Ending Encoder-Related Downtime in Oil & Gas Drilling Applications
Part 2 of a Series: Draw Works Encoders

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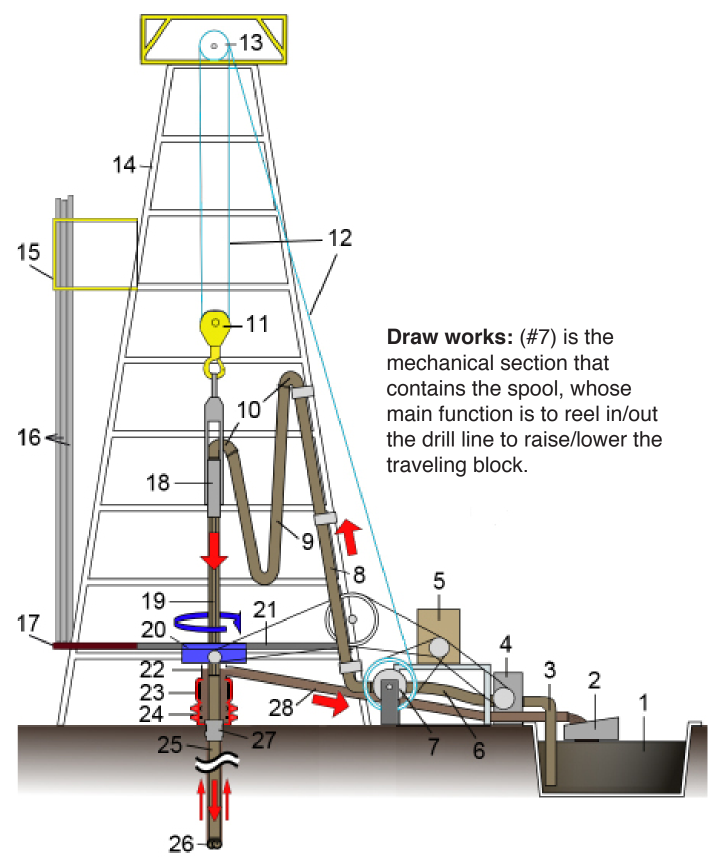
This series of white papers describes how to dramatically reduce encoder failures and encoder-related downtime in a range of applications for encoders in oil drilling and rework applications, from the top drive to coil tubing rigs. Encoders are an essential part of the control system yet cause serious downtime issues—these papers explore problems and practical solutions.

An appendix to this paper is available with information on feeding cooling fluids directly through the draw works encoder and eliminating the off-axis encoder drive assembly.

Draw Works History

An overview of drilling equipment components:



Draw works: (#7) is the mechanical section that contains the spool, whose main function is to reel in/out the drill line to raise/lower the traveling block.

From Wikipedia:
http://en.wikipedia.org/wiki/Drilling_rig#By_method_of_rotation_or_drilling_method

Often a draw works uses two huge locomotive-grade electric motors meshed with a massive gearbox to drive the drum then adds a tiny encoder with 20kg bearings, glass disk, fragile electronics in a pressed aluminum can! Talk about a mismatch!

The encoder can be applied to the back of the motor, or for more accurate position control, it is applied to an intermediate gear shaft or directly to the drum shaft itself.

Because drill string position is critical, as well as velocity and torque control of the draw works operation, one encoder failure can bring a draw works and an entire drilling operation to a halt. Many draw works vendors add multiple encoders in an attempt to provide at least one working encoder on the system.

Fundamental Challenges

Vibration. As draw works are moved from drill site to drill site, they see terrific vibration. Stub shafts are frequently less-than perfect causing vibration that can break couplings or break tether brackets on hollow shaft encoders.

Physical Impacts. Because the encoders protrude from the motor frames and gearboxes they are the most likely items to be hit during transportation. They are often used as stepping points for maintenance staff.

Rewiring. Each time the draw works is moved from site to site the control system wiring is torn down and then rebuilt. This introduces many field wiring errors. These wiring errors can destroy many common encoders as outputs are frequently shorted, voltage is applied directly to outputs, etc.

Temperature Cycling. Draw works applications start at -50°C or -40°C, or the motor heat may bring the ambient air to 80°C in hot climates. These temperature cycles cause direct electronic failures but even more commonly cause seal failures in standard encoders.

