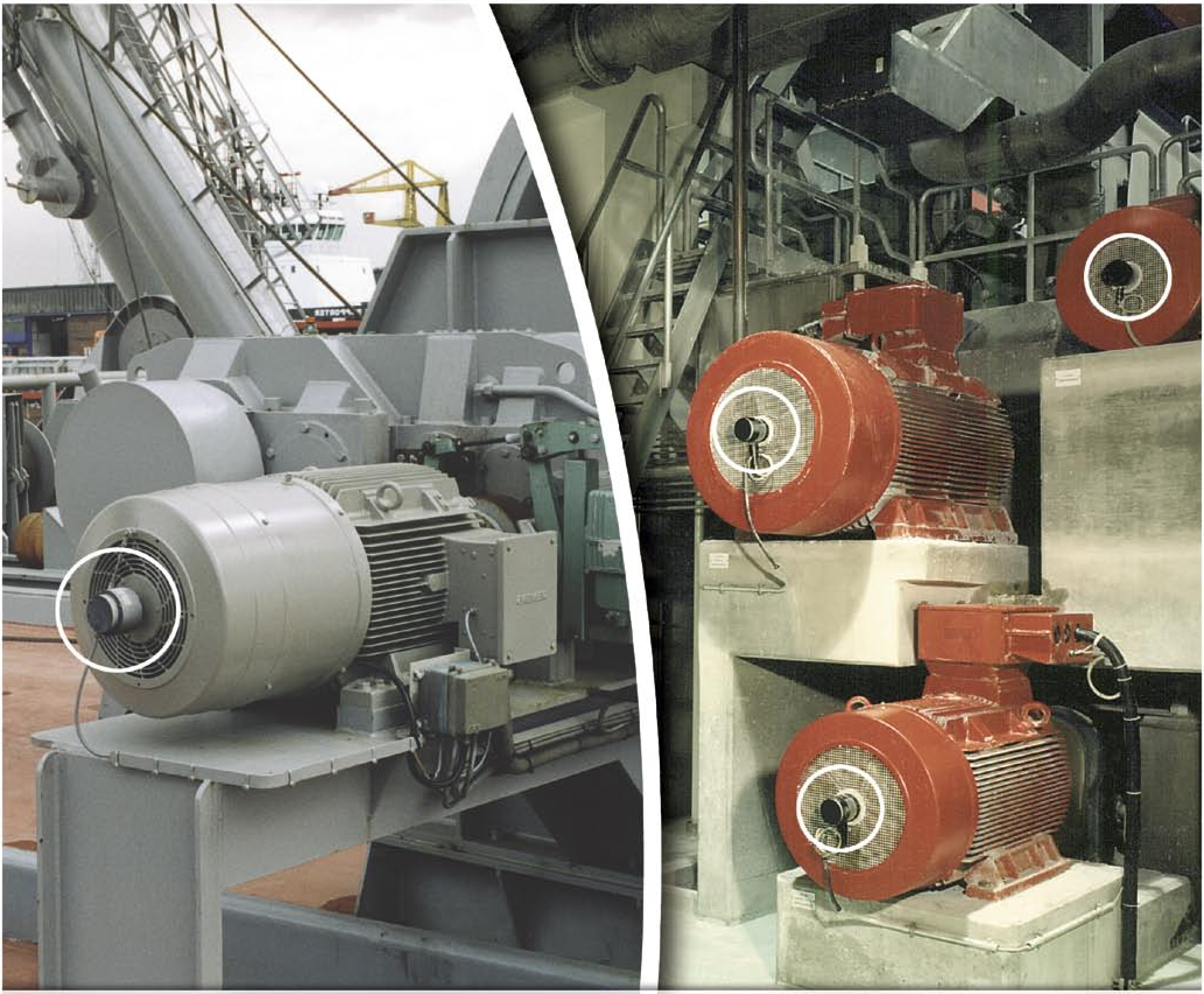
