuation if the packing element has a nominal bore of twenty inches or less. For elements of more than twenty inches nominal bore, the diverter control system should be capable of operating the vent line and flow line valves (if any) and closing on pipe in use within forty-five seconds. See Section 16E.2.1.

16E.5.2 The diverter control system may be supplied with hydraulic control pressure from the BOP control system. In this case there is usually more accumulator capacity, pump capacity and reservoir capacity than is required for the diverter system. These should, however, comply with the recommendations which follow for a self-contained diverter control system. An isolation valve should be installed in the line from the main hydraulic supply to shut off the supply to the diverter control system when it is not in use. The function of this valve should be clearly labelled and its position status should be clearly visible.

STORAGE EQUIPMENT (SELF-CONTAINED UNITS)

16E.5.2.1 A self-contained diverter system control system should have a control fluid reservoir sized to hold a minimum of two times the usable hydraulic fluid of the accumulator system. See Section 16E.2.2.

PUMP REQUIREMENTS (SELF-CONTAINED UNITS)

16E.5.3 The pump system(s) for diverter system control systems should be designed to automatically stop the pump(s) when the full design accumulator charging pressure is reached and to automatically re-start the pump(s) when the pressure decreases to not more than 90 percent of the charging pressure. The automatic pressure control system should additionally include a secondary overpressurization protection device such as a relief valve. The relief valve should be set to relieve overpressurization at not more than 110 percent of the design accumulator charging pressure. Relief valves should be designed to automatically reseat and shut off within 25 percent below the pressure setting. Refer to Section 16E.2.3.2 for additional recommendations.

16E.5.3.1 The pump system(s) should be capable of recharging the diverter control system accumulators to full system design pressure within five minutes after one complete divert mode operation of the diverter control system. This should be verified by fully charging the accumulators, isolating the pumps from service, and sequencing the divert functions using accumulators only. The pumps should then recharge the accumulators within five minutes. Pump requirements relative to the BOP stack are given in Section 16E.2.3.

16E.5.3.2 An alternate means (back-up system) should be employed to permit sequencing the diverter system should the primary closing system become inoperative. This can be accomplished by alternative pump system capacity, separate isolated accumulator capacity, nitrogen back-up capacity or other means. The back-up system should be capable of meeting the recommendations of Section 16E.5.1. The back-up system should be automatically or selectively available on demand.

ACCUMULATOR VOLUMETRIC CAPACITY

16E.5.4 The diverter control system should have sufficient accumulator capacity to provide the usable hydraulic fluid volume (with pumps inoperative) required to operate all of the divert mode functions plus fifty percent reserve. Refer to Section 16E.2.4 and subsequent sub-paragraphs for a complete description of accumulators and calculation method.

DIVERTER CONTROL MANIFOLD

16E.5.5 The diverter control manifold consists of control valves, regulators and gages. The control valves should graphically represent the actual diverter equipment arrangement and be clearly identified as to their purpose and functional position.

16E.5.5.1 The diverter control system should be designed to prohibit closing the diverter packer unless a vent line has been opened. If the diverter in use is equipped with an insert packer and/or pressure energized flow line seals, the control system sequencing circuitry should additionally prevent closing the diverter packer if the insert packer is unlocked or if the flow line seals are not energized.

16E.5.5.2 Where applicable, the control system should be capable of switching the diverted flow from one vent line to the other (for example, port to starboard) while the diverter packer is closed without shutting-in the well.

16E.5.5.3 Regulators used in the diverter control system should reduce operating pressure to within the manufacturer's limits for the components being operated and be capable of adjustment to within the recommended operating parameters. If relief valves are used to limit maximum pressure, they should be of the self-reseating type and should reseat within ten percent below the relief setting.

16E.5.5.4 All hydraulic and pneumatic components of the diverter control system should have a rated working pressure at least equal to the maximum design working pressure of the system in which they are installed.

16E.5.5.5 An air storage or nitrogen backup system should be provided with capability to operate all of the pneumatic functions at least twice in the event of loss of rig air pressure.

CONTROL PANELS

16E.5.6 All of the diverter control functions should be operable from the rig floor. A second control panel should be provided in an area remote from the rig floor. The remote area panel should be capable of operating all diverter system functions including any necessary sequencing and control of the direction of the diverted flow. Panels should meet applicable recommendations of Section 16E.2.6.

CONTROL HOSES

16E.5.7 Piping systems and/or control system hoses should meet the recommendations of Section 16E.2.7.1.

CONTROL FLUIDS

16E.5.8 Control system fluids should meet the recommendations of Section 16E.2.2.

