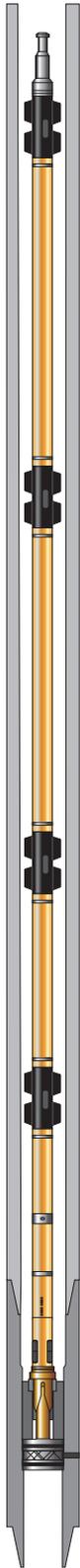


## Tensor MWD System



The Tensor MWD system's proven design is compatible with collar diameters from 3 ½ in. to 9 ½ in. and operates at flow rates from 75 to 1,200 gpm. Industry leading sensors and electronics, coupled with a trusted mechanical architecture create an MWD system which delivers exceptional accuracy and reliability while minimizing the total cost of ownership.

Tensor Drilling Technologies commitment to customer success is demonstrated by an exemplary support network encompassing market leading repair services, comprehensive training (both e-learning and hands-on), localized support teams, and a dedicated website delivering best in class support materials.

### Features and Benefits

#### Reliable

Drawing on an established reputation in the industry, Tensor Drilling Technologies provides high quality, reliable downhole systems for directional surveying and formation logging. Tensor Drilling Technologies quality processes ensure products are manufactured and maintained to a uniform high standard.

#### Cost Efficient

The system operates in standard non-magnetic drill collars. The positive pulser can be routinely serviced in less than one day enabling quick turnaround of equipment. Extended battery life is achieved through energy efficient hardware and intelligent power management software.

#### Configurable

A choice of solenoid positive pulser or motor driven pulser allows the customer to select the most appropriate for their application.

Additional modules for gamma and Centerfire resistivity are available to enable expansion of services into the LWD market.

#### Modular

Flexible module configuration enables alternative sensor positions. Modules are interchangeable between collar sizes for flexibility of use. Short, lightweight modules allow cost-effective logistics, assembly and maintenance turnaround.

#### Retrievable and Reseatable

The Tensor MWD probe can be retrieved and reseated. In the event that the pipe becomes stuck in a hole, the MWD probe can be "fished" reducing the risk of loss. This capability also enables efficient probe upgrade and battery replacement if operations require.

#### High Temperature as Standard

The Tensor system is recognized as the system of choice for hot hole applications, with 175 °C operating temperature as a non-price premium standard.

#### Optimized Telemetry

Downlink capability allows the operator to select the optimum transmission sequence and data resolution for each application with minimal impact on rig operations.

# Tensor MWD System - Specifications

## Technical Specifications

Collar O.D.	3.5 in.	4.75 in.	6.75 in.	8.25 in.	9.5 in.
Tool Connections	2 3/8 in. I.F.	3 1/2 in. I.F.	4 1/2 in. API I.F.	6 3/8 in. API REG	7 3/8 in. API REG
Equivalent Collar Stiffness (OD x ID)	2.96 in. x 2.25 in.	4.75 in. x 2.81 in.	6.71 in. x 3.25 in.	7.93 in. x 4.00 in.	9.42 in. x 4.00 in.
Make-up Torque	3,500 lbf-ft	9,600 lbf-ft	30,000 lbf-ft	54,000 lbf-ft	62,000 lbf-ft
Flow Rate Range	75 - 165 usgpm	100 - 300 usgpm	150 - 800 usgpm	400 - 1,200 usgpm	400 - 1,200 usgpm
Max. Dogleg Rotation	50°/ 100 ft	15°/ 100 ft	10°/ 100 ft	8°/ 100 ft	4°/ 100 ft
Max. Dogleg Sliding	100°/ 100 ft	30°/ 100 ft	21°/ 100 ft	14°/ 100 ft	7°/ 100 ft
Probe OD	1.875 in.	Max. Pressure	20,000 psi	Max. Sand	0.5 %
Max. Temperature Operating	347 °F	Max. Temperature Survival		347 °F	
Max. LCM Tolerance	40 ppb evenly mixed medium nut plug				

## Sensor Specifications

Directional	Tri-axial fluxgate magnetometers and Q-flex accelerometers		Gamma	Nal Scintillation
Measurement	Range	Accuracy	Parameter	Specification
Inclination	0 - 180°	+/- 0.1°	Memory Update	7.2 samples/ ft at 50 ft/hr
Azimuth	0 - 360°	+/- 0.25°	Real Time Update	3.6 samples/ ft at 50 ft/hr rotating 2.4 samples/ ft at 50 ft/hr sliding
Toolface - Magnetic	0 - 360°	+/- 0.5°	Resolution	1 API
Toolface - Gravity	0 - 360°	+/- 0.5°	Sensitivity	2.5 counts per API
TMF	0 - 100 µT	+/- 0.075 µT	Memory	32 Mb.
Dip	-90 - 90°	+/-0.15°	Sampling Period	Programmable 1-60 seconds
GT	0 - 2.000 g	+/- 0.001 g		
Temperature	-32 - 392 °F	+/- 1 °F		
Peak Shock	0 - 250 g	+/- 1 g		

## Surface System Specifications

Surface System	SAI - Safe Area Interface
Rig Floor Display	Certified Zone 1, Intrinsically safe
Pressure Transducer	4 - 20 mA, 0-5000 psi, Zone 1, intrinsically safe
Hook Load Sensor	4 - 20 mA, - 0 100 klb, Zone 1, intrinsically safe
Depth Encoder	Incremental, Two Channel in quadrature, Zone 1, intrinsically safe
Plotter	Printrex Thermal Plotter

## Directive™ - a Tensor MWD

### Directive Directional Module

The Directive technology suite has redefined expectations for accuracy and reliability of Directional Modules. The market leading electronics, designed and manufactured by Tensor Drilling Technologies, dramatically improves Tensor MWD performance. Users benefit from improved reliability and preventive diagnostics significantly reducing total cost of ownership. TENSOR is the proven and most cost-effective probe MWD platform for High-Temperature, High-Pressure [HTHP] applications - while reducing NPT and increasing mean time between failure [MTBF].