Environment. The drilling site can be 100% condensing humidity, with salt water, ice, dirt, hydrocarbons and acids all present.

Safety Certifications. Approving insurers and drilling operators vary significantly in their safety certification requirements, but most draw works applications are either ATEX, IECEX Zone 1 or UL Class 1 / Div 1 (US NEC 500) or UL Class 1 / Zone 1 (US NEC 505) certification.

Expansion. It seems that typically every control and monitoring system wants to have its own separate encoder feed signal from the draw works. Any encoder system needs to be expandable, allowing separate isolated electrical outputs from the encoder.

Failure Modes

Electrical failure. Encoders onsite are frequently exposed to voltage surges and short circuits caused by the site wiring issues. Standard encoders can't withstand either condition.

Optical electronic failure. Typical encoder construction uses optical sensors with a glass disk. Lines on the disk interrupt a light beam to a photoeye. **(Fig 1)**

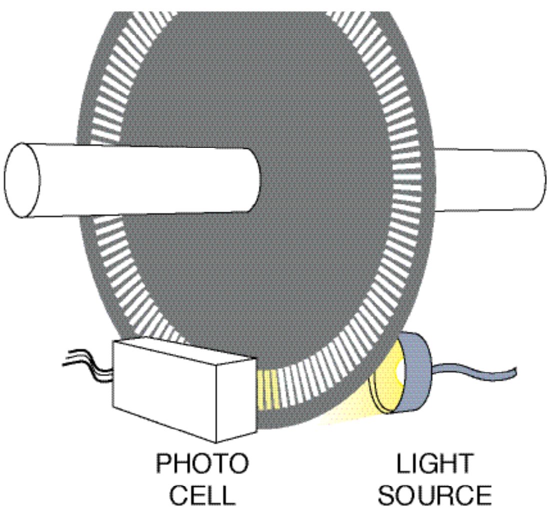


Fig 1

But this system can easily be disrupted by dirt and water that interrupt or distort the beam, and the glass disk is very prone to cracking or shattering.

Bearing failure. Typical encoders use a tiny ball bearing to support either a solid or hollow shaft construction. These bearings frequently fail when subjected to vibration and loads caused by tethering hollow shaft models, spline coupling systems or belt-driving shafted models. Moreover, the "stacked" encoders often added by control systems are exposed to huge wobble, as the rough pipe threads used to stack them do not provide good centering. **(Fig 2)**

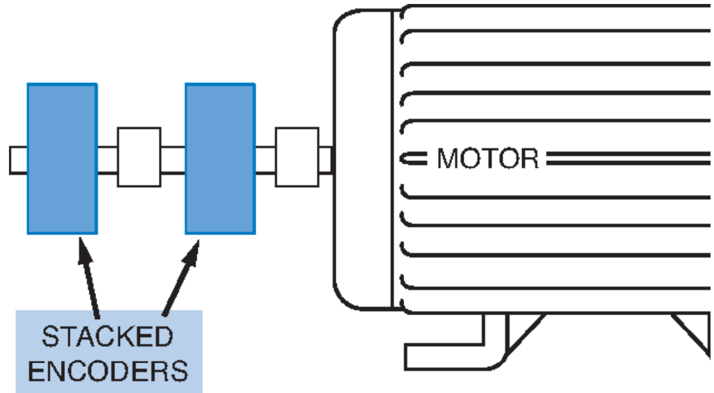


Fig 2

Seal failure: The repeated temperature cycling causes pressure on the encoder seals which then give way. More temperature cycles draw dirt, dust, water and oil into the optics and bearings, causing optical system or bearing failure.

Practical Solutions

Mechanical issues. Select severe duty models with improved sealing. Labyrinth and combination seals are used instead of simple rubber washers or seals. **(Fig 3)**

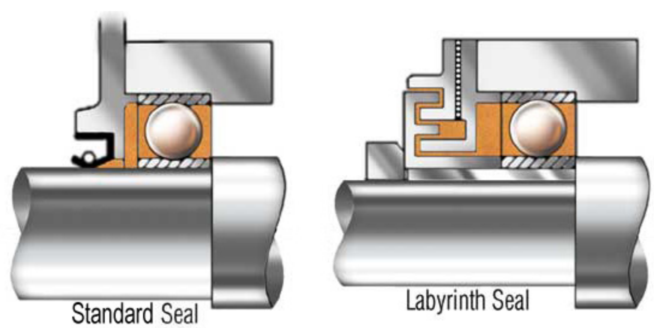


Fig 3

This greatly decreases ingress of water and dirt. While water and dirt don't directly cause potted magnetic sensors to fail, they can cause any bearing to fail over time.