ELECTRICAL POWER SUPPLIES

16E.5.9 Electrical power supplies should meet the recommendations of Section 16E.2.8.

SECTION 16E.6
EMERGENCY BACKUP CONTROL SYSTEMS

16E.6 In the event that, supply of power fluid or pilot signals is lost, an emergency backup control system may be employed to operate critical functions. Types of emergency backup control systems for subsea controls include acoustic control systems, ROV (Remotely Operated Vehicle) operated control systems and LMRP recovery systems. For surface installations, a nitrogen backup system may be used.

ACOUSTIC CONTROL SYSTEMS

16E.6.1 Acoustic signal transmission can be used as a backup means for controlling critical BOP stack functions in the event the main subsea control system becomes inoperative. The acoustic control system includes a surface electronics package, subsea electronic package and a subsea electro-hydraulic package.

ACOUSTIC SYSTEM SUBSEA ACCUMULATORS

16E.6.1.1 A dedicated subsea accumulator bank should be provided that can be charged from the main BOP control system. The main BOP control system should provide a means for charging the acoustic accumulators in a manner that will isolate the main control system from the acoustic control system in the event the main control system pressure is depleted.

ACCUMULATOR VOLUMETRIC CAPACITY

16E.6.1.1.2 The acoustic subsea accumulator system should be compensated for subsea hydrostatic pressure gradient and sized to provide the usable hydraulic fluid (without input replenishment) to operate all functions selected for emergency operation plus fifty percent reserve. The remaining pressure of the reserve fluid after operation should meet the recommendations of Section 16E.3.4.1 item 2.

The functions typically selected for emergency operation include:

Riser Connector	—	Unlock
Shear Ram	—	Shear
Upper Ram	—	Close
Middle Ram	—	Close
Ram Locks	—	Lock (if applicable)

ACOUSTIC SYSTEM HYDRAULIC CONTROL FUNCTIONS

16E.6.1.2 The acoustic control system should be designed so that the electric control system functions can be tested without actuation of the BOP stack functions. To accomplish this, a two-way acoustic communication system is recommended. Commands are sent subsea from the surface control unit while accumulator pressure is shut off subsea. Status monitoring signals are sent back to the surface to verify electric function actuation.

16E.6.1.2.1 Solenoid valves provide hydraulic pilot signals to shift hydraulic valves to the open position. These in turn direct the accumulator supply pressure that operate the BOP stack functions. The solenoid valves must be suitably isolated from seawater. The hydraulic valves should be connected to the stack functions by way of shuttle valves (or alternate means) to allow acoustic operation of the stack without affecting operability from the main control system.

16E.6.1.2.2 A manifold supply isolation valve should facilitate testing the actuation of the solenoid valves without power fluid being supplied to the BOP stack control valves.

16E.6.1.2.3 A means should be provided to allow venting the subsea accumulator pressure prior to or during retrieving the accumulators to the surface.

16E.6.1.2.4 Hydraulic components and piping systems should have a rated working pressure at least equal to the rated working pressure of the control system.

ACOUSTIC SYSTEM ELECTRONIC CONTROL FUNCTIONS

16E.6.1.3 The acoustic control electronic system should be designed and constructed to provide a maximum operational integrity for the operating depth and distance specified and should provide security command signal coding to prevent operation by other equipment in close proximity. Frequencies used should not interfere with other equipment on the drilling rig.

16E.6.1.3.1 Two actions should be required to initiate the function(s) (i.e., actuate the "arm" function and actuate the "close" control function).

16E.6.1.3.2 A minimum of two subsea transducers providing parallel sending and receiving capability in a "space diversity receiver" system (where each transducer is connected to a separate receiver) may be used. Capability for extending and retracting the subsea transducer arms, if used, may be included in the primary control system design unless an automatic means is incorporated.

16E.6.1.3.3 Subsea battery power to operate the acoustic control system should be capable of sustaining operation for a minimum of 180 days after deployment without recharging assuming the following duty cycle:

Operation of 100 command functions over a period of 180 days.

A low battery alarm may be provided.

16E.6.1.3.4 Combined or separate battery chargers may be used to charge the batteries for the surface and subsea battery systems. Means should be employed to insure the safety of charging subsea batteries within a sealed container.

16E.6.1.3.5 Subsea electronics and battery pack should be housed in a watertight container designed to withstand the subsea pressure to which it is exposed. If both are within the same container, the battery pack should be sealed from the electronics.

16E.6.1.3.6 Subsea electrical equipment should meet the applicable recommendations of Section 16E.4.14.