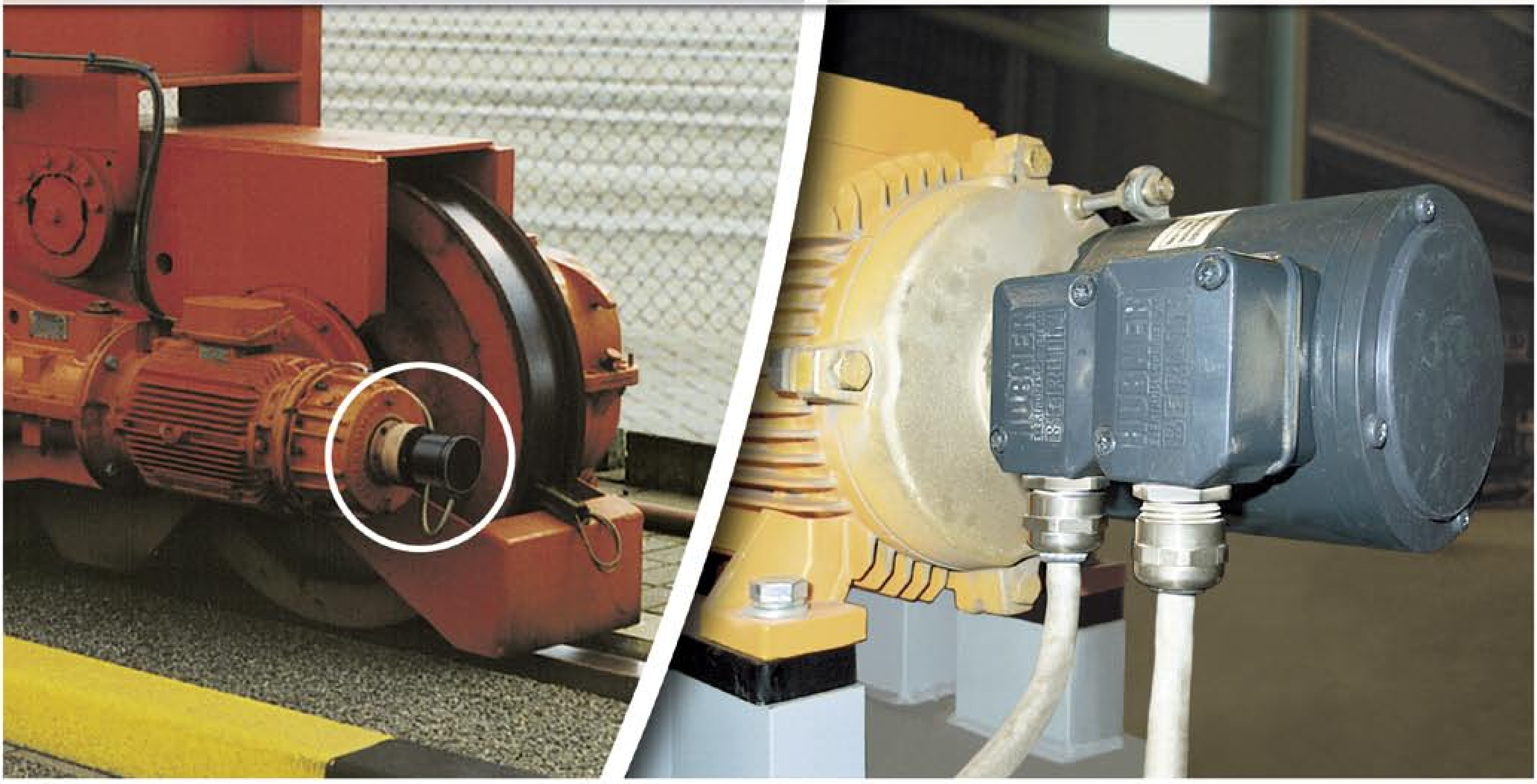


