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A (NEW) MINING SCOOP**

## Technical

- Rolling Bearings in High-Speed Passenger Traffic
- Improved Performance for Hydraulic Seals

## Power Play

- Who is Thomas Davenport?

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All prices are U.S. published prices. AutomationDirect prices are from April 2012 Price List. Baldor prices taken from www.baldor.com 2/20/12. Dayton prices taken from www.grainger.com 2/20/12. Prices and specifications may vary by dealer and configuration. Prices subject to change without notice.

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Visit [www.powertransmission.com/newsletter](http://www.powertransmission.com/newsletter) to read these articles and many more!



### GEAR TECHNOLOGY E-News exclusive articles (online only!)

- Quality and Inspection Product Roundup (April 2012)
- Offshore Wind (March 2012)
- Green Heat Treating (February 2012)

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## THE BEST New IDEAS

In the publishing business we thrive on new ideas. We employ creative people who are constantly coming up with new and better ways to serve our readers and website visitors. Often those new ideas turn into fantastic new products—like our e-mail newsletters and product alerts, which have become an important part of how we communicate with you.

But sometimes the best new ideas aren't new at all. They're just old ideas that have been set aside or forgotten. Over the past few months, we think we've come up with a couple that deserve to be rekindled, rejuvenated and reintroduced.

The first is our "Ask the Expert" feature.

Our mission as a publishing company has always been one of education. For almost 30 years, we've helped people in the industry understand the best use of technology through our technical and educational articles. One of the best ways we can help our readers is by tapping into the pool of knowledge embodied by the many experts we've come to know through the years.

On *powertransmission.com* (before we even had a magazine), we used to have a very popular "Ask the Expert" forum. People from around the world would submit questions about bearings, motors, gears, clutches and other mechanical power transmission and motion control topics. We've decided to bring that feature back, both online and in print. Our goal is to take readers' technical questions and submit them to our panel of experts for written responses.

This model has already proven to be a big success over at *Gear Technology* magazine, where we reintroduced "Ask the Expert" a couple of issues ago. So far, we've received overwhelmingly positive feedback from readers who are hungry for this type of hands-on knowledge. I expect the same will be true in *Power Transmission Engineering*.

So beginning now, we're reinstating "Ask the Expert" on *powertransmission.com*. You'll find a link right on the home page where you can submit your questions. We'll send each question to one or more experts in the field to get the best answer as quickly as possible. Then we'll publish the best questions and answers right here in the magazine.

The second idea whose time has come again is the Buyers Guide. Our website, *powertransmission.com*, was founded in 1997—15 years ago—as a way for buyers of gears, bearings, motors, clutches, couplings and other power transmission components to find suppliers who could meet their needs. Although our mission has grown over the years, that fundamental core purpose remains the same. It's our job to make sure that people looking for components know where to find them.

So we're making a concerted effort to rejuvenate the Buyers Guide at *powertransmission.com*. We want you to know that you can go there to find the most current, relevant, accurate information on suppliers in the industry.

If you *are* a supplier in the industry, you can help us by making sure your listing is current and up-to-date. Now is the time to double-check your company's contact information and make sure you're listed in all the appropriate categories. And if you're *not* listed, it's time to sign up. Listings are free. You can sign up at [www.powertransmission.com/getlisted.php](http://www.powertransmission.com/getlisted.php).

More importantly, companies listed in the online Buyers Guide at *powertransmission.com* will automatically get included in the printed Buyers Guide, which will appear in our December 2012 issue. We're always looking for ways to make the Buyers Guide more useful and practical. If you have any suggestions, we'd appreciate them. You can send them to me directly at [wrs@powertransmission.com](mailto:wrs@powertransmission.com).

You never know where that next great idea is going to come from.

A handwritten signature in black ink that reads "Randy Stott". The signature is fluid and cursive.

**Randy Stott,**  
Managing Editor



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## Economy Continues—GENERALLY—to Improve

But Equity Markets—and the Institutional “Investors” who Move Them—

Not So Much

Our April 2012 launch of this column highlighted several key themes; we will re-state each and highlight developments, relying on our monitoring of 75 key global industrial companies and ongoing fieldwork:

- Europe matters—to Europeans
- Improving price/cost
- Energy
- Self-generated growth/urge to merge
- Global power cycle—though price pressure will limit profitability
- Asia/technology complex accelerates by mid-year
- Residential HVAC
- It's not all about China, as emerging markets continue to grow
- U.S. becoming structurally more attractive—if it can get out of its own way

**Europe matters—to Europeans.** Economically conditions have played out—though a few management teams cited a “step down” on the margin. Stock markets are discounting the worst, but recent elections in France (national) and Germany (regional) signal a lighter approach to austerity. While I would have voted

for Nicolas Sarkozy, and do not habitually favor French socialists, the winner—François Hollande—is appointing a centrist (by French socialist standards) cabinet and seeking to spend. And since European politicians—like any other—also enjoy being re-elected, the French result—coupled with a drubbing in a North German election—has prompted German Finance Minister Wolfgang Schäuble to suggest a little bit of inflation is okay. In terms of the current economy, Southern Europe and Spain are a disaster—but they can't go below zero and the resource-centric Nordic countries and Russia are growing.

**Improving price/cost.** Pricing is up, materials and oil are down—which augurs well for input costs and freight going forward.

**Energy.** We have concerns. Low natural gas prices are biting upstream gas activity in North America and are already crimping activity in pressure pumping. And I would anticipate a second, derivative impact on associated services in shale regions. Conversely, oil-related activity remains strong and our underly-

ing view of continued economic growth should support relatively high prices.

**Self-generated growth/urge to merge.** No change here; large corporates have a lot of cash, are hunting for growth and feel the need to bolster growth opportunities. They want channel, product and technology—and will pay to get it. Expect a lot more deals.

**Global power cycle (with continuing price pressure).** Broadly speaking, on-track. Price pressure remains intense, particularly in transformers; and while General Electric called out a flat price, we consider that an anomaly. As for the wind sector, enjoy '12 and hope for an extension of the production tax credit and higher gas prices. We have no insight on the former, but expect the latter, as producers begin to shutter activity in the face of low prices, high inventory and lack of storage.

Globally, expect continued acceleration in large power and process orders (Flowserve, Tyco called out in particular).

**Asia/technology complex accelerates by mid-year.** We are no longer hearing of supply chain issues owing to Thailand




flooding, and supply chains have been adjusted.

**Residential/HVAC.** Continuing to see reasonable improvement, owing to seasonal inventory build (and lean inventory) and better pricing. Lack of a heat wave so far has not helped.

**It's not all about China—or is it? Emerging markets continue to grow.** It may not be all about China—but the market thinks otherwise. Many investors see a potential “hard landing,” which in China means 6–7 percent growth and no acceleration in 2012—and marking stocks down accordingly. We think this view makes sense—but disagree on magnitude and end-market and think that election year uncertainty in China is at least part of the problem. We anticipate no construction-related turn before 2013—meaning 2–3 quarters of inventory reduction for construction equipment, engines, etc. But energy and capital investment are another story. China is short on power and grid, and wages are rising. We are already hearing about increased capital spending from automation companies and a second-half tech upswing (Asia is 40 percent technology) should drive electricity demand.

**U.S. is becoming structurally more attractive.** Low gas prices are a game changer. Recent announcements continue to show greater investment from chemical and petrochemical players that should support basic industrial demand. More a trickle than a torrent—the U.S. still could use lower corporate taxes, significant reinvestment in human capital (re-training), infrastructure (a highway bill) and improved regulatory environment. Let's wait and see in November.

**So what has changed in two months?**

On the margin, very little—but fear is up among institutional investors, and large corporates are redoubling their market surveillance efforts. Still, the trump card is what they do; and with continued investment, high cash positions and gradually improving economic conditions, we see ourselves in a classic mid-cycle recovery within the context of what may be the largest global financial engineering project of all time. 

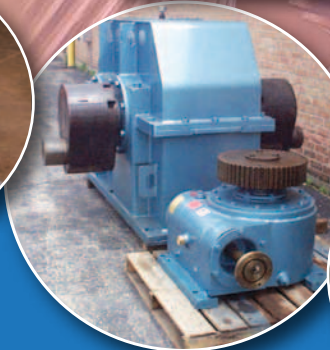
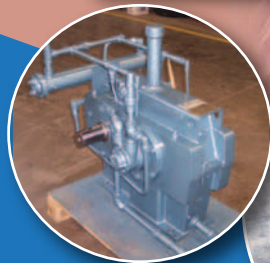
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## The Quick Fix

REXNORD SOLVES BEARING INSTALLATION/REMOVAL CHALLENGES

At a Midwestern producer of tubular steel products, measures taken to counteract the effects of impact on a quench tank roll made it difficult to remove and replace the conventional pillow block bearings that support the roll's shaft. The bearings were replaced with adapter mount roller bearings that are easier to install and also will be easier to remove. The mill produces oil and gas well casing steel and line pipe in diameters from 7" to 16", with wall thicknesses up to ½".

Previously, as the head end of a tube entered the quench tank to be cooled, impact tended to move the shaft that supported the roll to one side because the former bearings did not lock tightly enough to the shaft. To keep the shaft centered, the company welded steel washers to the end of the shaft. This made it difficult to remove and replace the bearings. The company's maintenance planner and supervisor explains, "Any time we changed a bearing, we had to cut the washer off and dress the shaft. If the bearing was there for a long time, the mill scale, dirt and grease would build up, and we couldn't get the bearing off of the shaft."



Rexnord ZA6215F adapter mount roller bearings with Shurlok technology incorporate a tapered locking sleeve to maintain bearing position on this quench tank.

The design of the replacement bearings addresses this common problem by incorporating a withdrawal sleeve into each bearing. As the adapter nut is unthreaded, the design automatically pulls the tapered adapter sleeve from the assembly, releasing the bearing from the shaft without causing damage, which saves both time and repair costs.

Bearing installation also could be problematic for the mill. The company's maintenance planner says, "The bearings we had on previously just had locking collars with no taper at all. Because things didn't work there in the past, we were just buying regular pillow blocks and tapping them in place ourselves."