16E.6.1.3.7 The surface control equipment should include a portable control unit, battery operated, with a portable cabled omnidirectional (horizontal) beam pattern transducer. This portable control unit should be capable of communication at a minimum slant range of 1 mile. The battery should be able to provide 50 transmissions in eight hours of operation. Ten transmissions should be capable of being performed within the first ten minutes. A low battery alarm should be provided. Refer to Section 16E.3.8.7.

ROV (REMOTE OPERATED VEHICLE) OPERATED CONTROL SYSTEMS

16E.6.2 Means may be provided to use hydraulic power supplied by an ROV to operate critical BOP stack functions. This system may serve as a backup control if the primary control systems are inoperative. The ROV operated system may also serve as a pressure assist as needed.

ROV INTERVENTION INTERFACES

16E.6.2.1 If the power fluid provided by the ROV for BOP intervention is seawater, it would require subsequent flushing and/or maintenance at the surface.

Some ROV's have a special provision for storing a small volume of a suitable hydraulic fluid in a bladder reservoir. This may be used for operating functions requiring a small volume of control fluid and should not require subsequent flushing or maintenance.

16E.6.2.2 The recommended type of connection is one that is pressure balanced so that it will not create a reaction force by the actuating pressure that will tend to disengage the connection.

ROV OPERATED FUNCTIONS

16E.6.2.3 The capability to unlock the riser and wellhead connectors by means of ROV interventions may be provided. In an emergency situation, the ability to shut in the well by means of ROV intervention may be useful. Other optional functions include:

Blind/Shear Rams Close
Pipe Rams Close
Choke or Kill Valves Open
Choke or Kill Valves Close
Accumulator Charge
Accumulator Discharge

16E.6.2.4 For a multi-function system, an operating panel may be mounted on the BOP stack in an accessible location and clearly labelled for identification by the ROV television cameras.

16E.6.2.5 ROV actuated stack mounted valves rated to the full working pressure of the subsea control system may also be used to perform various functions.

EMERGENCY LMRP RECOVERY SYSTEM

16E.6.3 Means may be provided for mechanical and hydraulic intervention, using tools run on drillpipe, for the recovery of the LMRP when normal methods are inoperative. Typical systems consist of; an LMRP frame mounted holding fixture, a re-entry funnel to which are connected LMRP lifting slings and hydraulic function hoses, a stinger assembly run on drillpipe and one or more darts which are used after re-entry to select the control functions to prepare the stack for LMRP recovery. Such a system permits disconnect of the riser connector, by way of hydraulic interface through a shuttle valve, so that the LMRP can be recovered and the riser and/or control system restored to functional condition.

BACKUP NITROGEN POWER SUPPLY

16E.6.4 A nitrogen back-up system consists of a number of high pressure gaseous nitrogen bottles manifolded together to provide emergency auxiliary energy to the control manifold. The nitrogen back-up system is connected to the control manifold through an isolation valve and a check valve. If the accumulator/pump unit is not able to supply power fluid to the control manifold, the nitrogen back-up system may be activated to supply high pressure gas to the manifold to close the BOP's.

A standard, full bottle of nitrogen contains the approximate equivalent of 6.2 fluid gallons. The nitrogen back-up should be connected to the control manifold in a manner that will prevent flow of nitrogen into the accumulator circuit and prevent hydraulic fluid from entering the nitrogen back-up circuit. The nitrogen back up circuit or the control manifold should contain valving to allow controlled bleed down of high pressure nitrogen gas to prevent uncontrolled dumping of the pressurized nitrogen into the reservoir.

Nitrogen back-up circuits may also be used with pneumatic or electro-pneumatic remote control circuits as an emergency power source should rig air pressure be lost. It is imperative that the nitrogen pressure be regulated to within the maximum working pressure of the system it operates and further protected from overpressurization by a relief valve.

SECTION 16E.7
AUXILIARY EQUIPMENT CONTROL SYSTEM FEATURES AND INTERFACES

16E.7 Various auxiliary equipment may be included in the riser system, thus necessitating additional control means. Auxiliary riser control systems referred to in the following paragraphs should comply with the guidelines stated in Section 16E.3 where applications are of a typical or similar nature.

16E.7.1 30″ Latch and/or Subsea Diverter Controls. If the riser/diverter system is employed while drilling below the surface pipe, a 30″ latch and ball/flex joint is typically used to connect to the wellhead. A subsea diverter assembly may also be deployed. A dedicated umbilical hose bundle and reel may be used. Control valves may be located at the hose reel console. The driller's control panel may provide remote control.