But don't rely on IP ratings…they don't tell the real story. Look at the vendor's sealing system. Are there multiple protective layers and systems to keep particles and liquids out?

Now reduce the external load on the encoder. Eliminate belt-driven, shafted encoders. Either select hollow shaft encoders or modular (two-piece) bearings that mount directly on the motor or gearbox to eliminate the belt drive.

Remember that for hollow shaft encoders, be sure the tether is flexible (or has pivoting joints) in the axial direction to allow for shaft movement and runout. Often customers may try to create their own tethers instead of using the vendor-supplied tether and they make these brackets much too strong. Strong tethers destroy the bearings in a hollow shaft encoder as it tries to “move” with the shaft runout/wobble.

If you keep breaking tether arms (or couplings) on your draw works, this is the canary in the coal mine…your hollow shaft encoder is mounted on a shaft with a lot of runout **(Fig 4)**.

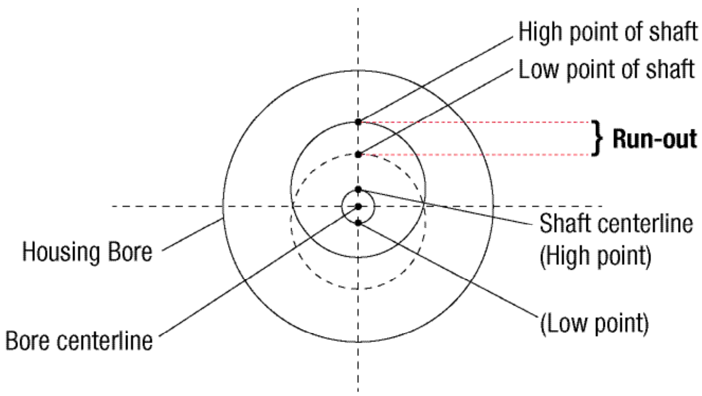


Fig 4

Or the shaft is far undersize, and the encoder is “tipped”. Check for shaft runout with a dial indicator gauge. A no-bearing modular style encoder has two big advantages here. First, it can ignore most reasonable shaft runout and still give an accurate signal for control. Second, it actually bolts to the motor or machine frame and provides impact protection for the shaft. This means you won’t be worried about shaft runout due to impacts or less-than-perfect installation.

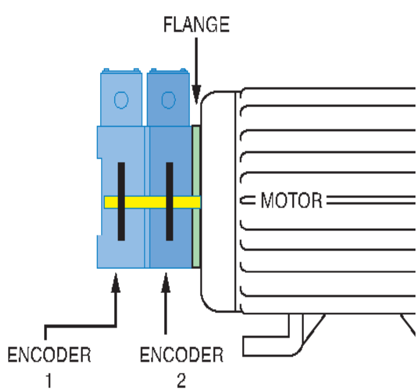


Fig 5

You can even “stack” no-bearing encoders easily to allow additional control systems their own encoder. **(Fig 5)** The big advantage here is that modular encoders are often thinner than their hollow shaft counterparts, allowing stacking on a single shaft and eliminating the wild wobble of the stacked hollow shaft systems. Most allow dual output, and some even have replaceable electronics allowing easy expansion from 1 to 2 sensors. (On modern no-bearing encoders, the two sensors don’t even have to have the same PPR!)

Speaking of bearings

The above mentioned no-bearing modular encoders eliminate all bearing issues. The difference is that the system utilizes the motor’s or shaft’s own heavy-duty mechanical construction. **(Fig 6)**

