FUNCTIONAL DESIGN DESCRIPTION TDS-8SA

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NATIONAL OILWELL VARCO

TITLE

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TDS-8SA

SIZE	DWG NO	REV
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SCALE NONE | WT LBS | SHEET 1 OF 11

1. Introduction

The TDS-8SA is Varco System's latest answer to the challenging demands of offshore drilling. It combines decades of proven experience with the inherent benefits of AC technology into a compact and powerful package to satisfy the most demanding drilling operations. Varco engineering utilized advancements in AC technology by designing the TDS-8SA around a 1150-hp AC motor that can produce 62,250 ft-lbs. of continuous drilling torque, or 100,000 ft-lbs. of make-up/break-out torque. Compact enough to operate safely in a 152-ft derrick, while providing 750 tons (650 ton option) of hoisting capacity, the TDS-8SA AC top drive offers improved productivity in directional, horizontal, and vertical drilling.

In today's competitive offshore drilling market, improving productivity by reducing cost per well is a top priority to operators in both horizontal and vertical drilling programs. Low maintenance, reduced downtime, and low acquisition costs are prime considerations for drilling contractors who strive to reduce the cost per well. Varco has produced a top drive system to meet all of these needs. The following TDS-8SA features describe how this drilling system will help you increase productivity and reduce the cost per well:

- AC motors have no brushes, brush gear, nor a commutator, reducing maintenance costs. Additionally, AC motors have no arcing devices.
- AC motor and Varco's integrated swivel reduce downtime, while providing the most advanced drilling package available on the market today.
- Hydraulic link tilt can tilt the elevator to either side of well center.
- Helical gearing produces efficient high torque transmission noise reduction.
- Large bore tool entry allows use of down-hole tools up to 3-11/16" diameter without breaking out the TDS.

All of the operational benefits, cost savings and proven time savings realized by utilizing a top drive hold true with this more advanced AC unit. The TDS-8SA provides drilling contractors with the following benefits:

- Drilling ahead with 93 ft stands.
- Eliminating two out of every three, or three out of every four connections.
- Back-reaming and forward-reaming capabilities.
- Full rotation and circulation when tripping out.
- Pulling through tight spots.
- Reducing the incidence of stuck pipe.
- Controlling stand connections.
- Making and breaking connections with the top drive.
- Drilling through bridges and tight spots without picking up a kelly.
- Well control.
- Instant stabbing and well shut-in at any position in the mast when tripping.
- Crew safety.

The TDS-8SA, from the innovators at Varco Drilling Systems, incorporates state-of-the art AC technology in the most important innovation in drilling since the rotary table.

2. Description

2.1 Major components

The TDS-8SA drilling system includes the following main assemblies and subassemblies:

- Motor housing and swivel assembly
- Motor cooling system
- Guide dolly and rail assembly
- PH-100 Pipehandler
- Hydraulic control system
- Counterbalance system
- AC motor control system

2.1.1 Motor Housing and Swivel Assembly

This assembly comprises the following subassemblies:

- Transmission and integrated swivel assembly
- AC drilling motor and brake hub

2.1.1.1 Transmission and Swivel Housing

The assembly consists of the following components:

- Bonnet
- Main body and transmission housing
- Motor pinion
- Compound gear
- Bull gear
- Main shaft
- Integrated swivel assembly
- Lubrication system

The single-speed helical gear transmission provides a 8.5:1 ratio from the motor to the main shaft. The main body and gear case cover house the transmission, the main thrust, and radial bearings. The bonnet houses the upper take-up bearing and supports the AC motor and washpipe assembly. The bull gear attaches using a ring fedder. The main body and transmission housing provide a sealed oil lubrication reservoir for the gears and bearings. An oil pump feeds the bearings and gears. The filtered lubrication oil constantly circulates through the main thrust bearing, upper taper bearing, lower radial and compound gear bearing, and over the gear meshes. An industry-standard washpipe packing assembly is located between the main shaft and gooseneck, and allows for the rotation of the drill string. The bonnet supports the assembly and attaches to the gearcase to provide lateral support.