16E.7.2 Riser Fill/Dump Valve Controls. A jumper hose from the subsea pod or a direct umbilical may be used to control the riser fill/dump valve. Remote control may be built into the hose reel console and/or the driller's control panel.

16E.7.3 Control for Upper Riser Accessories. Riser components such as upper ball joint, telescopic joint packing element pressure, stowable tensioner ring, and remotely operated hydraulic choke and kill connectors may be controlled from the driller's panel via the surface control manifold and dedicated jumper hoses.

SECTION 16E.8
PERIODIC INSPECTION AND MAINTENANCE

16E.8 The user should establish inspection and maintenance procedures for control systems for well control equipment.

16E.8.1 Inspections and maintenance procedures should take into consideration the manufacturers published recommendations.

16E.8.2 Inspection recommendations, where applicable, may include:

1. Verification of instrument accuracy
2. Relief Valve Settings
3. Pressure Control Switch Settings
4. Nitrogen precharge pressure in accumulators.
5. Pump Systems
6. Fluid Levels
7. Lubrication Points
8. General Condition of:
    1. Piping Systems
    2. Hoses
    3. Electrical conduit/cords
    4. Mechanical components
    5. Structural components
    6. Filters/strainers
    7. Safety covers/devices
    8. Control system sizing
    9. Battery condition

Reference Documents

1. API RP 14F July 1985 Edition
2. API RP 500B October 1987 Edition

16E.G
GLOSSARY

Accumulator. A pressure vessel charged with nitrogen gas and used to store hydraulic fluid under pressure for operation of blowout preventers.

Accumulator Bank. An assemblage of multiple accumulators sharing a common manifold.

Accumulator Precharge. An initial nitrogen charge in an accumulator which is further compressed when the hydraulic fluid is pumped into the accumulator storing potential energy.

Acoustic Control System. A subsea control system that uses coded acoustic signals for communication. An acoustic control system is normally used as an emergency backup having control of a few selected critical functions.

Air Pump/Air Powered Pump. Air driven hydraulic piston pump.

Annular BOP (Blowout Preventer). A device with a generally toroidal shaped steel-reinforced elastomer packing element that is hydraulically operated to close and seal around any drill pipe size or to provide full closure of the wellbore.

Blind Ram BOP (Blowout Preventer). A BOP having rams which seal against each other to close the well bore in the absence of any pipe.

Block Position. The center position of a three-position control valve.

Blowout. An uncontrolled flow of pressurized wellbore fluids.

BOP (Blowout Preventer). A device attached to the casing head that allows the well to be sealed to confine the well fluids in the wellbore.

BOP Closing Ratio (Ram BOP). A dimensionless factor equal to the wellbore pressure divided by the operating pressure necessary to close a Ram BOP against wellbore pressure. Usually calculated for maximum rated wellbore pressure.

BOP Control System. The system of pumps, valves, lines, accumulators, fluid storage and mixing equipment, manifold, piping, control panels and other items necessary to hydraulically operate the BOP equipment.

BOP Stack. The assembly of well control equipment including BOP's, spools, valves, and nipples connected to the top of the casinghead.

BOP Stack Maximum Rated Wellbore Pressure. The pressure containment rating of the ram BOP's in a stack. In the event that the rams are rated at different pressures, the BOP Stack Maximum Rated Wellbore Pressure is considered equal to the lowest rated ram BOP pressure. In stacks which do not contain any ram BOP, the BOP stack maximum rated wellbore pressure is considered equal to the lowest rated BOP pressure.

Bumpless Transfer. The transfer from main electrical supply power to an alternate electrical power supply without losing signal and/or memory circuit normally associated with power interruption.

Check Valve. A valve that allows flow through it in one direction only.

Choke Line. A high pressure line connected below a BOP to transmit fluid flow to the choke manifold during well control operations.

Choke and Kill Valves. BOP stack mounted valves which are connected below the BOP's to allow access to the wellbore to either choke or kill the well.

Closed Loop Circuit. A hydraulic control circuit in which spent fluid is returned to the reservoir.

Closing Unit (Closing system). See BOP Control System.

Control Fluid. Hydraulic oil or water-based fluid which, under pressure, pilots the operation of control valves or directly operates functions.

Control Hose Bundle. A group of pilot and signal hoses assembled into a bundle with an outer protective sheath. For subsea applications it may contain a hydraulic supply line.

Control Line. A flexible hose or rigid line that transmits the hydraulic power fluid to a function.

Control Manifold. The assemblage of valves, regulators, gages and piping used to regulate pressures and control the flow of hydraulic power fluid to operate system functions.