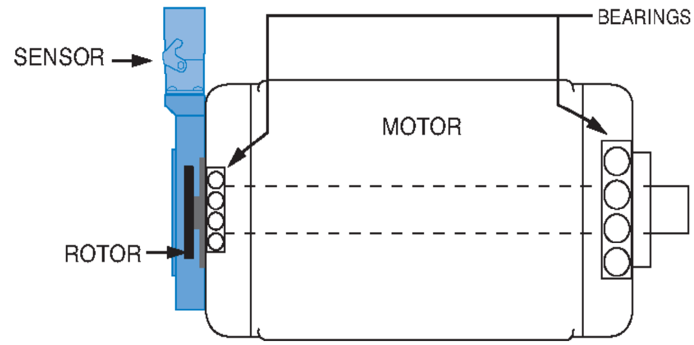


Fig 6

The magnetic ring or rotor is mounted onto the motor shaft or stub shaft. The magnetic ring rotates in front of a magnetic sensor which provides the measurement of position and speed, just as it does in a conventional magnetic encoder with bearings. As long as the motor parameters (axial movement, radial positioning accuracy) are within the mounting and operating limits of the encoder, no-bearing encoders are the way to go for maximum durability and life.

But modular encoders require a machined flange or face…you’ve got rigs in the field with no flanges. What to do? You can either add a field-mounted flange, and then use a no-bearing encoder, or you can mount a better, severe duty hollow shaft encoder.

Let’s look at these options. Adding a flange to an existing motor or gearbox is actually a quite simple operation. Using a centering jig, the flange is added and permanently fixed with bolts or welding. Then the centering jig is removed. Now the no-bearing encoder can be added to any machine.

But what if you can't add a flange? This is the right place for a severe duty encoder with much larger bearings. Two encoders are shown for comparison. The first unit, an industry standard HS35 style, features 2 bearings rated at approximately 50kg each. The second severe duty unit, which mounts on the same shaft size, offers 2 bearings rated at 2200kg each. **(Fig 7)**

Fig 7

Even when the encoder is not exposed to high forces the huge bearings greatly increase life because they withstand minor contamination better and offer much longer life under minor loads. (And yes, they withstand those 100kg steel-toed climbing workers better, too.) All those tough mechanical bits are an essential part of an encoder. But just as important is what goes inside.

First, ditch the optical encoder system. Optics are a great system in a nice lab with semiconductor chip machines. Optics are not a good solution in a muddy field drilling operation with rain coming down and temperature swings every day. Switch to magnetic encoders.

Magnetic encoders don't require fragile glass disks or dust-free operation. Magnetism reaches through moisture, oil and dirt unaffected enabling the magnetic sensor to correctly and accurately detect rotation under all conditions. **(Fig 8)**

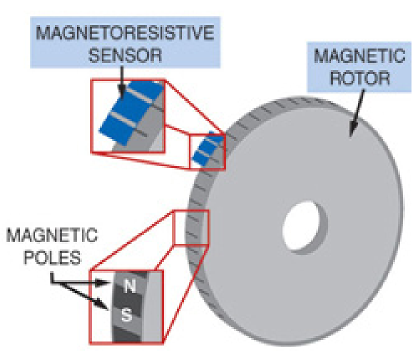


Fig 8

Vendors offer magnetic encoders in a broad variety of form factors including shafted models, hollow shaft, and modular styles **(Fig 9)**.

Fig 9

Magnetic systems enable the encoder vendor to imbed the electronics in solid potting plastic compounds. This ensures the electronics ignore liquids and increases shock, impact, and vibration resistance. **(Fig 10)**

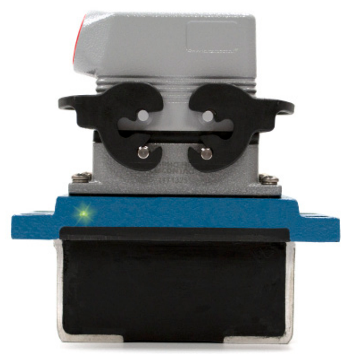


Fig 10

The encoder must protect itself. Insist on units with automotive or better grade input voltage regulators to protect against surges of at least 50v. Moreover, the outputs should be fully protected against all types of short circuits—line-to-line, line-to-ground, and line to V+ or higher. Wiring errors, such as wiring power to an incorrect pin, should not cause encoder failure. Instead of wiring to a terminal box, consider premade cables using connectors certified for the safety standards. This will eliminate the time spent troubleshooting rewiring errors. Good connector systems are now widely available for ATEX, UL Class/Div and UL Class/Zone applications, and encoder vendors are adopting them.

Do you want to know about draw works encoder failures before they happen?

Get predictive diagnostics. These internal systems troubleshoot the encoder for you, and warn if the signal is drifting out of acceptable range. Often these systems warn of a problem before it causes a drive trip.