2.1.1.2 AC Drilling Motor and Brake Hub

The TDS-8SA uses one 1150 hp AC drilling motor. The AC drilling motor is an open-frame type, in that the cooling air passes through the inside of the motor. The drilling motor, manufactured specifically for top drive applications, has internal temperature sensors, vacuum varnish-impregnated windings, high-capacity bearings, and tapered output shafts to improve serviceability of the pinion gear and brake hubs. The motor mounts vertically on top of the transmission gearcase cover. The shaft is double-ended, with a drive pinion on the lower end and a brake hub mounted on the upper end.

2.1.2 Motor Cooling System

The local blower cooling system provides local cooling air to the drilling motor. The blower propels local cooling air through the drilling motor and forced convection air to the transmission oil heat exchanger. The system consists of a heavy-construction pressure motor cooling blower and duct mounted on the drilling motor. An explosion-proof 20 hp, double-shafted 3,450 rpm AC electrical motor directly drives the blower and the axial fan for motor and transmission cooling respectively. A moisture separator mounted at the inlet duct assists with the removal of water from the intake air.

2.1.3 Transmission Lubrication System

The transmission lubrication system provides lubricating oil to the TDS-8SA transmission. The main body and transmission housing provide a sealed oil lubrication reservoir for the gears and bearings. An oil pump feeds the bearings and gears. The constant speed pump is direct-coupled to an explosion-proof, 4 hp, 1730 rpm, 3-phase induction motor. The filtered lubricating oil constantly circulates through the main thrust bearing, upper taper bearing, lower radial bearing, and over the gear meshes.

2.1.4 Guide Dolly and Rail Assembly

The TDS-8SA drilling system travels on dual parallel rails by means of a guide dolly attached to the gearcase. This assembly attaches to the traveling block and includes attachment points for the service loops and rotary hose. The rail assembly, typically supplied by others, is permanently attached to the derrick and extends to within ten feet of the drill floor. Centralized lubrication manifolds provide roller lubrication. The guide dolly transmits the drilling torque through the guide dolly and into the guide rails.

2.1.5 PH-100 Pipehandler The PH-100 Pipehandler consists of the following major components:

- Powered rotating link adapter and 10-port slip ring
- Bi-directional link tilt
- Remote upper IBOP actuator
- Torque backup clamp

2.1.5.1 Powered Rotating Link Adapter

The powered rotating link adapter allows hydraulic lines to remain connected as the pipehandler rotates with the drill stem components while tripping out or when positioning the link tilt. The powered rotating link adapter contains a hydraulic drive motor to rotate it in either direction. An electric solenoid valve, connected to a switch on the driller's console, operates the hydraulic motor. A pinion gear on the hydraulic drive motor rotates the positioning gear that is attached to the top of the rotating link adapter. During make or break operations, the rotating link adapter can be locked into any of 24 index positions by selecting the pipehandler clamp mode and actuating a hydraulically operated shot pin. When the hydraulic drive motor is not powered, the link adapter can rotate freely. The link tilt cylinders and the torque arrestor frame hang from the rotating link adapter. The link adapter is attached to the stem support. The internal hydraulic fluid passages in the stem connect to the respective fluid passages in the rotating link adapter. Fluid is fed from the main manifold into the stem through the radial passages at the upper end. This fluid is routed from the stem through its grooves to the link adapter and out to all actuators on the pipe handler. While rotating, or while in any stationary position, fluid flows between the two components.

2.1.5.2 Bi-directional Link Tilt

The link tilt assembly consists of two hydraulic cylinders and clamp assemblies. The link tilt assembly is attached to 350-ton, 132-inch long elevator links with clamp assemblies. The latch on the cylinder assembly limits the travel of the elevator to the derrickman position, which is adjustable. Releasing the latch by pulling a cable allows the elevator to travel to the mousehole or over-drill position. The link tilt operates from a three-position switch located on the driller's console. The TILT position moves the links toward the mousehole or the derrickman. The DRILL position tilts the link back to clear the drill pipe and raise the elevator to allow drilling down to the floor. The spring-centered position holds the link at any intermediate position. A separate float switch is used to allow the links to hang free. The links may be stopped at any intermediate position. The links float back to the well center when the FLOAT position button on the driller's console is operated.