The Directive Directional Module [DM] is the core of the Tensor MWD system and has three main sub-assemblies:

- Micro-Processor Unit [MPU]
- Triple Power Supply [TPS]
- Orientation Module [OM]

### Proven Reliability

System development included HALT testing over a temperature range of -60 - 220 °C/ -76 - 428 °F under vibration levels up to 80 g RMS.

Rigorously verified with more than 10,000 field test hours of benchmarking at temperatures up to and beyond 175°C, more than 1,000 hours drilling and more than 50,000 feet drilled in various formations in North America with both EM and mud pulse telemetry.

### Rugged Design

Complete redesign of PCBs has delivered a reduction in components and an improved layout. New encapsulation technology packages the electronics with market leading thermal and vibration protection. The multi-layered, pre-formed Ulti-Pak™ delivers unmatched protection thus improving reliability and realising real reductions in total cost of ownership.



### High Temperature as Standard

Directive electronics are rated to 175 °C/ 347 °F as standard thus delivering premium performance at a non-premium price



### Directive Micro Processor [MPU]

The Directive MPU is the heart of Directive Directional Module and is responsible for controlling the acquisition, storage and transmission of data from the MWD and LWD systems.

### Shock Evaluation

On-board accelerometer electronics monitor lateral, transverse, and total shocks. Transmission of real time shock levels allow modification of drilling parameters to reduce shock and vibration therefore increasing ROP. Memory can be downloaded post-run and used together with lifetime recorders to define preventative maintenance schedules.

### Memory

With 32 MB of on-board memory the Directive MPU is capable of recording multiple channels of survey, logging and diagnostic data at a resolution to meet any operational requirements.

### Rotation Sensing

The MPU uses either accelerometers or magnetometers to measure drill string rotation. The tool can be programmed to transmit different data parameters based on the measured rotation to efficiently use all available transmission bandwidth.

### Re Sync Capability

Allows the tool to automatically recover telemetry signals when the tool signal is lost, without having to stop the drilling process to regain signal.

# Directive™ Directional Module

## Downlink Capability

The user can change the operating behavior of the tools while downhole using pressure cycles. This allows for increased drilling efficiency and fewer trips out-of-hole to reconfigure the MWD system.

## Industry Wide Capability

The Directive MPU is compatible with Scinturion™ Gamma and Centerfire™ resistivity tools and has been tested with a variety of industry standard surface receiver systems. Proven compatibility with Tensor v1.6x compliant surface receiver systems.

## Simple Firmware Management

Tensor Drilling Technologies delivers firmware upgrades that are installed by the customer to ensure the MPU delivers the exact performance and data that is required by an evolving and dynamic industry.



## Triple Power Supply [TPS]

The Directive Triple Power Supply is a modular switching power supply assembly designed for use in downhole tools. The Triple Power Supply converts input battery voltage to +5 and ±13 V output supply. Both durable and reliable, the tool delivers market leading performance for downhole power needs.

## Improved Reliability

Completely redesigned electronics provide proven durability with reliable performance across the entire temperature range.

## Accurate Performance

The Directive TPS gives market leading stability and accurate output in all operating environments.

## Predictive Testing

The Triple Power Supply is designed to be easily

tested during routine maintenance. Performance is tracked allowing any problems to be identified before they cause failures thus delivering improved utilization

## Electrical Specifications

Input Voltages	19 - 32 Vdc
Output Voltages	+5 Vdc ± 100 mV @ 100 mA +13 Vdc ± 0.5 V @ 150 mA

## Orientation Module [OM]

The Directive Orientation Module was designed to maintain industry standard measurement accuracy while reducing total cost of ownership.

## Redesigned for Reliability

A reduction in the number of electronic boards and utilizing surface mount technology drives the Directive mission statement of lowering total cost of ownership.

## 4 x Sensor Calibration Stability

Recognizing that the requirement for re-calibration is a major cause of DM downtime the Sensor was designed with a major focus on calibration stability. Improved mechanical architecture together with electronic stability the OM has been proven to deliver up to 4 x sensor calibration stability, the equivalent of >2000 hrs operating at 175 °C / 473 °F.

## Performance Confidence

Industry demands for repeatable accuracy drove the development of a sensor with market leading specifications. The Directive OM delivers a 2 x improvement in the requirement of 0.25° Azimuth accuracy in all orientations, locations and temperatures.

## Directive Specifications

### Dynamic Specifications

Vibration	20 g RMS
Shock Limit	1.000 g / 0.5 millisecond 1/2 sine all axes

### Temperature Specifications

Operating Temperature	-25 °C to +175 °C -13 °F to 347 °F
Maximum Thermal Gradient	3 °C per minute 5.4°F per minute