Control Panel. An enclosure displaying an array of switches, push buttons, lights and/or valves and various pressure gages or meters to control or monitor functions. Control panel types include: diverter panel; driller's panel; master panel; and mini or auxiliary remote panel. All of these panels are remote from the main hydraulic manifold and can be pneumatic, electric or hydraulic powered.

(a) **Diverter Panel.** A panel that is dedicated to the diverter and flowline system functions. It is positioned for ready driller's access and visual observation of the activated functions.

(b) **Driller's Panel.** The BOP control panel mounted at the driller's position on the rig floor.

(c) **Master Panel (Hydraulic or Electric).** The panel mounted in close proximity to the main accumulator unit. All control functions are operable from this panel including all regulators and gages.

(d) Mini or Auxiliary Remote Panel. A limited function panel mounted in a remote location for use as an emergency backup. On an offshore rig it is normally located in the toolpusher's office, and on a land rig, at least 100 feet from the well center on the leeward side of the prevailing wind.

Control Pod. The assemblage of valves and pressure regulators which respond to control signals to direct hydraulic power fluid through assigned porting to operate functions.

Control Valve (Surface Control System). A valve mounted on the hydraulic manifold which directs hydraulic power fluid to the selected function (such as annular BOP close) while simultaneously venting the opposite function (annular BOP open).

Control Valve (Subsea Control System). A pilot operated valve in the subsea control pod that directs power fluid to operate a function.

Electric Pump. An electrically driven hydraulic pump, usually a 3 piston (triplex) pump.

Electro-hydraulic (EH) System. A control system that uses an electrical signal to actuate a solenoid operated hydraulic valve to hydraulically pilot a control valve to operate a function.

Function. Operation of a BOP, choke or kill valve or other component, in one direction (example, closing the blind rams is a function, opening the blind rams is a separate function.)

Hose Bundle. See control hose bundle.

Hydraulic Connector. A mechanical connector that is activated hydraulically and connects the BOP stack to the wellhead or the LMRP to the BOP stack.

Hydrophone. An underwater listening device that converts acoustic energy to electric signals.

Junction Box (J-Box) (Electrical). An enclosure used to house the termination points of electrical cables and components. May also contain electrical components required for system operation.

Junction Box (J-Box) (Hydraulic or Pneumatic). A bolt-on plate having multiple stab-type terminal fittings used for quick connection of the multi-hose bundle to a pod, hose reel or manifold.

Kill Line. A high pressure line between the rig pumps to a connection below a BOP. This line allows fluid to be pumped into the well or annulus with the BOP closed during well control operations.

LMRP (Lower Marine Riser Package). The upper section of a two-section subsea BOP stack consisting of the hydraulic connector, annular BOP, ball/flex joint, riser adapter, flexible choke and kill lines, and subsea control pods. This interfaces with the lower subsea BOP stack.

Limit Switch. A hydraulic pneumatic or electrical switch that indicates the motion or position of a device.

Manifold. An assemblage of pipe, valves, and fittings by which fluid from one or more sources is selectively directed to various systems or components.

Manipulator Valve. A three position directional control valve that has the pressure inlet port blocked and the operator ports vented in the center position.

Mixing System. A system that mixes a measured amount of water soluble lubricant and, optionally, glycol to feed water and delivers it to a storage tank or reservoir.

Multiplex. A system that uses multiple electronic signals that are coded and transmitted through a conductor pair. This eliminates the requirement of a dedicated conductor pair for each required signal.

Non-Retrievable Control Pod. A pod that is fixed in place on the LMRP and not retrievable.

Pilot Fluid. Hydraulic control fluid that is dedicated to the pilot supply system.

Pilot Line. A hydraulic line that transmits pilot fluid to a control valve. Pilot lines are normally grouped in a common bundle or umbilical.

Pilot Response Time. For subsea systems, the time it takes when the hydraulic function valve is activated on the surface for the signal to travel through the pilot line and activate a control valve in the pod.

Pipe Ram BOP. A hydraulically operated assembly typically having two opposed ram assemblies that move radially inward to close on pipe in the wellbore and seal the annular space.

Pipe Rams. Rams whose ends are contoured to seal around pipe to close the annular space.

Pod. See Control Pod.

Potable Water. A water supply that is acceptably pure for human consumption. On an offshore rig, it is usually produced by watermakers and used as supply water for mixing control fluid for a subsea control system.

Power Fluid. Pressurized hydraulic fluid dedicated to the direct operation of functions.

Precharge. See Accumulator Precharge.

Ram BOP. A blowout preventer that uses rams to seal off pressure in the wellbore.

Readback. An indication of a remote condition.