2.1.5.3 Remote Upper IBOP Actuator and Manual Operated Lower IBOP

The two ball type IBOP valves are full size, internal opening safety valves. The remotely operated upper valve and the manually operated lower valve form the well control system. Both valves have 7-5/8" regular R. H. connections and 15,000psi pressure ratings. A two-position switch at the driller's console operates the OPEN and CLOSE functions of the upper IBOP valve. When the switch is operated, a hydraulic cylinder through a non-rotating lever arrangement attached to the torque arrestor slides up and down in an actuator shell. This lever arrangement drives a small crank arm on each side of the valve, which opens and closes the upper IBOP valve.

2.1.5.4 Torque Backup Clamp

The backup clamp assembly is located below the lower shoulder of the saver sub. It includes two gripping jaws with die inserts and a clamping cylinder. The clamping cylinder grips the box end of the drill string when connected to the saver sub. A torque arrestor frame hanging from the rotating link adapter supports the torque backup clamp cylinder. The cylinder attaches to the torque arrestor frame and floats up or down to allow for thread engagement/disengagement and reacting backup torque while making and breaking connections.

2.1.6 Hydraulic control system

The hydraulic control system consists of reliable, industry-standard components that operate the following assemblies:

- Counterbalance system
- Lubrication system
- Powered rotating head
- Remotely actuated IBOP
- Torque backup clamp
- Link tilt
- Guide dolly retract

2.1.7 Counterbalance System

The counterbalance system prevents damage to tool joint threads while making or breaking connections with the TDS-8SA. The system replaces the function of the hook compensator spring. The system consists of two hydraulic cylinders and attachment hardware, a hydraulic accumulator, and a hydraulic manifold. The hydraulic cylinders are located between the integral system links and the traveling block. The cylinders connect to a hydraulic accumulator. The accumulator is charged with hydraulic fluid and maintained at a predetermined pressure setting by the counterbalance circuit in the main hydraulic control system manifold.

2.1.8 AC Motor

The TDS-8SA uses an 1150-hp AC motor. It is located on top of the gearcase, which minimizes the distance from the well center line to the rear of the guide dolly and rails. Varco selected AC drilling motors for use on the TDS-8SA because they provide the following benefits:

- Reliability
- Low maintenance
- Non-polluting
- Wide operational range
- May be stalled indefinitely at full continuous torque
- 60% overload capability for up to 15 seconds
- Non-sparking

The AC motor available to power the TDS-8SA is rated at 600/690 (nominal) VAC, 3-phase. Input frequencies vary from 0 to 117 Hz (base speed: 800 RPM at 40 Hz). The motor is rated at 1150 hp with a maximum continuous output torque of 7,550 ft-lb. It features a maximum speed of 2,300 RPM (at 117 Hz) and an intermittent torque capability (for connection makeup/breakout) of 12,500 ft-lb. (160% of Continuous torque)

The motors are manufactured specifically for top drive applications. They feature:

- Internal winding core temperature sensors (2 per phase)
- Double varnish-impregnated windings
- Upgraded bearing/shaft seals
- High-capacity bearings
- Tapered and ground, double-ended output shafts

2.2 Control System

2.2.1 Control Module

The control system consists of an industrialized PC Single Board Computer (SBC) or Programmable Logic Controller (PLC) with embedded motion control. All communication with the top drive is via Ethernet or a Profibus DP bus operating at 1.5 MHz. The tool uses remote I/O modules for communicating to the control system.

2.2.2 Control Station

The operator interface / control station can be provided via a Varco Drillers Console (VDC) or an HMI interface. Command signal communication from the operators control station to the tool controller will be Profibus DP and / or Ethernet. When an HMI is present, the Top Drive can be controlled from either the driller's chair, the assistant driller's chair or VDC, depending on which station has ownership. There are no local controls for the Top Drive.