To address the problem, the company selected Rexnord ZA6215F adapter mount roller bearings with Shurlok technology for the application because they incorporate features that eliminate the previous installation and removal problems. These bearings are utilized in industries such as forestry, mining, steel, cement/aggregate and air handling. They come equipped with a positive locking system, tapered mounting sleeve, hourglass rolling elements and super-finished raceways and rollers.

These features allow for quick and easy installation, reduce shaft damage caused by loose mountings, provide three degrees of static and dynamic misalignment and provide a cool running, quiet, high speed and high load capacity design. An innovative tapered sleeve



Bearings operate in a difficult environment on this quench tank application. Impact of tubes entering tank caused the roller shaft to move sideways with previous bearings.



**Optical Strain Sensing (OSS) technology in new bearings changes color to tell the installer when the bearings have been correctly tightened to the shaft.**

design maintains mounting tightness during operation, provides 35 percent greater shaft grip than other adapter sleeve bearings, and allows for better shaft grip in the mill's application. To ensure a correct installation, the new bearings incorporate SpyGlass Optical Strain Sensing (OSS) technology, which provides visual feedback that tells the installer when the bearings have been correctly tightened to the shaft. The sensor incorporates materials that respond to strain by changing reflected light wavelengths. It is calibrated so that the window stays clear until there is enough strain on the locknut to provide a sufficient load. At that point, OSS window changes color, showing that the bearing is correctly installed.

Operating conditions for the bearings include the effects of impact, as well as typical mill scale, dirt and grease. The spokesperson says the bearings have performed well since their installation in early 2008. He reports that the company is considering using them on other applications in the mill based on their combination of features and performance.

### For more information:

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## product news

### Lee

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Lee Linear, a manufacturer of linear motion components, offers a variety of combinations of individual shafts and rail components. Lee Linear offers ready-to-mount linear systems that can be easily incorporated in almost all drive control applications. U.S. manufactured aluminum shaft support rails in standard lengths of both 24" and 48", are used in shaft rail assemblies as economical methods for mounting case hardened and precision ground 60 Plus or 440C shafting. The assemblies conform to industry specifications and provide stable and highly efficient linear motion guidance for continuous or intermittent

load operations. Shaft and rail systems are available in six standard configurations, which incorporate a single, double, or twin pillow block. Either two cast steel support blocks or an aluminum rail can support the carriage plate. The patented Lee Roller Bearing Pillow Block provides for self-alignment capabilities, easier clearance adjustment, and better corrosion resistance with longer life expectations and operations at higher speeds. Systems are available with either the Roller Bearing Pillow Blocks or with Precision Plus self-aligning linear ball bearing pillow blocks.

"Optimizing a system to obtain a maximum economic advantage can be challenging," said Lee's CEO, Alan Haveson. "Lee's shaft rail assemblies and systems provide cost-effective solutions. With our larger rolling diameter pillow blocks, we are able to provide smooth and consistent operations even at high speeds."

#### For more information:

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### Hansen

EXTENDS GEARBOX PRODUCT  
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Industrial gear unit specialist Hansen Industrial Transmissions (HIT), acquired by Sumitomo Heavy Industries (SHI) Ltd. in March 2011, recently announced that its European assembly center, based in the Antwerp gear plant, will integrate the engineering, production, assembly, sales and service of the Paramax industrial gearboxes of Sumitomo for the Europe, Middle East and Africa (EMEA) region. As such the company has forged, together with the Power Transmission & Controls group of SHI, a customer oriented sales and service platform. Alongside, a clear



product strategy for the EMEA region has been developed, offering its customers and end users a more accurate selection of gear units to serve both high and low torque applications. With the regional sales and service network all over the EMEA area, higher and more flexible availability of local contacts is assured. Integrating Paramax gear units in the HIT product portfolio and incorporating the production of Paramax in the Belgian gear plant later this year, customer responsiveness will improve significantly.

**For more information:**

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[www.hansenindustrialgearboxes.com](http://www.hansenindustrialgearboxes.com)

**Thomson**

RELEASES FLUORONYLINER BEARINGS

Thomson Food Grade FluoroNyliner Bushing Bearings feature a non-magnetic 303 Stainless Steel corrosion resistant sleeve with a self lubricating liner that is FDA and USDA compliant, enabling them to excel in challenging food processing, pharmaceutical and medical applications. They are offered in Open and Closed types, with specific machining options available to satisfy unique application requirements.

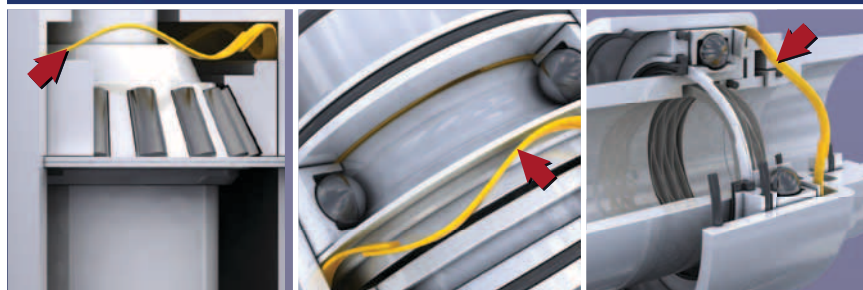
“By eliminating the need for ball bearings, these food grade bushing bearings can operate on soft shafting such as Thomson ‘corrosion proof’ 316 Stainless Steel or Ultra Light Aluminum LinearRace shafting to deliver exceptionally long life and reliable operation in wash-down environments,” says Tom Dwyer, business unit manager, Thomson Linear Bearings and Guides.

Thomson Food Grade FluoroNyliner Bushing bearings feature robust liner material that can withstand a maximum continuous PV value of 10,000 psi ft/min, can handle high loads with a maximum static pressure value of 1,000 psi, and provide maximum no load speeds to 400 ft/min. in temperatures rang-

ing from -400°F up to 385°F. They are available in optional Stainless Steel pillow block assemblies in Closed, Open, Flanged and Twin styles, and can be combined with a wide range of corrosion resistant LinearRace shafting options, including 440C and 316 Stainless Steel, Ultra Light aluminum and plated 60 Case, to deliver optimized perform-

mance specific to the application requirements.

“Stainless Steel pillow block assemblies are a particularly significant option in food processing applications, as carbon steel will corrode over time, and even aluminum is susceptible to corrosion caused by the caustic solutions commonly used in washdown environments,” explains Dwyer.



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Thomson also offers a number of additional 440 Stainless Steel corrosion resistant linear bearing alternatives to help keep machines up and running in application environments subject to corrosion challenges. These include Precision Steel Ball Bushing bearings that provide reliable operation in temperatures up to 600°F, Metric MultiTrac Ball Bushing bearings that provide twice the load carrying capacity of conventional ball bushing bearings, and self-aligning Super Ball Bushing and Super Smart Ball Bushing Bearings that, in combination with genuine Thomson 60 Case Shafting, can provide up to 50 percent longer life than imitation bearings and shafting.



### For more information:

Thomson  
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## Muncie

OFFERS GEAR PUMP AND  
POWER DRIVE TECHNOLOGY



Muncie Power has improved traditional gear pump technology with the development of the Optimum series hydraulic gear pumps, which offer a unique, bushing style design with enhanced durability and pressure capabilities while still maintaining a reasonable size and competitive cost. These specialized hydraulic gear pumps incorporate a distinctive load holding feature known as the "Opti-Grip." The "Opti-Grip" design contributes to proper housing alignment and also helps prevent casting separation and pressure bulging, which allows the Optimum pumps to operate at high pressures. Large shaft journal diameters resist shaft deflection,

and ultra-premium bushings allow for long-term usage in extreme conditions.

In addition, the Optimum series utilizes a 13-tooth gear design, which reduces the frequency of the hydraulic pressure pulses in the system, reducing hydraulic noise. The Optimum series is available in three frame sizes, W, X and Y, with flow rates from 6-62 gpm at 1,000 rpm with pressure capabilities up to 4,350 psi. Optimum products are designed to be bi-rotational and include side and rear ports, making them quite versatile. SAE straight thread ports are standard on all units, however; split-flange ports are optional for side ports on all frame sizes. This flexibility of-





fers reduced inventory levels for service replacement units.

**SS88 series.** Just what are your options if your truck has only one PTO opening and you need to drive more than one auxiliary device? Perhaps your best bet is to take advantage of Muncie Power Products' new Auxiliary Power Drive SS88 series Splitshaft PTO. The SS88 series makes it possible to mount two, 8-bolt type PTOs in the main drive shaft behind the transmission on medium and heavy duty vehicles. There are two through shaft torque options available for the SS88: 14,000 lb. ft. rating and the 21,000 lb. ft. rating. A high quality 6-pitch spur gear is equipped in the PTO drive gear for the SS88 and can endure the torque ratings of the large 8-bolt PTOs, such as the Muncie 82 series. Air or hydraulic through shaft options are available to disengage the rear axle which allows for stationary operation. PTOs can be mechanically, air-mechanically and/or air-clutch shifted depending on the series specified.

#### For more information:

Muncie Power Products  
201 East Jackson Street  
Muncie, IN 47305-2834  
Phone: (765) 284-7721  
[www.munciepower.com](http://www.munciepower.com)

## Graphalloy Bushings

### OFFER OIL FIELD SOLUTIONS

Graphalloy wear rings and bushings from Graphite Metallizing Corporation provide performance superior to standard metal stationary and rotating wear parts in pumps for CO<sub>2</sub> service in oil field applications. Self-lubricating Graphalloy, a graphite/metal alloy, alleviates concern about bearing failures or possible flashing of CO<sub>2</sub>.



The ability to operate without additional lubrication is important in CO<sub>2</sub> injection applications because CO<sub>2</sub> has low lubricity. Standard metal wear parts rely on the lubricity of the liquid being pumped for proper operation so they are prone to failures in pumps used to inject CO<sub>2</sub>. In addition, due to high suction pressure required to keep CO<sub>2</sub> as a dense phase liquid, flashing is always a possibility.

CO<sub>2</sub> injection in older, low flowing wells is becoming an increasingly popular method for permeating rock formations and forcing more oil to the surface. Many older wells still contain vast amounts of oil locked in the pores of rock layers deep underground. CO<sub>2</sub> injection often releases more oil in older wells than can be released by water injection.