Also if there is a trip, the technician can check the local LED easily—if it's red, it's an encoder problem, if it's green, look elsewhere for the real problem.

Older encoders had virtually no external diagnostics and required an oscilloscope to troubleshoot, or required the connection of a computer. The old method of troubleshooting was to immediately swap the encoder, then look for the real problem. Time consuming, especially when a spare isn't handy, the work crew waits for the spare, then discovers replacing the encoder doesn't get them running again.

Summary

Draw works are a tough application for encoders. Temperature swings, impacts, vibration all take their toll. But by upgrading the encoder, users and OEMs can experience dramatically lower downtime. Key points—eliminate the encoder bearings if you can using no-bearing encoders that bolt directly to the machine frame, make the bearings huge if you can't eliminate them. Eliminate optics. Eliminate field rewiring.

The appendixes shows various Nidec-Avtron encoder models that have been proven to dramatically increase reliability of draw works applications. Models with safety certifications (ATEX, IECEX, UL, CE) are shown.

Appendix 1: Feeding Cooling Systems Through the Draw Works Encoder

Many newer draw works designs use liquid cooling feeds **(Fig 11)**

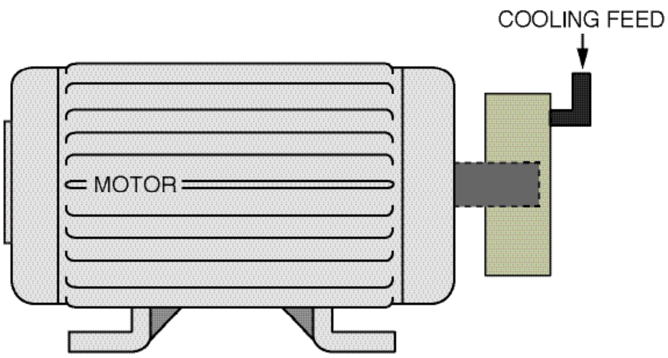


Fig 11

This leaves no small stub shaft to mount or drive the encoder. Morever, most safety-rated hollow shaft encoders are only open at one end, that is, they don't allow anything to pass through the back cover of the encoder.

To solve this problem, vendors have experimented with small off-axis belt-driven encoders and other similar solutions. But now the fragile encoder is dependent on a belt drive, which decreases reliability even more. **(Fig 12)**

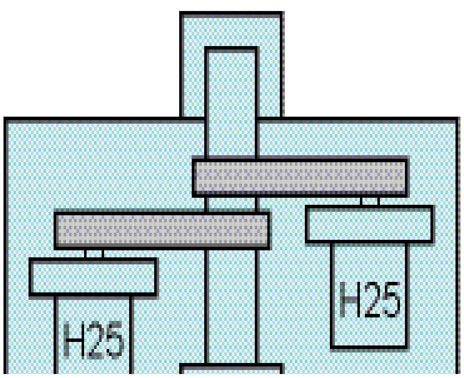


Fig 12

But a no-bearing modular encoder solves the problem in an ideal way—the rotor and stator housing allow the large shaft bore carrying the liquid to pass directly through the center of the encoder. The magnetic sensor system is potted and ignores any stray liquids or mud. The encoder doesn't disturb the shaft or liquid-coupling system in any way. **(Fig 13)**

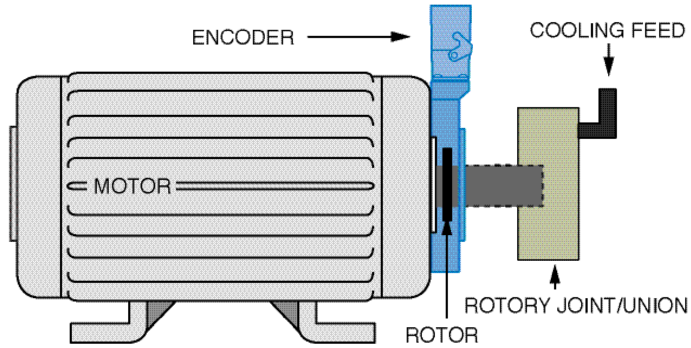


Fig 13

The safety rating of the encoder is maintained electrically, not via the housing, so the shaft can pass freely through the encoder stator and rotor.