2.2.3 Drive Systems

TDS-8SA rotation for drilling, spinning, torque make up and break out are electrically powered using a Variable Frequency Drive (VFD). The optional Dolly Retract System is powered using a proportional electro-hydraulic solenoid valve. The Rotating Head, IBOP and Link Tilt are powered using standard electro-hydraulic solenoid valves.

3 Design Data

3.1 Specifications

Transmission	8.5:1 double reduction helical gear
Transmission lube	Constant speed pump, force fed, filtered air cooled
Powered rotating head	360°

System weight	38,750 lbs.

Drilling parameters (1150 hp)

Drilling speed range	0 to 270 rpm continuous
Drilling torque	62,250 ft lbs. maximum continuous
Drilling horsepower	1150 maximum continuous
Static locking air brake	60,000 ft-lbs.

Rated Capacities

Hoisting	750 tons (650 ton option), API-8C, PSL-1, SR-1
Drilling (rotating)	650 tons, API
Water course (main shaft bore)	7,500 psi

Pipehandler (PH-100)

Torque capacity	100,000 ft-lbs.
Drill pipe size	3-1/2" through 6-5/8"
Connection size range (O.D.)	4-1/2" through 8-5/8"
Upper IBOP (remote)	7-5/8" API Reg. RH, box and box
Lower IBOP (manual)	7-5/8" API Reg. RH, box and pin
IBOP pressure rating	15,000 psi CWP
Elevator links	350, 500, 750 tons API

3.2 Environmental

	Operating	Ocean Wet Towage	Location Move
Wind:	20 m/sec	51.5 m/sec	36 m/sec
Temperature:	-20°C / +55°C (1)	-20°C / +55°C (1)	-20°C / +55°C (1)
Pitch/Roll amplitude	None	±15°	±10°
Pitch/Roll period	N/a	15 sec	15 sec
Heave	Tbd	Tbd	Tbd
Heave period	Tbd	Tbd	Tbd
Center of rotation	N/a	30 m	15 m

Note: Ocean Wet Tow and Location Move are non-operational conditions.

(1) With the exception of the GEB-20 motor which is rated for -20°C / +45°C (+55°C at reduced torque and power)

4. Design Codes and Verification

The TDS-8S operates above the drill floor at well center. The Top Drive is designed to operate in a zone 1 hazardous area. All electrical equipment mounted on the TDS-8S tool is certified for zone 1. The standard Remote I/O J-box for the TDS-8S is designed to be mounted in a safe area. If the derrick mounting is not in a safe area, the Remote I/O is relocated to the control system and replaced with a standard marshaling junction box.

4.1 Relevant Codes and Standards

- "Rules for Certification - Lifting Appliances" DnV, (1989)
- "Code for Lifting Appliances in a Marine Environment" Lloyd's Register of Shipping, (1987)
- "Specifications for Structural Steel Building - Allowable Stress Design and Plastic Design", AISC, (June 1, 1989)
- Varco Dynamic Design Loading Specification

4.2 Design Verification

Design is subject to third party verification by a recognized certifying authority, usually designated by customer requirements.

5. Design Philosophy

5.1 General Approach

The design is intended to provide semi-automatic, remote controlled drilling and tripping operations. The design utilizes experience gained from existing top drives in operation. Structural components of the TDS-8SA are design to withstand the static, dynamic and fatigue loads likely to be imposed during it's life time. The design and analysis of structural components are performed using design safety factors and methods specified in the DnV specification "Rules For Certification of Lifting Appliances". Loading criteria is defined in the "Varco Dynamic Design Loading Specification". When applicable, more stringent environmental loading is taken from the customer's specifications.

5.2 Design Life

The design life of a top drive system is approximately a 20 years of intermittent drilling and tripping operations. This corresponds to a drilling program averaging approximately 10,000ft wells, completed at a rate of about two per month. On parts where fatigue damage is likely to occur, such as pinions and racks, the stresses will be shown to be below the fatigue limit under operational load conditions. A lubrication and maintenance program, combined with routine change out of wear components like bearings for motors and gears, will maintain the unit in peak operational condition for its design life.