Reel (Hose or Cable). A reel, usually power driven, that stores, pays-out and takes-up umbilicals, either control hose bundles or armored electrical cables.

Regulator (Pressure). A hydraulic device that reduces upstream supply pressure to a desired (regulated) pressure. It may be manual or remotely operated and, once set, will automatically maintain the regulated output pressure unless reset to a different pressure.

Relief Valve. A device that is built into a hydraulic or pneumatic system to relieve (dump) any excess pressure.

Remote Panel. See Control Panel.

Reservoir. A storage tank for the BOP control system control fluid.

Response Time. The time elapsed between activation of a function at the control panel and complete operation of the function.

Retrievable Control Pod. A subsea pod that is retrievable remotely on a wire line.

Riser Connector (LMRP Connector). A hydraulically operated connector that joins the LMRP to the top of the lower BOP stack.

Selector Valve. A three position directional control valve that has the pressure inlet port blocked and the operator ports blocked in the center position.

Shear Ram BOP (Blowout Preventer) (Blind/Shear Rams). Rams having cutting blades that will shear tubulars that may be in the wellbore, while the rams close and seal against the pressure below.

Sheave. A wheel or rollers with a cross-section designed to allow a specific size of rope, cable, wire line or hose bundle to be routed around it at a fixed bend radius. Normally used to change the direction of, and support, the line.

Shutoff Valve. A valve that closes a hydraulic or pneumatic supply line.

Shuttle Valve. A valve with two or more supply pressure ports and only one outlet port. When fluid is flowing through one of the supply ports the internal shuttle seals off the other inlet port and allows flow to the outlet port only.

Solenoid Valve. An electrically operated valve that controls a hydraulic or pneumatic pilot signal or function.

Spent Fluid. Hydraulic control fluid that is vented from a function control port when the opposite function is operated.

Stored Hydraulic Fluid Volume. The fluid volume recoverable from the accumulator system between the maximum designed accumulator operating pressure and the precharge pressure.

Straight-Through Function. A subsea function that is directly operated by a pilot signal without interface with a pod mounted pilot operated control valve. Straight-through functions typically require a low fluid volume to operate and its response time is not critical.

Umbilical. A control hose bundle or electrical cable that runs from the reel on the surface to the subsea control pod on the LMRP.

Usable Hydraulic Fluid. The hydraulic fluid volume recoverable from the accumulator system between the maximum designed accumulator operating pressure and the minimum operating pressure.

Water-Based Hydraulic Fluid. Control fluid mixture composed of water soluble lubricant and water.

Wellhead Connector (Stack Connector). A hydraulically operated connector that joins the BOP stack to the subsea wellhead.

16E.H
SCHEMATIC SYMBOLS

NOTE: GRAPHIC SYMBOLS FOR FLUID POWER DIAGRAMS BASED ON ANSI Y. 32.10

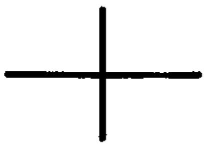
: Main Lines

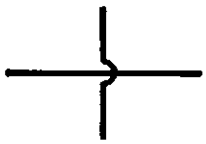

: Hydraulic Lines

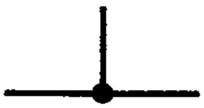

: Pneumatic Lines

: Pilot Lines (dashes)

: Drain Lines (dotted)


: Lines Crossing (not Connected)


: Lines Crossing (alternate)


: Lines Connected

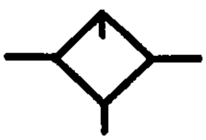

: Connected to Reservoir (above fluid level)


: Connected to Reservoir (below fluid level)

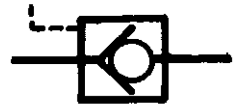

: Plugged Port

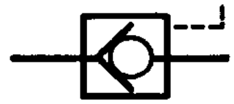

: Filter or Strainer

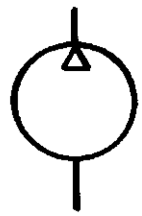

: Lubricator Without Drain

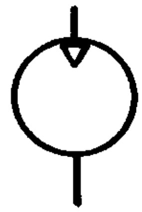

: Lubricator With Drain

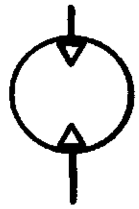

: Check Valve (free flow is from left to right)


: Pilot Operated Check Valve (pilot to open)


: Pilot Operated Check Valve (pilot to close)