"Use of self-lubricating, non-galling Graphalloy materials in pumps for CO<sub>2</sub> service provides substantial cost savings by avoiding expensive downtime and field repairs caused by wear part failures," said Eben Walker, general manager of Graphite Metallizing Corporation. "Graphalloy is currently the material of choice for many oil field applications in North America and around the world."

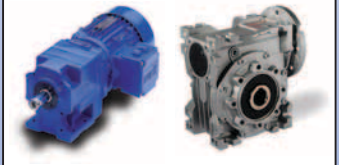
#### For more information:

Graphite Metallizing Corporation  
1050 Nepperhan Avenue  
Yonkers, New York 10703  
Phone: (914) 968-8400  
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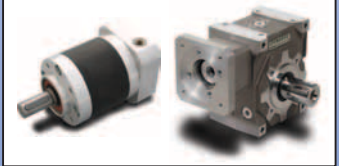
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# product news

## Ondrives

### INTRODUCES REMOVABLE TOP LINEAR SHAFT SUPPORTS

Ondrives US Corporation announces removable top profile linear shaft supports. Top loading offers easier assembly and re-alignment of shafts and bearings when needed with less down-

time. The removable top allows quick replacement without the loss of alignment position. These patent pending LPB Shaft supports are also low profile, only 0.87" high for 0.25" shaft diameter. They are precision manufactured in aluminum, are gray anodized and have alloy steel fasteners. Ondrives US Corporation also manufactures precision

ground stainless shafting in 303, 316 and 17-4 PH with a hardness of RC 40.



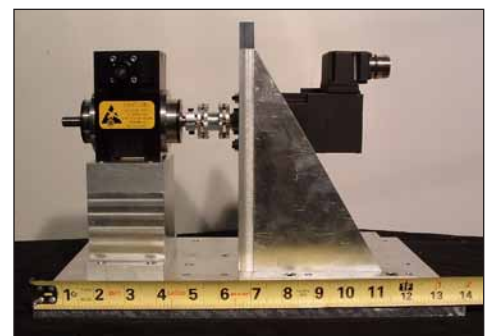
### For more information:

Ondrives US Corporation  
216 N Main Street  
Freeport, NY 11520  
Phone: (888) 260-7466  
[www.ondrivesUS.com](http://www.ondrivesUS.com)

## Sakor Dynamometers

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Sakor Technologies, Inc. recently introduced the MicroDyne series of small motoring dynamometers. Suitable for a wide range of automotive, military and aerospace testing applications, this newest innovation from Sakor is capable of testing all types of small rotary devices such as motors, pumps, generators, compressors and more. The MicroDyne is a fully functional, four-quadrant dynamometer engineered specifically for low power applications. Versions are available in sizes from 100 watts to five kilo-



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watts. For applications operating at five kilowatts and above, Sakor's AccuDyne AC dynamometer system is readily compatible with larger rotary components as well as conventional engine and power-train systems, hybrid vehicle drives and electric motors. Both the AccuDyne and MicroDyne offer precise speed and torque control. This is especially true in low speed applications where full torque can be applied all the way to stall (zero speed). Modern drive technology also allows the systems to provide seamless crossover between motoring and loading modes. Advanced features for more sophisticated testing requirements include inertia simulation, engine simulation, and NVH testing capability.

**For more information:**

Sakor Technologies  
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ETP Express (Model R Stainless Steel) keyless shaft locking bushings feature high torque capacity. They are suitable for locking into position gears, pulleys, sprockets and other components in a machine's power transmission system. Handling torque ranges from 34 to 6,400 ft. lbs., these stainless steel ETP Express-R shaft locking bushings work in systems requiring frequent wash-downs because they are easily cleaned and won't corrode. They have sealed, clean lines that resist debris collection and clean easily without any special maintenance, according to the company.

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# product news

“The torque transmission capacity for these ETP Express-R stainless steel bushings is two-and-a-half times greater than conventional bushings. Their unique design made of stainless steel makes this possible,” reports Robert Mainz, Zero-Max sales manager. “They are ideal for the high performance requirements of servo systems and especially systems where space limitations

are present. They provide high torque transmission and have a very compact footprint.”

ETP Express-R bushings feature just one radial actuation screw for fast mounting, repositioning and phasing of the components to the shafts. They position in seconds and can be readjusted many times just as quickly and without any axial movement of the

bushing or component along the keyless shaft. An Allen wrench is all that is required to mount and lock these bushings into place.

## For more information:

Zero-Max  
13200 Sixth Avenue North  
Plymouth, MN 55441  
Phone: (800) 533-1731  
[www.zero-max.com](http://www.zero-max.com)

## Bauer

SUPPLIES GEAR MOTORS FOR BRIDGE CONSTRUCTION

Russky Island is located just off of Vladivostok, Russia, with the Eastern Bosphorous strait separating the island from the Muravyov-Amursky Peninsula. As part of a massive regeneration project, development work began to turn the island into a large-scale, state-of-the-art tourist resort. Plans were drawn up for the construction of a bridge that would link the island to the mainland. That same year, it was announced that these new facilities would host the APEC summit in September 2012. A fast-track construction schedule was initiated resulting in the last section of the central span being lifted into place on April 2, 2012. The bridge is expected to be opened for traffic by July 2, 2012.

With Vladivostok being the largest Pacific port in Russia, the bridge had to be high enough to allow passage for any



class of vessel. In addition, the Eastern Bosphorous strait is 1,460 meters wide in the bridge project area. The finished bridge breaks numerous world records, rising more than 70 m above the high



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water level, with a central span 1,104 m long. Pylons 320 m high will hold stay cables 580 m long.

One of the most demanding phases of construction was the assembly of the central span, made up of 103 panels, each 12 m long, 26 m wide, and weighing a total of 23,000 tons. The panels are aerodynamically designed to give the bridge maximum stability in the high winds for which the region is renowned. The panels were delivered by barges which were carefully positioned under the installation using GLONASS, a Russian global satellite navigation system.



Lifting the enormous panels from the barges to an elevation of 70 m and into position was a precision operation taking about one and a half hours to complete. A special crane needed to be developed for this unique application. That development was put in the hands of the Mostovik Crane Factory, which specializes in the manufacture of large-capacity cranes for the most challenging applications. A custom-designed Mostovik derrick crane was installed

on the bridge center span deck, cantilevered over the nose and facing toward the strait. The crane was equipped with a wind gage, a lifting height indicator, and an indicator that shows precise panel position during the lift.

The application requirements for this crane would have to lift and safely position panels weighing more than 300 tons each and operate reliably in ex-

treme temperatures as low as  $-30^{\circ}\text{C}$ . To meet these requirements, Mostovik Crane Factory turned to Bauer Gear Motor.

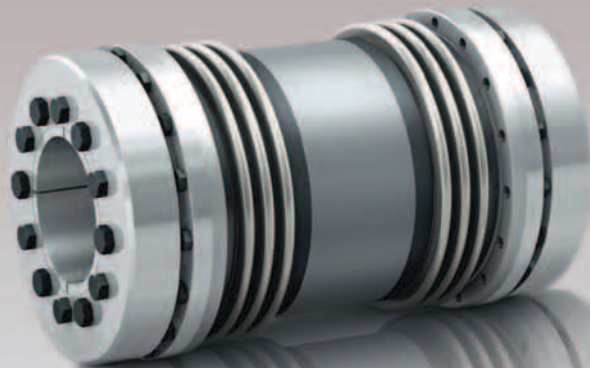
Bauer supplied BF Series geared motors, with torques from 10100-13400 Nm. BF Series geared motors can be mounted in any required position – horizontally, vertically or suspended. Total flexibility in mounting options includes



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The BF Series geared motors are completely enclosed and sealed to IP65 as standard (IP66 optional) against dust and water spray. Important for use in the Russky Island bridge application, the geared motors also provide comprehensive corrosion protection.

### For more information:

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# ZERO

**Air Bearings Provide a *More-Precise*  
View of Print Head Variations**

Photos courtesy of EFI and New Way Air Bearings





An EFI printer for which the print head reference system was developed.

# FRICITION SOLUTION

**In the printing industry, image is everything** and reproducing images that are visually pleasing can be a challenge for large-format printers. The human eye can discern print resolutions of 300+ dpi using more than 10 million colors. Unfortunately, slight variations in print heads as well as in the mechanics of the printers themselves are often directly translated into artifacts in a print image that the human eye can easily distinguish.

Electronics for Imaging, Inc. (EFI), located in Foster City, California, has made a name for itself as a leader in digital print servers and controllers as well as super-wide format printers and inks. In order to understand some of these print head variations, EFI contracted motion control specialist Axis New England to design and develop a reference mechanical system for the in-house testing of various print heads from

different manufacturers. Understanding the differences in the print heads requires a reference system with precise mechanics that will minimize print artifacts. To accomplish this level of precision, Axis New England utilized air bearings.

New Way Air Bearings is an independent manufacturer of modular air bearing products and a provider of porous media air bearing solutions. The company manufactures a standard line of modular, off-the-shelf components including: transition and precision zone air bars; flat round and rectangular air bearings; vacuum preloaded air bearings; radial air bearings; air bushings; and air slides. The company's flat round air bearings were the first to be offered as a complete product line and they remain one of the most popular standard components offered by New Way. The 65 mm flat round bearing seemed a suitable choice for the needs of the mechanical system in question.



Unlike rolling-element bearings, air bearings utilize a thin film of pressurized air to provide a 'zero friction' load-bearing interface between surfaces that would otherwise be in contact with each other. And unlike traditional 'orifice' air bearings, New Way delivers the air through a porous medium to ensure uniform pressure across the entire bearing surface. This enables a consistent, robust, non-contact performance that virtually eliminates traditional bearing-related problems like friction, wear, and lubricant handling. It also offers distinct advantages in precision positioning, speed, acceleration, and—as it related to EFI's requirements—straightness and flatness of motion.

New Way's porous media air bearings are used as an enabling technology in an increasing array of linear and/or rotary motion applications in diverse industries including: semiconductor, flat panel display manufacturing, CT scanning, medical, automotive, aerospace, metrology and precision machine tool.

"We knew we would be limited with a rolling-element bearing," said Greg Ellrodt, senior systems engineer at Axis New England. "New Way's porous media air bearing technology provides consistent, precision performance characteristics that contact bearings just can't touch."