5.3 Material & Component Selection

5.3.1 Mechanical Construction

All materials used in the fabrication are Varco standard design and suppliers.

Surface protection for the equipment is per Varco Paint Specification VPS 00001.

All material selection decisions are based on fitness to the application as defined above, availability, manufacture-ability, serviceability, cost, and standardization with respect to other Varco products. In addition, the following will be considered:

- Structural components - chosen on basis of strength, durability, and resistance to stress. Material to be selected from family of existing Varco Material Specifications to the extent practicable, with tractability appropriate to the application.
- Pressure containing components (e.g. hoses, accumulators, cylinders): to be commercially available with appropriate service ratings.
- Fasteners, fittings - Materials are resistant to the environment, through either sacrificial coating scheme or other environmentally resistant properties.
- Non-metallic seals - commercial seals, chosen on basis of chemical and environmental resistance, and long service life.

5.3.2 Electrical Construction

Electrical System / Components

Reference "Electrical Standards" design specification 3DS00079 and "Electrical Documentation Standards" DS00072 .

Control Panel & Electrical System

- The TDS-8SA utilizes (IEC / CENELEC) Ex electrical components and is constructed according to IEC standards for marine applications. All hazardous area equipment is certified for zone 1, exterior mounted safe area equipment is all designed for a marine application .All hardware, other than the main drilling motor, is rated for IP 56 minimum and $-20\ ^{0}$ C to $+45\ ^{0}$ C. The main drilling motor is rated IP44.

- The standard TDS-8SA control will be provided by one (1) control module (CM), either a Single Board Computer (SBC) or Programmable Logic Controller (PLC). This module may be an SBC located in the Multi Tool Controller (MTC) cabinet or alternatively an SBC or PLC located in a stand-alone top drive control cabinet. The Control Module (CM) receives inputs from various electrical sensors, encoders, operator interfaces, and other devices mounted on the tool or operators station. Command inputs to the CM from the operator's station result in outputs to drive the tool. The CM provides interlock control of various tool functions monitors sensor and encoder feedbacks. In general, the system of programmed interlocks provides a safety net to help prevent inadvertent damage.

- The Multi Tool Controller (MTC) which is housed in an IP 44 enclosure, is designed to be located in a non-hazardous area. The MTC is a generic controller, which can control up to seven (7) individual tools independently of each other. The Multi Tool Controller houses several SBC Control Modules with other associated hardware, one of which is dedicated to controlling the TDS 8SA, the SBC includes all necessary software to control the TDS-8SA, programmed sequential control and operational interlocks for both operator and tool safety. The SBC system is based on Profibus DP serial communications running at 1.5 Mbaud for tool field equipment where remote I/O technology minimizes derrick and tool cabling and provides the flexibility to utilize smart type sensors / devices. Profibus DP is a recognized industry standard method of serial communications, which utilizes a RS 485 hardware platform. Field communications can be either via copper or fiber, which provides redundancy and also noise immunity.

- The stand-alone control cabinet may house an SBC or PLC, and is rated at a minimum of IP44. The control system is based on Profibus DP serial communications running at 1.5 Mbaud for tool field equipment where remote I/O technology minimizes derrick and tool cabling and provides the flexibility to utilize smart type sensors / devices. In some cases the remote I/O may be relocated from the derrick into the stand-alone cabinet.

The TDS-8SA design takes into account the hazardous area classification of a particular drilling operation. Electrical and control system designs will be chosen that satisfactorily meet or exceed the conditions for safe operation within the respectively classed areas. Rig floor level systems may be subject to more stringent levels of classification than derrick mounted systems. Standard components will be used as practicable.

5.4 Control System

The Control Module (CM) receives inputs from various electrical sensors, encoders, operator interfaces, and other devices mounted on the tool or operators station. Command inputs to the CM from the operator's station result in outputs to drive the tool. The CM provides interlock control of various tool functions monitors sensor and encoder feedbacks. In general, the system of programmed interlocks provides a safety net to help prevent inadvertent damage, and are not relied on as a primary operating system. The operator is ultimately responsible for safe operation.