OUTDOOR HeavyDuty INDOOR



Features of HeavyDuty Technology

Requirements for rotary encoders in tough industrial use

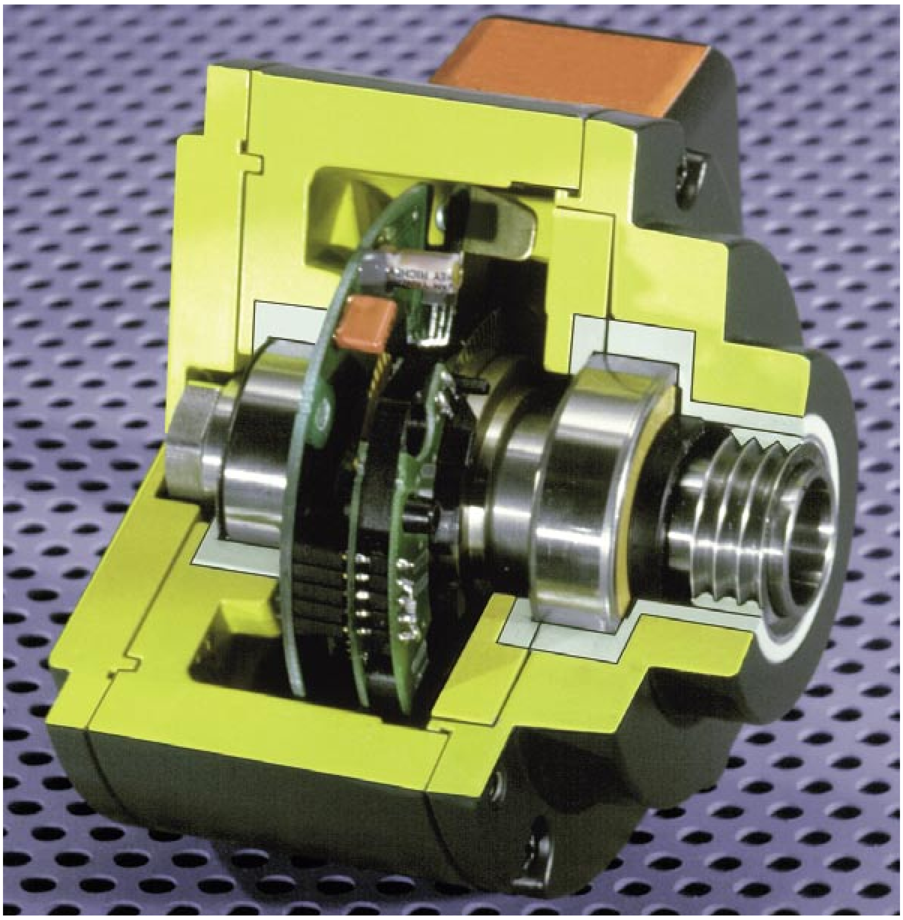


Fig. 1: HeavyDuty-Technology at its best: solid aluminium housing, generously dimensioned ball bearings with an insulated mounting, sensor electronics with power transistors, labyrinth seal

Lothar Wilhelmy, Kai-Hans Otto

Several hundred-thousand rotary encoders for speed measurement in closed-loop drive controls are manufactured in Germany. The largest portion consists of products for servomotors with a 58 mm housing diameter. In machinery and plant manufacture, special demands are made with regard to the frame size, and thus for electrical and mechanical robustness. This article explains the technology of encoders that have proved their value in tough environmental conditions. After all, downtime costs can very quickly become several times more expensive than the costs of the encoders themselves.

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Brief review

The HeavyDuty Technology at Hübner in Berlin originated in 1934, with the development of a completely immersed underwater motor – a pioneering action in view of the somewhat inadequate insulation materials available at the time. The company profited from this experience in electromechanical engineering in 1955, as the German Federal Republic built the most modern steelworks of its day in Rourkela, India, and Hübner supplied the tachogenerators for the drives in the hot-rolling mill. This was the birth of speed sensors in HeavyDuty Technology, as the know-how thereby gained was implemented in 1978 in the robust OG 9 incremental rotary encoders, which were adapted shortly after as the POG 9 for use in paper machinery. The "P" in the type designation of this product, which meanwhile has become widespread in the machinery and plant manufacturing sector, indicates its original application. Right from the start, these encoders were distinguished by the B10 Euro-flange that has now become an industry standard, with an 11 mm shaft diameter and the associated mechanical and electrical attributes of HeavyDuty Technology.

Mechanical requirements

Paper machines were again responsible for an innovative leap when HeavyDuty Technology was applied to the HOG 10 hollow-shaft rotary encoders for direct mounting on the drive machinery, see **title picture** at top right. The robust design also permits open-air operation, see **title picture** at top left and bottom left.

Generously dimensioned ball bearings are fitted in the solid die-cast housing, on both sides of the sensor electronics, see **fig. 1**. True, this design takes up a bit more space than the single-ended bearing support of typical encoders, but has the advantage that the shaft can withstand larger forces in the radial and axial directions. This means that the shaft can be extended, to take a second device, such as a mechanical centrifugal switch that triggers a switching action when a given speed limit is exceeded, or an electronic speed switch with one or three settable switching speeds for control functions in the drive aggregate.