: Compressor, Fixed Displacement, Pneumatic


: Motor, Uni-Directional, Pneumatic


: Motor, Bi-Directional, Pneumatic

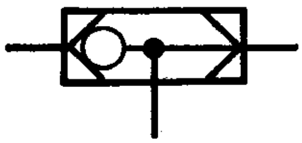

: Internal Combustion Engine

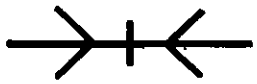

: Pressure Gauge

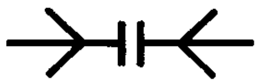

: Temperature Gauge

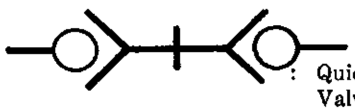

: Flow Rate Flowmeter

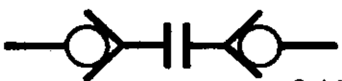

: Totalizing Flow Meter


: Shuttle Valve


: Quick Disconnect, Connected


: Quick Disconnect, Disconnected


: Quick Disconnect, with Check Valve, Connected


: Quick Disconnect, with Check Valve, Disconnected


: Manual Shut Off Valve, Normally Open


: Manual Shut Off Valve, Normally Closed

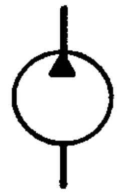

: Orifice, Fixed

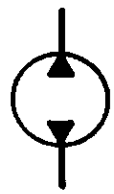

: Adjustable Orifice

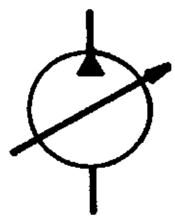

: Accumulator, Spring Loaded

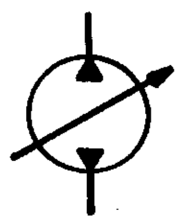

: Accumulator, Gas Charged


: Receiver, Air or Gas

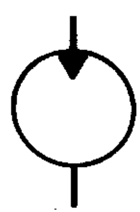

: Pump, Hydraulic, Uni-Directional, Fixed Displacement

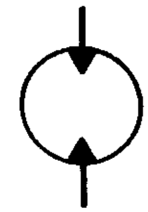

: Pump, Hydraulic, Bi-Directional, Fixed Displacement


: Variable Displacement Hydraulic Pump, Uni-Directional

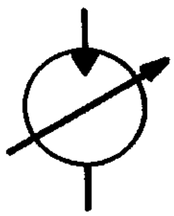

: Variable Displacement, Bi-Directional Hydraulic Pump


: Electric Motor

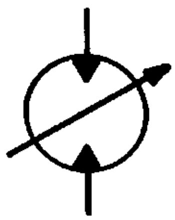

: Hydraulic Motor Fixed Displacement, Uni-Directional



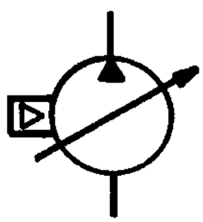
: Hydraulic Motor, Fixed Displacement Bi-Directional



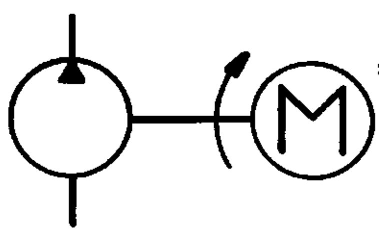
: Hydraulic Motor Variable Displacement, Uni-Directional



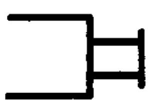
: Hydraulic Motor, Variable Displacement, Bi-Directional



: Air Operated Variable Displacement Uni-Directional Hydraulic Pump

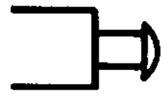


: Electric Motor Driven, Fixed Displacement Uni-Directional Hydraulic Pump



: Manual Operator

: Lever Operator

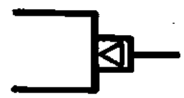


: Push Button Operator

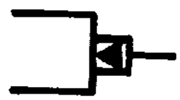
: Foot Pedal Operator

: Mechanical Operator

: Two Position Detent



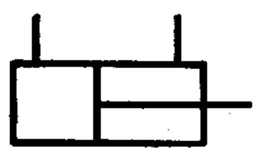
: Pneumatic Pilot



: Hydraulic Pilot

: Solenoid Operator

: Spring

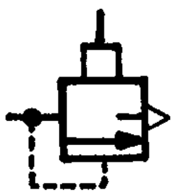


: Cylinder, Double Acting

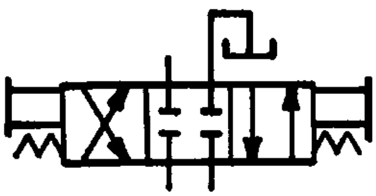
: 3 Position, Double Air Pilot Operated, Spring Centered