5.5 Failure Modes

In general, the TDS-8SA mechanical, electrical, and hydraulic systems are designed to provide the least obstructive or destructive failure mode. In general, electrical devices are chosen to assure fail safe mode in order to force the operator to make a decision before proceeding further.

Hydraulic systems are fitted with solenoid operated and load-holding valves as applicable to assure safe handling of loads in the event of failure.

6. Functions & Operations

6.1 General Operation

General operation of the top drive is defined as semi-automatic, where driller is in constant control of the top drive through use of the VDC or HMI screen and / or rotary throttle.

- Drill Mode - TDS-8SA VFD and operational controls are setup for drilling ahead.
- Spin Mode - TDS-8SA VFD and operational controls are setup for spinning into string prior to making up, or spinning out from the drill string after breaking out.
- Torque Mode - TDS-8SA VFD and operational controls are setup for making up to the drill string prior to drilling ahead, or breaking out from drill string to add another stand for drilling ahead, or breaking out from drill string to prepare for tripping out of the hole.
- Brake On - TDS-8SA Brake is set on full time.
- Brake Off - TDS-8SA Brake is set off full time.
- Brake Auto - TDS-8SA Brake is set as necessary based on throttle active signal in drilling mode. configuration.
- Maintenance Mode – Full Manual control of the TDS-8SA is only available in Maintenance mode. This mode is enabled via a keyed switch on the control module cabinet door. No interlocks are enforced, this mode is intended to be used for maintenance and emergencies only.

6.2 Changing Modes

Modes of operation may be changed anytime during operation, however, interlocks will be enforced to prevent damage to the equipment.

6.3 Interlocks

A general list of interlocks follows. If the system is not properly configured or not fully powered up prior to attempting operation, an appropriate message will be displayed, however, this may simply be information to the operator and not an interlocking condition.

- TDS-8SASelection - Top Drive selection may be interlocked if not configured properly.
- TDS-8SADirection Change - Forward / Reverse direction change will be interlocked while motor is rotating.
- TDS-8SA Mode Change –Drill, Spin, Torque mode change is interlocked while motor is rotating.
- TDS-8SA Brake Mode –Brake Set / mode change is interlocked depending on configuration and rotation.
- RLA Rotation/Extend - RLA rotation is interlocked with link tilt extended.
- PH100 TW Clamp - PH100 TW Clamp (initiation) interlocked if TDS-8SA motor is being rotated.

- Link Tilt Extend - Link tilt extend will be interlocked if RLA is rotating.

6.4 Configuration / Trending

Configuration Access available with base level system.

- RPM Limit - Sets maximum TDS-8SA motor rotation speed.
- Drill Torque Limit - Sets maximum TDS-8SA motor torque while drilling.
- Make Up Torque Limit - Sets maximum TDS-8SA motor torque for making up to drill string.

Trending screens are available to the user in the SBC configuration. These screens can be used to capture and display finite amounts of data and a result that covers a user specified amount of time or cycles.

- Peak RPM - User configurable mechanism to record and display recent highest RPM value.
- Average RPM - User configurable trending to calculate the average RPM over a specified time period.
- Peak Torque - User configurable mechanism to record and display recent highest torque value.
- Average Torque - User configurable trending to calculate the average torque over a specified time period.

6.5 Modification Facilities

Modification of some alarms and alarming criteria are also available to the user. These screens can be used to configure alarming levels for the following.

- Peak RPM - User configurable alarm to notify operator if motor RPM peak is detected above or below the user defined value.
- Average RPM - User configurable alarm to notify operator if motor RPM average is detected above or below the user defined value.
- Peak Torque - User configurable alarm to notify operator if motor peak torque is peak detected above or below the user defined value.
- Average Torque - User configurable alarm to notify operator if motor Average torque is detected above or below the user defined value.