Axis matched these characteristics with a precision Tru-Stone granite guideway, a combination that enabled EFI to meet the stringent five-micron straightness and planar flatness specifications

required between the lower-axis vacuum table and the upper-axis print-head fixture over the center 30" print zone.

Finite element analysis (FEA) and the utilization of Invar alloy with a low coefficient-of-thermal-expansion were also required to maintain specifications in the operating environment. Further, New Way's gimbal-mount design and Omron's precision laser sensors allowed the flatness to be dialed in "to spec" with slight adjustments to the air bearings.

The center of gravity of the X-axis carriage was optimized to minimize the pitch and yaw moments on the air bearings induced by the Parker Trilogy linear motor's 2G acceleration—up to 2.5 m/s. An ultra-quiet Iguus cable track was required to minimize velocity ripple during the print process.

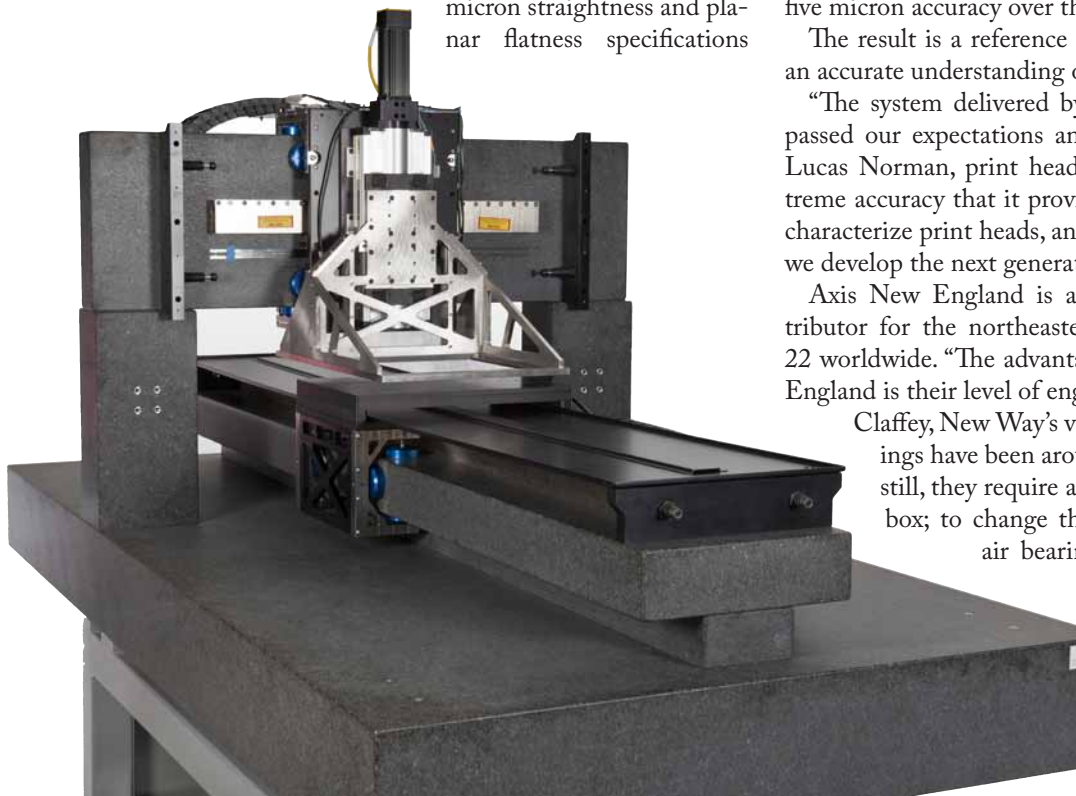
The system utilized a Delta Tau Turbo ultra-light controller with Copley Xenus macro drives on a fiber optic network. This allowed for the seamless integration of the Renishaw Resolute series of high-accuracy, absolute linear encoders with 50 Nm resolution on the Y and Z axes, and Renishaw's dual-output, tonic series incremental encoder. One signal was used to synchronize the printing to the motion, while the other was used in the control loop. The entire system was laser-aligned and calibrated with the Renishaw XL-80 laser system; compensation tables were applied to the Delta Tau controls to obtain a better than five micron accuracy over the lengths of travel.

The result is a reference system that provides EFI with an accurate understanding of print head variation.

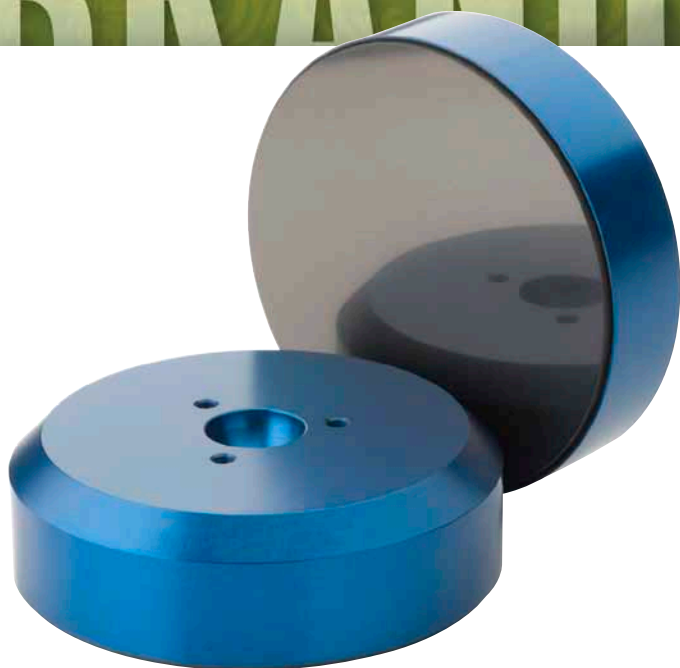
"The system delivered by Axis New England has surpassed our expectations and original specifications," said Lucas Norman, print head engineer II at EFI. "The extreme accuracy that it provides is furthering our ability to characterize print heads, and will play an important role as we develop the next generation of inkjet printers."

Axis New England is a New Way Air Bearings distributor for the northeastern United States, and one of 22 worldwide. "The advantage of working with Axis New England is their level of engineering expertise," noted Tim


Claffey, New Way's vice president of sales. "Air bearings have been around a long time but sometimes, still, they require an engineer to think outside the box; to change the paradigm. Axis understands air bearings. Not only do they convey



EFI reference mechanical system for the in-house testing of print heads



New Way 65 mm flat round air bearing.

the advantages exceptionally well, but they show their customers exactly how to get there, quickly, cost-effectively, and successfully. The differences are often measured in orders of magnitude. EFI is just one example.” 

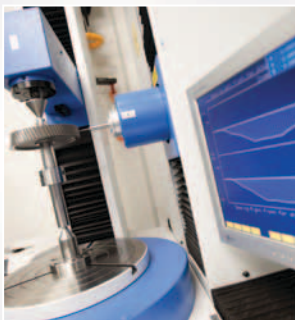
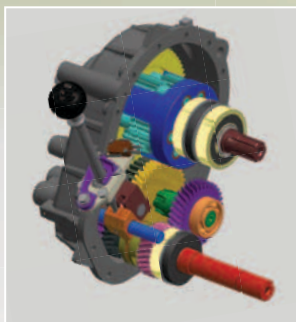
### For more information:

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Greg@axisne.com  
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Michael Wright, director of marketing  
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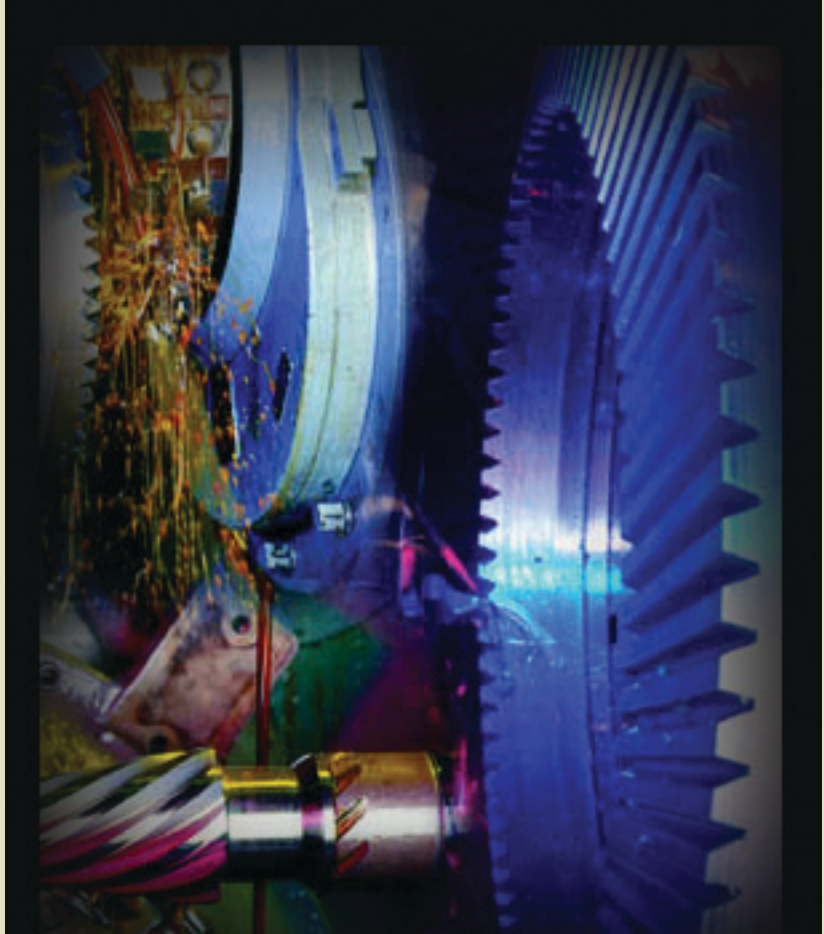
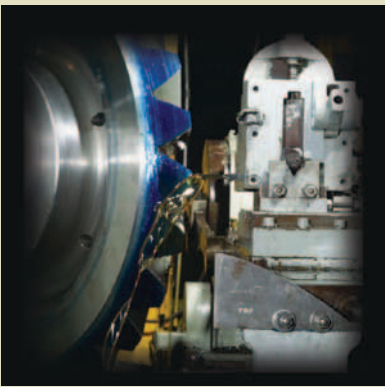
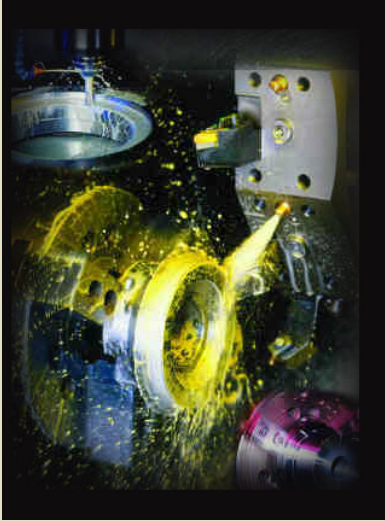
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# Predictive Motor Maintenance (PdM):

## Use it or Lose It (Money)

Jack McGuinn (Senior Editor)



Photo courtesy of Integrated Power Services

Regardless of where you do business, when discussing, analyzing or worrying about “The Economy” these days, you’re not thinking Main Street—you’re thinking global. With that stipulation, it is also accepted wisdom that quality products and sharp pencils are not enough to be and remain competitive. Accordingly, everyone is looking for an edge, an advantage, in order to beat back—or at least keep up with—the competition.