: 3 Position, Manual Operated, Spring Centered

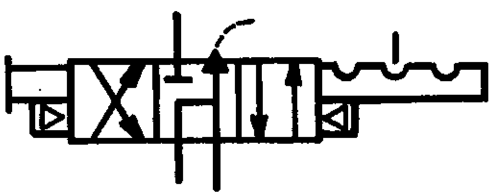
: 3 Position, Double Air Pilot Operated, with Manual Override, Detented, Valve



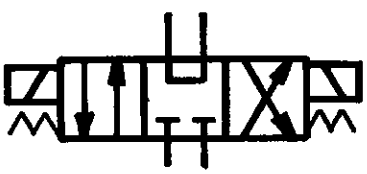
: Relief Valve, Remote Pilot Set, Vented to Atmosphere



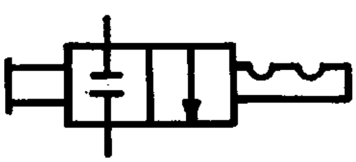
: 4 Way, 3 Position, Manual Operated, Spring Centered, Center Position, All ports Blocked



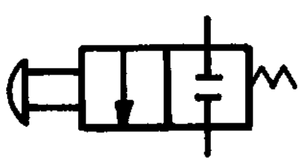
: 4 Way, 3 Position, Pilot Cylinder Operated with Manual Override, Detented, Pressure Blocked, Cylinders Vented to Ambient In The Center Position, Valve



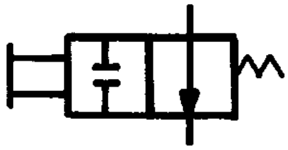
: 4 Way, 3 Position, Solenoid Operated, Spring Centered, Pressure Connected To Return, Cylinder Ports Blocked, Valve



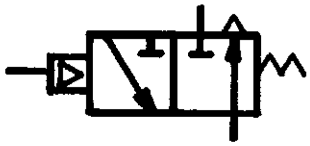
: Two Way Manual Operated, Detented Valve (shown in the closed position)



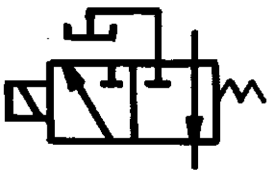
: Two Way, Push Button Operated, Spring Return, Normally Close Valve



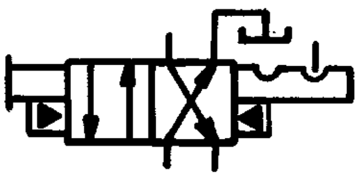
: Two Way, Manual Operated, Spring Return Normally Open Valve



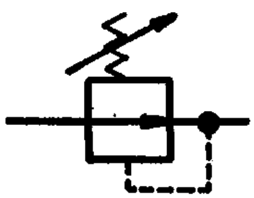
: 3 Way, Pneumatic Pilot Operated, Spring Return, Normally Closed Valve (fluid vents to ambient)



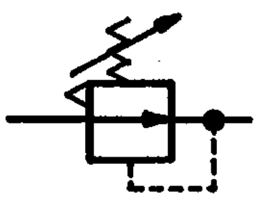
: 3 Way Solenoid Operated, Spring Return, Normally Open Valve (fluid vent is connected to reservoir)



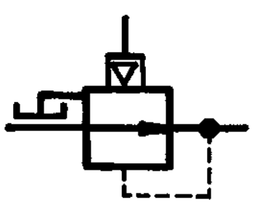
: 4 Way, Two Position, Hydraulic Pilot Operated with Manual Override, Detented Valve (fluid vent is connected to reservoir)



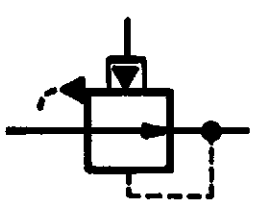
: Regulator, Manual Set, Non-Relieving



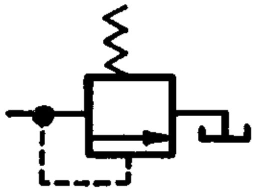
: Regulator, Manual Set, Relieving Type (fluid vented to ambient



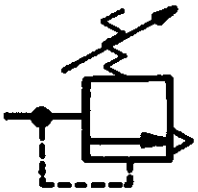
: Regulator, Air Pilot Operated, Relieving (fluid vent connected to reservoir)



: Regulator, Hydraulic Pilot Operated, Relieving (fluid vented to ambient)



: Relief Valve, Non Adjustable, (vent connected to reservoir)



: Relief Valve, Adjustable (vented to ambient)

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