Typically a simple cover and v-ring seal are used to keep large objects out of the encoder. **(Fig 14)**

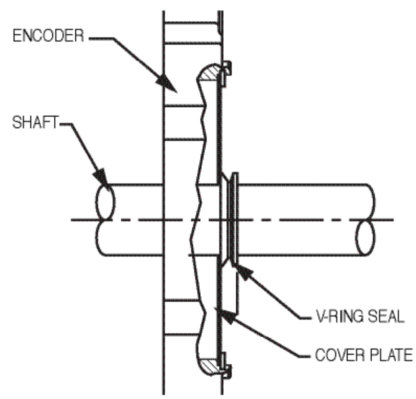


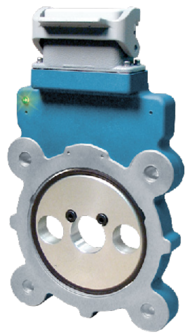
Fig 14

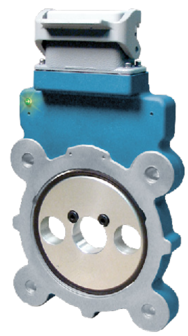
But ensure your encoder has a wide sensor-to-rotor air gap, as materials will get into the rotor area, so the encoder must be able to withstand contamination in this area.

Bottom line: No-bearing modular magnetic encoders eliminate the extra cost and failures associated with off-axis encoder drive systems used on draw works with liquid cooling systems.

Appendix 2: Nidec-Avtron Encoder Models Suited for Draw Works in Oil and Gas Drilling:

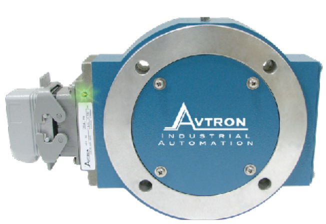
XR56, XR115





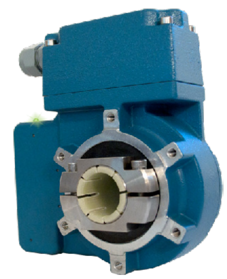
Modular magnetic encoders for flange mount
Allows up to 85mm (3 3/8”) shaft
Allows cooling liquid feed directly through the encoder
No bearings
Potted electronics
Single or dual independent PPR outputs
Predictive diagnostics
Requires XRB1 Isolator for Zone 1 applications
ATEX Zone 1, IECEX; UL Pending

XR850, XR125



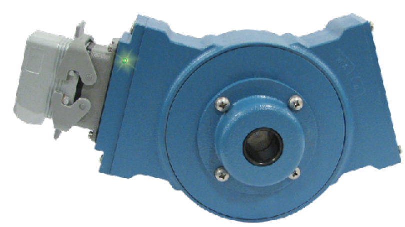
Modular magnetic encoders for flange mount
Allows up to 115/200mm (4 ½” / 7 7/8”) shaft
Allows cooling liquid feed directly through the encoder
No bearings
Potted electronics
Removable sensors
Single or dual independent PPR outputs
Predictive diagnostics
Requires XRB1 Isolator for Zone 1 applications
ATEX Zone 1, IECEX; UL Pending

XR45



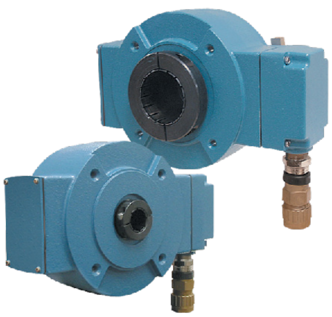
Hollow shaft magnetic encoders
Allows up to 30mm (1 1/8”) shaft
Huge bearings
Labyrinth seals
Potted electronics
Predictive diagnostics
100G/300G shock rating
Requires XRB1 Isolator for Zone 1 applications
ATEX Zone 1, IECEX; UL Pending

XR685



Hollow shaft magnetic encoder
Allows up to 28.5mm (1 1/8”) shaft
Huge bearings
V-ring seals
Potted electronics
Removable sensors
Single or dual independent PPR outputs
Predictive diagnostics
100G shock rating
Requires XRB1 Isolator for Zone 1 applications
ATEX Zone 1, IECEX; UL Pending

M6



Hollow shaft magnetic encoders
Allows up to 60mm (1 1/8”) shaft
Large bearings
V-ring seals
100G shock rating
No Isolator required for Zone 1 applications
ATEX Zone 1

For more information about this article or encoders & tachometers in general, contact:

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