One area that can help in that regard is predictive motor maintenance (PdM). Granted, it’s not the most exciting of manufacturing endeavors, but ignore doing it at your own peril. Aside from the green results realized, robust PdM ensures that your operation is running on all cylinders and at the same time saving significant energy dollars. One can also think of PdM as a quality assurance hedge—i.e., you could be manufacturing the re-invented wheel on your shop floor, but if the motors used in their production are not up to par, you can count on downtime that you’ll never get back, as well as the occasional product defects that result from faulty motor operation.

Call it “best practices” if you like, but common sense seems even more appropriate. Consider: On one hand your product or products are selling well. New orders and new customers? Indeed, yes. But then get a gander at your bottom-line production costs and suddenly things don’t look so rosy.

For the unconverted, the U.S. Department of Energy/Energy Efficiency and Renewable Energy reports that “Motor-driven equipment—such as pumps, air compressors, and fans—consumes about 16 percent of all the energy used in U.S. industrial applications. Industry as a whole consumes more than 700 billion kWh and spends more than \$30 billion annually for electricity dedicated to motor-driven systems.”

Not exactly chump change. The report continues: “Plants can begin reducing this energy usage and cost by selecting motor-driven equipment with the highest possible energy efficiency, and implementing effective system management practices.”

And of special interest to the manufacturing big-boys—and U.S. taxpayers—“The D.O.E.’s Industrial Technologies Pro-

gram (ITP) works with the nation’s most energy-intensive plants to uncover opportunities for reducing energy use and costs while maintaining—or increasing—productivity. ITP resources can also help industrial plants reduce maintenance costs, improve the reliability and efficiency of their motor-driven systems, and minimize unscheduled downtime.” Perhaps we can all agree that the program is a positive example of our tax dollars at work.

The G also has *free software* available; e.g., *MotorMaster+* and *MotorMaster+ International* are capable of assisting plant managers in maintaining and managing their motor-intensive production lines for greater energy efficiency. According to a non-D.O.E. report cited by the department, the two packages “have already helped industry save more than \$2.4 million and 50,700 MWh annually.”

So what are you waiting for? Perhaps our discussion with some motor mentors will convince you that, for optimum plant efficiency, conducting rigorous PdM is a significant step in that direction.

But first, some perspective: Is PdM an important consideration for manufacturers?

“Unfortunately, no,” says Dr. Howard Penrose, vice president of Glen Ellyn, Ill.-based Dreisilker Electric Motors, Inc. “Over 60 percent of manufacturing/industrial facilities perform *reactive* maintenance, sometimes even if they have the

## Predictive Motor Maintenance

# (PdM)

technology and the ability to perform PdM inspections. There is a greater recognition of the importance of PdM, but the effort necessary to implement and sustain depends on the will of the company, managers and personnel.”

That response begs the question: Is conducting PdM difficult? Are special skills required?

The short answers, provided by Covington, are “Very” and “Yes.”

Expanding on the topic, Penrose explains that “PdM programs are as complex or simple as required by the application. For instance, a non-critical DC motor may only require periodic inspections of the brush height and tension and insulation testing. The program may or may not include vibration analysis if it is determined to be cost-effective. On the other hand, motor circuit analysis, electrical signature analysis, PD (partial discharge) testing, vibration analysis, laser alignment checks, infrared analysis, oil/grease analysis, and additional, advanced testing may be required on more critical machines. It is important, however, to select PdM practices that meet both the needs of the application and the ability to support them.”

Their answers anticipate the next question: Can one assume (as did this reporter) that PdM is all about the software.”

While “Software is used to support the method of analysis (vibration analysis, MCE [motor carrier evaluation], etc.),” ac-

ording to John Covington, senior vice president of marketing for South Carolina-based IPS (Integrated Power Services). Penrose adds that “The idea behind ‘predictive maintenance’ is a series of tests and inspections to identify trends in the condition of equipment. The result is the ability to estimate remaining life once a fault is detected. Software can assist with the process, but is not the backbone of a PdM program.”

Another software-related issue relates to various vendor packages’ adaptability to different motor-driven environments. Just how application-specific is it?

“Most applications are configured based on the equipment or process they are measuring,” Covington says. “A motor is a motor, a fan is a fan, in any industry.” Penrose adds that “there are software packages from overall trending systems to individual programs for specific PdM test equipment.”

With software just a cog in the PdM process, Penrose says that “The key to PdM programs is the correct selection of tools and inspections to detect the potential problems that you may have with a machine. This selection can be made using manufacturer recommendations, equipment history or tools such as the reliability-centered maintenance (RCM) process.”

Touching briefly on another aspect of PdM field testing: dangerous?

“Limited—if proper PPE (personal protective equipment) and safety precautions are observed,” says Covington.



Photo courtesy of Integrated Power Services

“Field testing electric motors requires the technician to be aware of electrical shock and arc flash hazards, as well as potential energy and rotating component dangers,” Penrose says. “However, most of the test equipment manufacturers have developed safety plugs, which a technician can plug their equipment into without having to open a cabinet.”

As with other industries, standards abound for the motor industry, including PdM. Published by the IEEE (Institute of Electrical and Electronics Engineers), are they stringent?

“Absolutely; anyone that says they aren’t don’t doesn’t understand the industry,” Covington states.

“The only teeth that a standard has is that it demonstrates consensus that a particular method or action is ‘standard’ within the industry,” Penrose points out.

“It does, however, require an understanding of the standards in question. For instance, many think that the insulation standard is 1MegOhm plus 1 MegOhm-per-kilo-volt rating of an electric motor. However, not only is this not correct in modern motors, but the purpose of this value is to determine if the insulation system is in a condition to be subjected to higher stress electrical tests, not whether the insulation system is satisfactory for operation. There are no ‘standards’ police to ensure that a standard is followed, other than safety, environmental, manufacturing and certification standards.”

Revisiting for a moment the foot-dragging by some U.S. manufacturers relative to PdM—is it about older-technology, “old warhorse” motors vs. new-technology efficiencies?

“Actually, no,” says Penrose. “There is a misunderstanding that goes back many years where incorrect information got out that energy efficient motors were less reliable and more sensitive to electrical systems than standard motors. This was, in fact, due to a study on a non-energy-efficient electric motor that had a marketing stamp on it. Instead, energy and premium efficient motors are found to have better engineering, higher quality materials and greater reliability than standard-efficient electric motors.”

And then there is the “size matters” issue with PdM. Or does it?

“Yes,” says Covington. “They have different operational complexities based on size.”

“The scope of work to maintain a larger motor may be significantly greater than a smaller electric motor,” Penrose points out. “For instance, comparing a 100hp, 3-phase, 460-volt motor to a 5,000hp, 3-phase, 4,160-volt motor can be very different. If the 100hp is a totally enclosed, fan-cooled motor, the maintenance department may grease the bearings on a schedule, perform vibration analysis and maybe insulation resistance or motor circuit analysis testing. On the other hand, if the 5,000hp is a WPII (*weather-protected; the WPII motor is defined by NEMA MG1-1.25.8.2*) enclosure, inspec-



Photo courtesy of Integrated Power Services

tions may also include winding temperature by RTD (resistance temperature detector), continuous monitoring of vibration, checking and cleaning filters, oil analysis, bearing RTD monitoring, etc.”

Electric motor testing is divided into two segments—static testing and dynamic testing.

What’s the difference?

Penrose explains that “Static testing relates to tests performed while an electric motor is turned off (locked and tagged out). The purpose of this type of testing, when referring to motor circuit analysis, is to be able to detect insulation failure/degradation. The types of testing and detection of insulation faults cannot be performed, at this time, while a machine is energized. Dynamic testing evaluates the condition of the power, air gap, rotor, bearings and any components that may be loose or misaligned.”

“Static (testing) is offline, or stationary,” says Covington, and it “typically involves more electrical testing. Dynamic is running and tends to be more mechanical.”

And speaking of testing, does PdM for AC motors differ markedly from DC versions?

“Yes, (in that it’s) rotor vs. armature; stator vs. main poles and inner poles,” says Covington.

“While there are some similarities such as with vibration analysis for bearings, the brushes, armature and commutator—as well as the power supply—for a DC machine add complexity to a program,” says Penrose. “One of the reasons for the popularity of AC over DC motors is that the AC motor is less complex and easier to manage and maintain. The DC motor has brushes, brush holders, carbon dust, contact surfaces, additional wiring, field and interpole coils that generate significant heat, etc. The program may include such PdM inspections as checking the brushes and commutator.”

Any discussion of PdM should include some attention to a close cousin of PdM—condition-based monitoring (maintenance) (CBM). While the latter is grist for another time, we asked where it might fit—if at all—in the PdM universe.

“Condition-based is the extension of PdM, with service requirements established based on pre-determined, alarm-level status limits,” says Covington.

Penrose adds that “The concept behind condition-based maintenance is the recognition that standard maintenance practices will actually cause equipment failure. CBM involves performing maintenance tasks based upon condition inspections and/or testing of the machine. The end result is normally a significant cost savings and increased availability of equipment, with the cost savings being an average of three-to-four times that of a reactive maintenance program. Reactive programs: generate a significant level of unpredictability of production; cause MRO stores to increase; result in the need to increase inventory; and inflict unnecessary stress on company employees.”