The extended shaft also means that a second speed sensor system can be provided, one which is electrically independent of the first system as indicated by the two terminal boxes, see **title picture** at bottom right. In this way, independent control loops can be set up – even with different numbers of pulses per turn – or redundant signals acquired for safety monitoring.

Both ball bearings have an insulated mounting in the housing, as shown in **fig. 1**, to prevent shaft currents in the drive machine flowing through the earthed encoder housing. Such currents are extremely dangerous for the ball bearings, since spark erosion can cause lasting damage to the balls and the bearing surfaces. A labyrinth seal is the first line of defense to keep dust out of the sealed bearings.

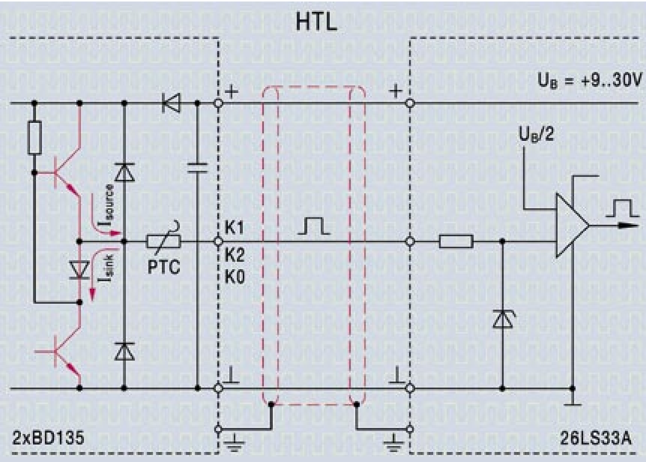

Fig. 2: High-voltage transistor line drivers (HTL technology) with power transistors to drive long cables

Fig. 3: Assembled PCDs are tested for resonant frequencies

Another feature of HeavyDuty Technology are the large, EMC-protected terminal boxes, which can be rotated through 180° to position the cable opening to the left or right of the encoder. Customer-specific solutions with internal cable terminals, metal connectors or fixed cables are also possible.

Fig. 4: In a test rig the electromagnetic compatibility (EMC) is optimized

Electronic requirements

The sensor electronics and the incremental disk are located between the bearings as already mentioned. Wherever possible, the incremental disk is made of metal, to improve shock resistance. Plastic disks are not used, because although they are also shock resistant, their shape tends to lose stability at higher temperatures and they are not very resistant to chemically aggressive environmental conditions.

When holding brakes bite, shock waves up to 2000 g can be generated in the shaft

The sensing is performed by shock- and vibration-resistant optical ASICs, using LEDs with controlled brightness. The square-wave signals of HeavyDuty rotary encoders usually have to be transmitted over considerable distances under high EMC levels, particularly if the signal cables are routed close to motor cables. As a standard, Hübner has therefore always employed high-voltage transistor line drivers (HTL) with signal levels up to 30 V, to ensure a correspondingly high signal to noise ratio for reliable detection of the signals at the receiver.

Signal cables typically have a specific capacitance of 100 pF/meter, so that, for example, the push-pull line driver outputs of each channel have to continually charge and discharge a cable capacitance of 10 nF for a 100 meter cable with the switching frequency. With a typical slew rate of 10 V/µs, the square-wave signals generate charging and discharging currents of 100 mA. Even longer cables, which have a characteristic impedance Z ≈ 120 Ω, load the line driver with up to 250 mA at 30 V signal levels. The line drivers for the Hübner rotary encoders from Series 9 onwards (corresponding to about 90 mm housing diameter) have therefore been designed with power transistors that can handle peak currents up to 300 mA, see **fig. 2**. These transistors also have considerable power dissipation capability in the event of a short-circuit. PTC sensors are mounted between them, to sense the increase in temperature and reduce the output current to a safe level, while maintaining the form of the output signals. This is the major difference between this considerably more complex technology and the usual IC-line drivers, which switch off all outputs (and hence the signals) in the event of a short-circuit – a situation that can cause undefined states in a speed control. The space needed for the power transistors and the removal of dissipated heat requires a certain housing volume that is provided by Hübner rotary encoders from Series 9 onwards. In practice, it has worked out well to limit the power dissipation by terminating the signal cables by a 1 kΩ resistor, rather than one with the same value as the characteristic impedance. In high-EMC environments, HTL technology is also available with additional inverted signal outputs. The six channels then require six power outputs stages according to **fig. 2**.