What follows is some necessarily brief attention to several PdM-related issues that readers may be unfamiliar with.

### **Voltage imbalance—big problem?**

“Not too often,” Covington believes, but it does “create current unbalance and excessive heat in three-phase induction equipment.”

With a different take, Penrose believes that “Voltage unbalance is still a relatively prevalent problem. The optimal unbalance is less than 2 percent from the average voltage in order to maintain efficiency. Past that point—up to the maximum of 5 percent unbalance—the motor must be de-rated due to heating caused by circulating currents. Most of the time, the unbalance is caused by unequal loading of single-phase systems on transformers. (But) some of the time, it can be caused by loose connections. The proper method of correcting the un-

balance is by first identifying it and then correcting the problem, such as balancing single phase loads.”

### **Infrared thermography—a common method of motor testing?**

“Some companies will use infrared for electric motor testing,” Penrose says. “It can accurately determine ball bearing temperatures at the bearing housing, detect unusual hot spots and some level of misalignment, and other issues visually. It’s most powerful application in relation to electric motors, however, is the inspection of connections and disconnects inside electrical panels.”

### **Dynamic motor analysis.**

“Online electrical signature analysis (ESA)—sometimes referred to as motor current signature analysis (MCSA)—has been available since the early 1980s. This technology can detect most power supply, electric motor and some bearing issues, (as well as) load-related problems through a reading from the motor control center or disconnect. Instead of going out to each motor in a plant, the ESA technician can get virtually all of the readings in a fraction of the time from the motor control center.”

We close with responses from Penrose and Covington to the question, What’s “hot” in today’s PdM world?

Covington: “The cost of differed maintenance based on not responding to a predictive indicator of some type is an emerging issue.”

Penrose: “The biggest issue that seems to exist related to PdM is follow-through by decision-makers on findings related to the program. This mystery often relates to providing urgency in a language that the decision-maker can understand. For instance, when performing PdM and a fault is detected, if you state that a bearing is going to fail in 30 days, it had better fail on day 30—not 29 nor 31. The reason is that most people do not understand that PdM findings are *estimations* based upon *experience*.”

“In other cases, the PdM program may be used to determine the risk-of-failure of a machine and no action may be performed other than planning for equipment failure. If this is not communicated to the PdM techs, frustration results.”

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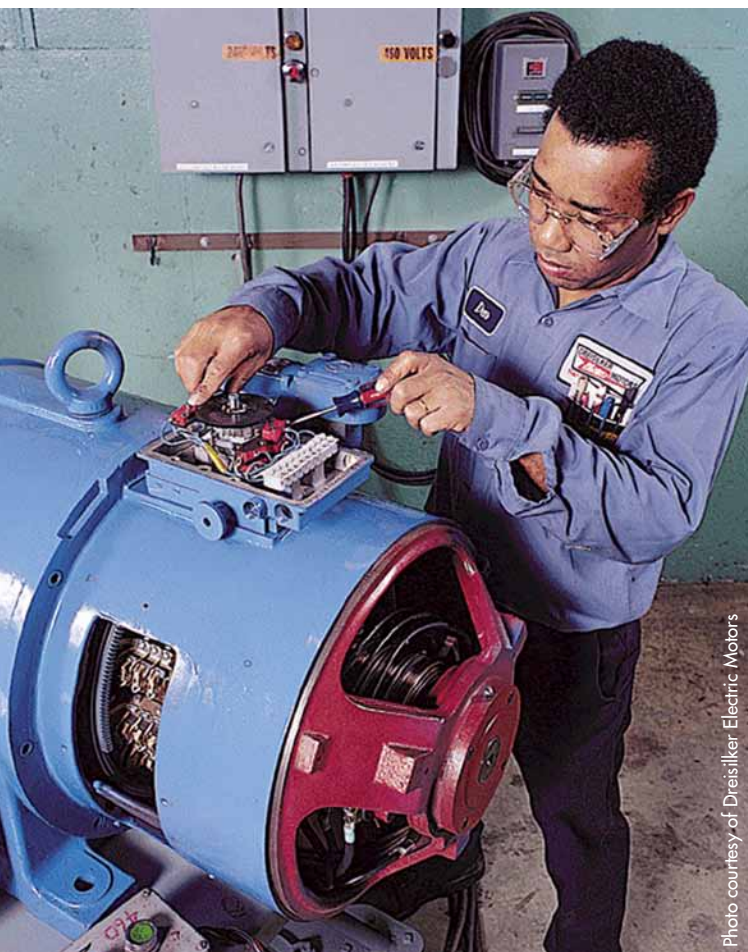
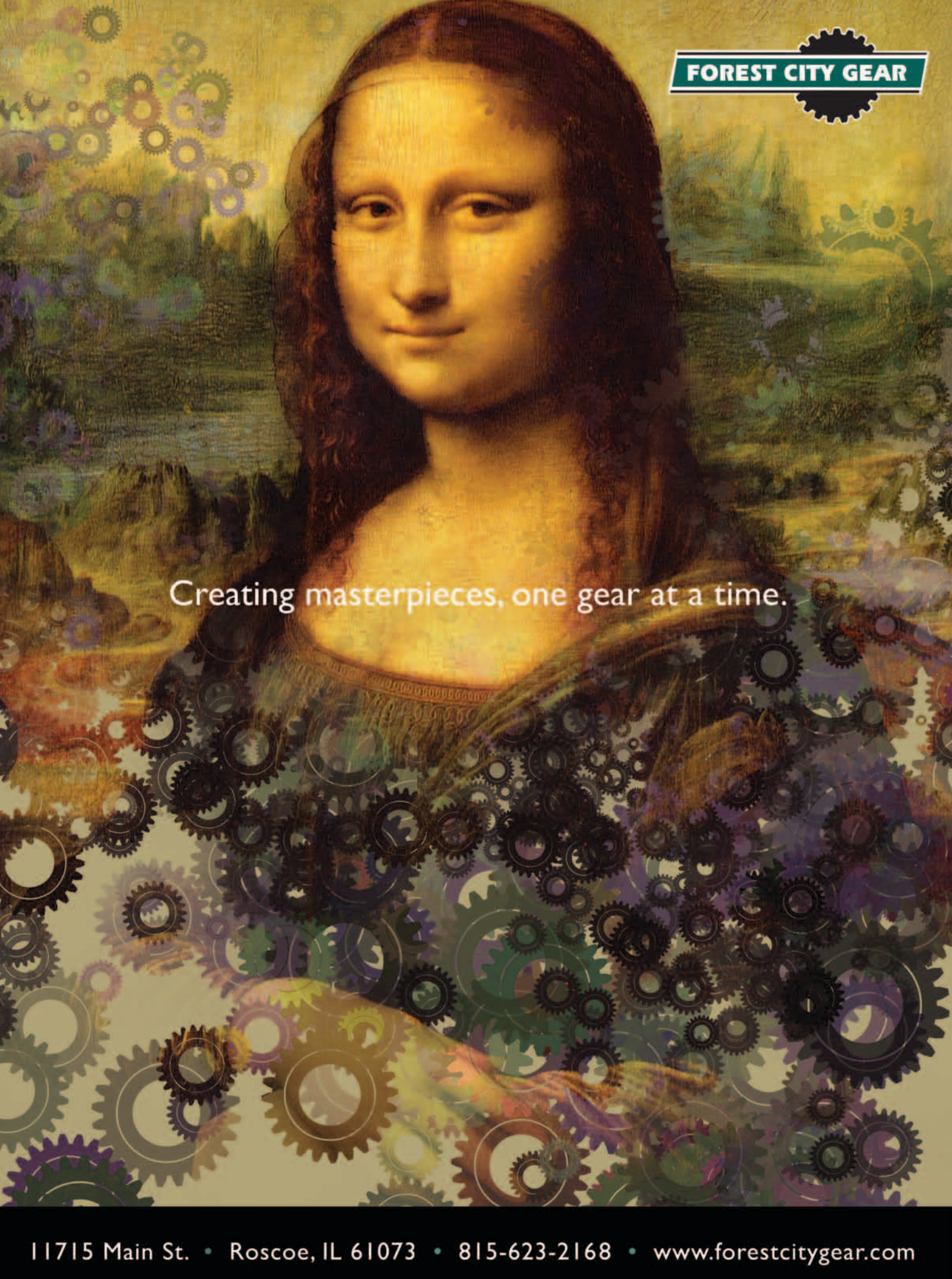


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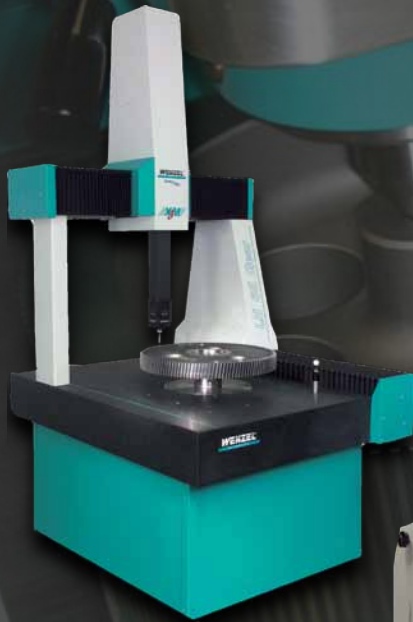
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# Nervy Enterprise AND Edgy Engineering: A Can't-Miss Mix



*Fairchild and Baldor partner to  
create AC-powered scoop*

Coal River Energy agreed to field test the first Fairchild AC powered scoop with new Baldor technology at its underground mine in West Virginia. At the end of the test, mine executives, impressed with the scoop's superior performance, bought the unit and placed an order for a second scoop.



**Fairchild International**, a U.S.-based manufacturer of underground mining equipment, has produced battery-powered DC scoops since the early 1980s. With 17 different models available, Fairchild offers a size to fit any coal mining operation, making it the leader in the industry.

Maintaining that leadership position led Jack Fairchild, Jr., the company's vice president of sales, to the decision in 2011 that it was time to move from DC technology to AC technology. Making the change would require a major investment for the company, but Fairchild was determined to be the first to launch an AC-battery-powered scoop.

(This article first appeared in Baldor Electric Company's Solutions Magazine, 2011, No. 7. Reprinted courtesy Baldor.)

“In this industry, if you want to remain successful, you have to stay ahead of the game,” explains Fairchild. “We also felt strongly that AC technology provides so many advantages that making the investment would be worth the risk. This is the technology for the future and is the best way for us to take our product line to the next level.”

Fairchild believed that the key to the project’s success was to build the right team. At the beginning of the project in 2008, Fairchild brought together his employees to discuss who they should partner with. They wanted to work with companies that had engineering and technical knowledge, good communications skills and the willingness to be a member of a team. As a result, Fairchild chose EnerSys for the battery, Magnatec for the drive and Baldor for the motors and gearbox.

### Engineering New Products

Baldor engineers Nick Marsh (strategic account executive for the mining industry) and John Clark (senior customer order engineer for specialty gearing) led the design team effort for product development. With Baldor’s history in the mining industry and experience in moving from DC to AC technology in other projects, both engineers were confident they were up to the technical challenge. However, according to Marsh, the hardest and most critical part of the project comes at the very beginning.

“It’s our job to take the time to ask all the right questions up front so we can get detailed specifications,” explains Marsh. “In this case, we helped the Fairchild team think through the machine and the application so we could address all of the possible issues and requirements. It’s critical to get a clear understanding of their requirements and expectations so we can design and build the exact product they need.”

From a motor perspective, that means detailing the exact torque and speed requirements. And because the motor would be controlled with a variable frequency drive (VFD), the Baldor team worked closely with the drive manufacturer to optimize performance. According to Marsh the traction motor developed for Fairchild is based on the Baldor-Reliance RPM AC motor design—with a good many enhancements.

“We optimized the pole design to meet the torque and speed requirements,” explains Marsh. “This motor is MSHA explosion-proof-approved, and we added a robust sealing system so it can more than handle the underground environment. And, as requested by the customer, we also added a feedback device for better speed control.”

With motor specifications in hand, the gearing team began its design work by starting with an existing gearbox base and then building from there. Engineers created a new gear ratio to meet Fairchild’s exact needs for torque and speed, building a box with new gears and bearings strong enough to handle the force. For Clark, the bigger design challenges came from some special requests by Fairchild.

“The company wanted us to design the gearbox so it could be used on either side of its dual-tram scoop,” explains Clark. “This universal design means they only need to stock one gearbox because it is interchangeable. A box that can be flipped gives them the flexibility they need to manage their inventory.”

One other feature Fairchild wanted was a self-contained brake, mounted directly on the gearbox. In the past, Clark explains, brakes were mounted with brackets hanging off the side of the box, thus taking up a great deal of space.

“To accommodate this request, we created new patterns and new castings for the top of the gearbox,” says Clark. “This was



a great idea because now that the brake is a part of the gearbox, it's more secure and provides much better performance."

Because this was a new design, the project team attached special instrumentation on the box to capture data, while Fairchild ran the completed unit under test at its facility. Clark says the data was critical for him to understand what the gearbox was doing and how it performed under test.

However, Clark was not content with just collecting and studying data.

"I visited Fairchild after the test was finished and tore the gearbox down so I could examine and evaluate it myself," says Clark. "I looked at the gear patterns to make sure there were no issues, and I did the same thing with the bearings, making sure there was no unusual wear. What I found was that everything looked great."

### Achieving Results

While the AC-powered scoop performed beyond expectations at the Fairchild location, Ken Mosley, Fairchild vice president of customer service, was eager to get some running time on the scoop at an actual mine site. Coal River Energy agreed to take a unit and use it at one of its coal mines and provide feedback on what it thought of the new technology.

"I was fairly confident that it would run successfully at the mine, but then again you never know what might happen," says Mosley. "It turned out to be a manufacturer's dream because they started running the scoop and it never quit. After three months of testing we met with them to get their feedback, and to our surprise, they asked to purchase the unit. It was even more exciting when they quickly ordered a second unit plus put in an order for one of their DC scoops to be con-




**A commitment to craftsmanship and quality has made Fairchild International a leading manufacturer of underground mining equipment.**

verted to AC. We couldn't have scripted a better introduction of a new product."

Mosley says the reasons Coal River Energy was so quick to adopt the new technology come down to performance, durability and longevity. He describes the new AC scoop as a workhorse, ideally suited for slope-graded mines and with machine torque greater than any other scoop on the market. He says that everything he wanted this scoop to do, it does.

"This new scoop goes faster and maintains a constant speed—even going uphill," explains Mosley. "This AC unit runs cooler, and less heat means all of the other equipment lasts longer and reduces the amount of maintenance required. But most importantly, the battery life in our new unit is now twice the life of DC units."

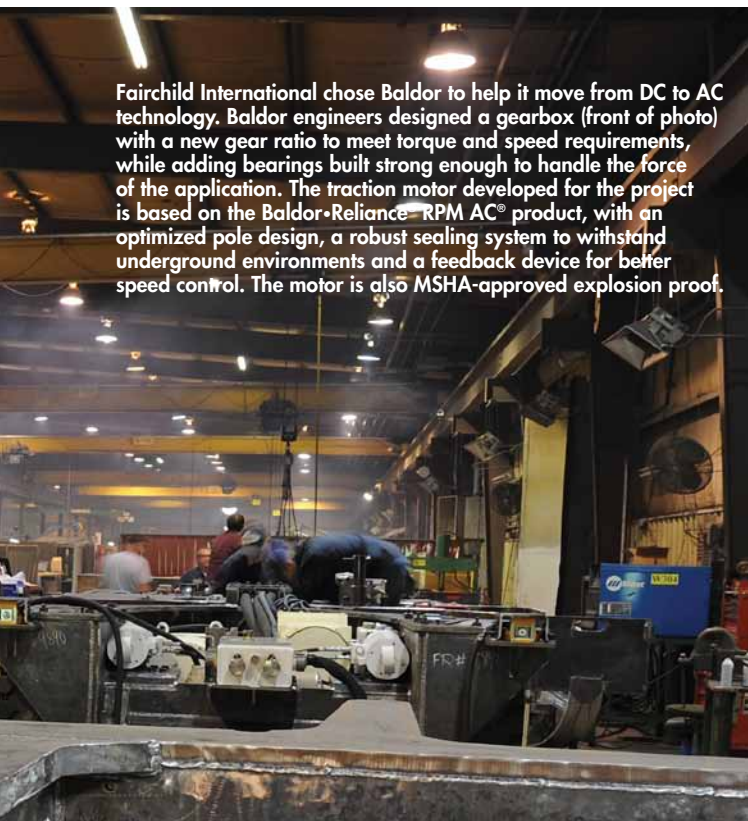
Fairchild achieved his goal of being the first to introduce AC technology to battery-powered scoops. He says he never doubted the team could pull it off because he involved all the right people. So, what comes next?

"This is the technology of the future," claims Fairchild. "Right now, we are ahead of the game, and that's exactly where I want to stay. We will continue to improve the technology, perfecting it for our complete line of equipment. Who knows what the future will bring?" 

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Fairchild International chose Baldor to help it move from DC to AC technology. Baldor engineers designed a gearbox (front of photo) with a new gear ratio to meet torque and speed requirements, while adding bearings built strong enough to handle the force of the application. The traction motor developed for the project is based on the Baldor-Reliance RPM AC® product, with an optimized pole design, a robust sealing system to withstand underground environments and a feedback device for better speed control. The motor is also MSHA-approved explosion proof.

# Rolling Bearings in High-Speed Passenger Traffic

Matthias R. Kilian

*(From Proceedings of the 2010 Joint Rail Conference—JRC2010—April 27-29, 2010. Reprinted with permission.)*

## Management Summary

Passenger transport today moves significantly faster than ever before, often operating on separate tracks especially designed for high-speed trains. Accordingly, high-speed rolling bearings are very important components in the bogies of trains today. Maximum train speeds currently reach 380 km/h (236 mph) in the latest high-speed applications—80% higher than in the earlier days of high-speed traffic. This paper presents two application examples of modern, high-speed traffic, together with some typical bearing arrangements and housings. It provides insight regarding measures taken in the bearing industry to meet the requirements of contemporary, high-speed traffic, and it cites important standards and regulations applicable for—but not restricted to—European applications. To be precise, the focus here is on journal bearings; information on traction motor bearings, transmission bearings and housings is included, but described in less detail.



Figure 1—High-speed bogie (courtesy Siemens Mobility).



Figure 2—VELARO train based on ICE-3 technology (courtesy Siemens Mobility).

## Introduction

How fast trains can travel has long been critical to railway development.

In 1830 the world speed record was 48 km/h (about 30 mph). Less than a century later (1903), in Berlin, a Siemens railcar exceeded 200 km/h (ca. 125 mph) (Ref. 1). And with streamlined steam locomotives, there were speed records set of more than 200 km/h prior to World War II.

These speed records were not achieved in regular service, however.

In fact, the first regular-service, high-speed train—the Shinkansen—debuted in Japan, 1964. Its maximum speed was 200 km/h (ca. 124 mph), which was boosted the following year to 210 km/h (ca. 130 mph); its average speed was about 163 km/h (ca. 100 mph). And because only narrow-gauge track of 1,067 mm-width was available in Japan prior to the Shinkansen era, this high-speed train rolled with a custom, made-to-fit track system devoid of any local or freight traffic.

The result: uninterrupted, high cruising speeds and short traveling times—right from the beginning (Ref. 2).

In Europe, one of the first regular-service lines operating at 200 km/h was the TEE—between Paris and Toulouse—with specially adapted SNCF locomotives (French National Railways). But the ultimate breakthrough in European high-speed rail history was the French TGV, in 1981, with a maximum operating speed of 270 km/h (168 mph). Later versions reached maximum speeds of 300 km/h (186 mph) and 320 km/h (ca. 200 mph).

The German ICE was next. Still known in the early 1980s as the Inter City Experimental, the name was later changed to Inter City Express. The experimental-version ICE-V set a



new world speed record of 406.9 km/h (253 mph) in 1988. Regular service of the ICE trains started in 1991 when the required, new high-speed tracks were ready. The ICE is the fastest and most comfortable train class in Germany; in addition to the first version are successor versions ICE-2 and ICE-3. The latter is also the basis for newer developments for other countries. (As defined in Europe, high-speed rail is a system of rolling stock and infrastructure that regularly operates at or above 250 km/h on new tracks, or 200 km/h on existing tracks.)