A lot of testing to ensure toughness

The mechanical and electrical toughness is not just designed into the rotary encoders, but also verified through extensive testing.

- **Resonant frequencies:** During the development phase, the assembled PCBs are tested and optimized for the resonant frequencies of the components, in a test and measurement rig with continuously tunable frequency and amplitude (a sine-wave sweep from 10 to 2000 Hz), see **fig. 3**.
- The **electromagnetic compatibility** (EMC) is tested for burst-voltage capabi-

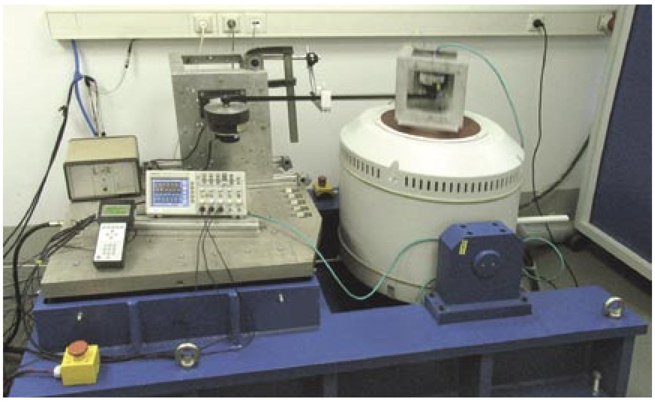

Fig. 5: Vibration testing of the actively operational encoder (right-hand side) in the x, y and z axes

Fig. 6: The encoders are exposed to quartz dust blown into the dust-testing chamber

Fig. 7: Incremental and absolute encoders, with hollow or solid shafts, complete the family of rugged encoders

lity in a pulse voltage test setup based on EN 6100-4-4 and –5, see **fig. 4**. The line drivers have to withstand voltage pulses up to 4 kV that are capacitively transferred to the cable leads over a 1-meter long coupling distance. The same conditions are used to test the signal transmission to the receiver components, such as the Hübner HEAG 151 to 154 digital converters.

The company-internal tests are followed by extensive test and measurement at an accredited test house:

- The **vibration testing** of the complete rotary encoders in compliance with IEC 60068-2-6 is made in the x, y and z axes with the encoders electrically active and being driven, see **fig. 5**.

- The **continuous shock test** as per IEC 60068-2-27 and -29 subjects the encoders to a shock acceleration of 2000 m/s^2 along all three axes, with a duration of 6 ms. This test has become particularly significant since it was demonstrated (using a low-inertia acceleration sensor) that when holding brakes bite, shock waves up to 2000 g can be generated in the shaft, which are thus transmitted directly to the hollow-shaft encoder.

To verify the **enclosure protection IP** (International Protection) as per IEC 60529, the encoders are tested for "Protection against ingress of foreign bodies" (first number in the IP code) and for "Protection against ingress of water" (the second number):

- The **dust protection testing** for IP 5X requires exposing the encoder to a whirlwind of finely distributed quartz particles for 8 hours, see **fig. 6**. For verifying the dust-tightness as per IP 6X the test conditions are made tougher by making a hole in the encoder housing and connecting this to a vacuum pump.

- The **water jet test** for IP X6 ("Protection against a strong water jet or heavy sea") involves directing a water jet onto the object under test, at a pressure of 12 bar and a flow rate of 100 liters/minute. Sealing to comply with IP X7 is tested by immersion in water at a depth of 1 meter.

- In addition, the encoders are subjected to a **sprayed salt mist test** for marine application and a humid heat test to verify their **tropical suitability**.

Further tests, including those for temperature, insulation resistance and high voltage, round off the testing program. Extensive **Quality certificates** confirm that the tests have been passed successfully, and provide the customer with the assurance that Hübner rotary encoders are fit for use in tough conditions. The certificates and further details can be downloaded at **www.huebner-berlin.de**.

The field-tested HeavyDuty Technology has now been applied to single-turn and multi-turn encoders with hollow or solid shaft as well, see **fig. 7**.

Summarizing, it can be seen that Hübner rotary encoders in HeavyDuty Technology are clearly in a different league from standard rotary encoders, and years of field-tested experience are necessary to ensure the toughness and reliability required in machinery and plant manufacture.

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