A further definitive aspect is the use of continuous welded rail that sufficiently reduces track vibrations and discrepancies between rail segments, thus enabling trains to pass at speeds in excess of 200 km/h (Ref. 3).

### Nomenclature

Because of the difference in technical terms used in Europe compared to other regions—North America, for example—some terminology issues should be addressed at the outset.

Starting with the bearings; there is the collective term, “rolling” bearing. Rolling elements can either be balls or rollers, and in Europe this term is used collectively. In America the term “anti-friction” bearing is probably more common for the general category of such machine elements. One can also find “rolling contact” bearing or just “ball and roller” bearing as general terms. Another distinction is the shape of the rolling elements; sub-categories of rolling bearings thus are “ball” bearings and “roller” bearings. The term “axle box” is defined as an “assembly comprised of box housing, rolling bearings, sealing and grease (Ref. 4).” A special type of rolling bearing used in the axle box is called a “cartridge” bearing, according to the cited European standard (Ref. 4).

And there are other names, too. “Wheel-set” bearing is one, “axle box rolling” bearing another. In America—especially in North America—such bearings are called “axle journal” bearings—or just “journal” bearings. The terminology largely depends on the continent, country or organization where it is used. In North America, the axial clearance of journal bearings is usually called “bench lateral play” or just “bench lateral.”

Weight or mass units are also different between the European continent and Great Britain or America; e.g., when this paper cites a mass in tons it always means metric tons.

### Bearings in Rail Vehicles

Although there are several other locations in rail vehicles where rolling bearings can be found, this paper concentrates on the bogie (*Ed.’s note: A bogie is an assembly of four or six wheels forming pivoted support at either end of a railway coach; it provides flexibility on curves.*) and therefore largely omits vehicles that do not run on bogies.

One exception is the TALGO train, which is not using classic bogies under its coaches. The TALGO train family is briefly mentioned in the next section. The author principally focuses on classic wheel-rail-systems and does not cover other systems like the Maglev technology (magnetic levitation).

Figure 1 shows the SF500 bogie used in several of the current high-speed trains. As stated on the manufacturer’s web-



Figure 3—ICE-3.

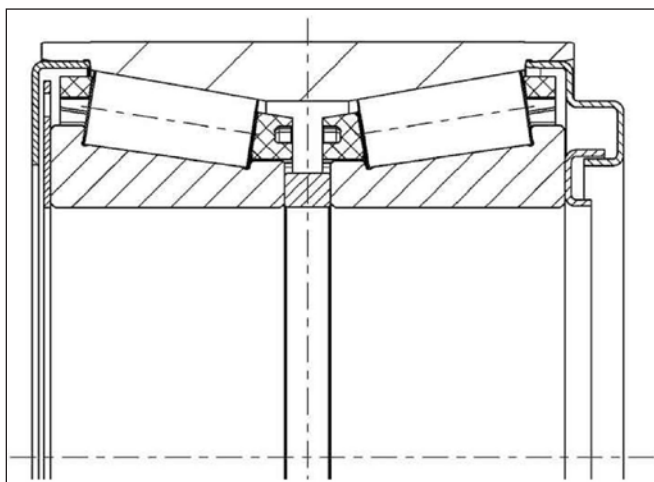


Figure 4—Tapered rolling bearing base unit.

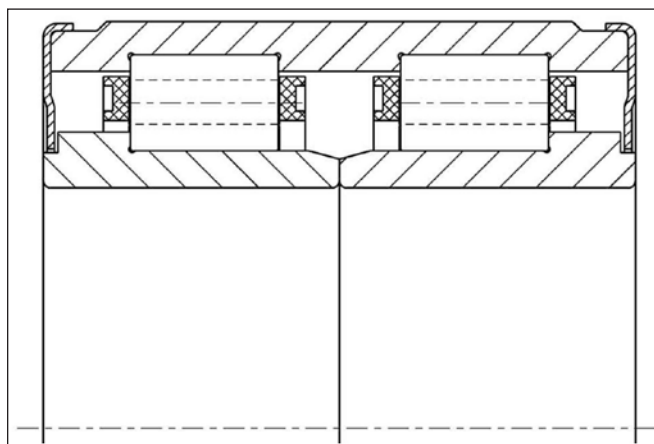


Figure 5—Example of cylindrical bearing design.

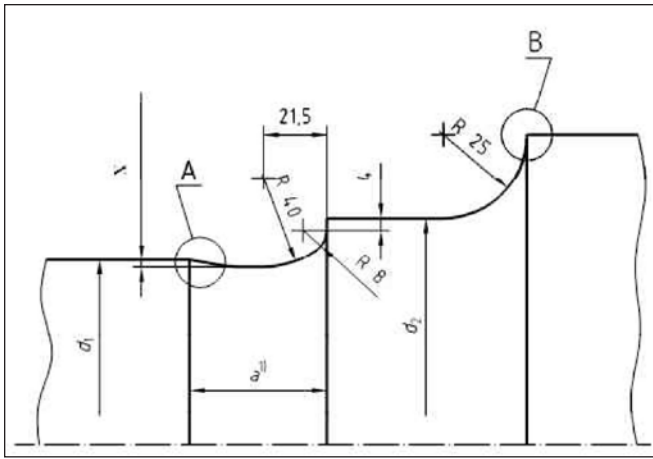


Figure 6—Journal details according to EN standards.

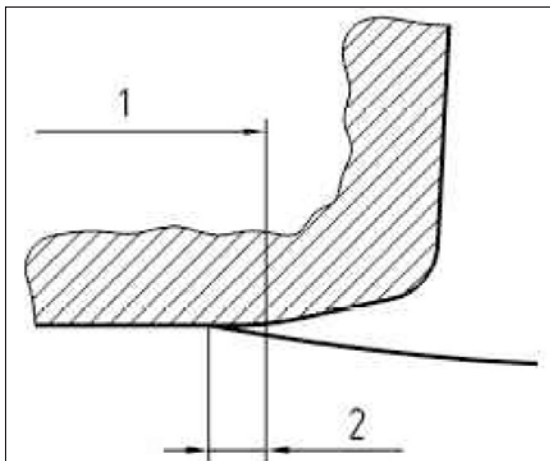


Figure 7—Detail A from Figure 6.

site (Ref. 5), this bogie is designed for ultimate riding comfort. Elaborate calculations on running-gear technology have led to a design distinguished by optimum properties of stability and comfort, as well as excellent track guiding behavior. The modular concept enables building the SF500 bogie as a driven bogie and also as a trailer bogie (Ref. 5).

In the bogie of a rail vehicle there are usually three major components of special interest for bearing suppliers.

With driven bogies these components are 1) the traction motor, 2) the transmission and, above all, 3) the axle box with the journal bearings (as they are called in North America).

For high-speed applications the axle box bearing system consists of a housing-and-bearing assembly.

The following will concentrate on the rolling bearings at the axle journal; housings, transmission bearings and traction motor bearings are addressed at the conclusion.

### Today's High-Speed Trains

Today there are high-speed traffic systems on almost all continents. Earlier generations of high-speed trains were mostly of the push-pull arrangement. In newer development of high-speed trains, however, the multiple-unit concept has established itself as the most common train configuration. The term multiple unit (MU) is used to describe a self-propelling train unit that is capable of coupling with other units of the

same or similar type while still being controlled from one cab (Ref. 6).

For high-speed applications the EMU (Electric Multiple Unit) is the dominating train type (Fig. 2). With combustion engine propulsion, such systems are called DMUs (Diesel Multiple Units). The referenced German high-speed trains ICE-1 and ICE-2 are push-pull train configurations with electric-driven power heads at both ends. The ICE-1 had two power heads at the train ends and 12 passenger coaches in between. The main difference of the ICE-2 is that it employs the “half-train” concept. “Full” trains are configured with two push-pull trains linked together. A half-train can operate as an independent push-pull train unit; it has just one power head. On the other end there is a control car that is not driven, but is equipped with a driver's cab; it takes on passengers just like the coaches. The engineer can shift from the power head to the control car and thus quickly change the driving direction. Six passenger coaches are fixed between the power head and the control car. For the main high-speed lines, two of these half-trains are usually coupled together, with the two control cars in the center. The passenger coaches of the ICE-1 and ICE-2 trains are non-driven in that there are only trailer bogies beneath them. The newer ICE-3 train (Fig. 3) and its relatives outside Germany are of the EMU design, with distributed power; these trains no longer use power heads.

One of the most successful representatives of today's high-speed traffic is the Siemens train family VELARO. The basics of this train are derived from the German ICE-3, but there are different versions of this train operating in different countries.

The train shown in Figure 2 for the Spanish state railway RENFE is called VELARO-E (E for España). The VELARO-RUS (Russia) is running on the 1,520 mm (59.8 in.) track gauge instead of the common 1,435 mm (56.5 in.). And there is the VELARO-CN (China) that is doing 350 km/h (ca. 220 mph) maximum service speed in the newest version.

The working name of the VELARO-CN project at Chinese Railways is CRH-3 (China Railway High-Speed). The number three reflects the ICE-3 origin of this train design. CRH-1 and CRH-2 were Bombardier and Kawasaki designs. Bombardier's latest high-speed train is called ZEFIRO, along with other high-speed trains that are not as new but often have new versions. A selection of high-speed trains, to-

Train	$v_{max.}$ [km/h]	$v_{max.}$ [mph]	Year	
Shinkansen	200	124	1964	
	210	313	1965	
	300	186	1997	
TGV	260	162	1981	
	270	168	1983	
	300	186	1989	
	320	199	2001	
ICE-3	300	186	2006	
	320	199	2007	
VELARO – E	350	218	2007	
	RUS	250	155	2009
	CN	350	218	2008
ZEFIRO	380*	236*	*	

\* project status

gether with their maximum speeds and first year in operation, is listed in Table 1. But there are other high-speed trains not included in this listing; two of them should be mentioned—at least briefly.

Consider the AMTRAK train ACELA, running on the Northeast corridor in North America. The maximum speed of this train is not as high as with other applications, but it still operates under the definition of “high-speed” because it runs at more than 200 km/h on existing tracks, and in certain track sections reaches up to 240 km/h (ca. 150 mph).

The AGV train by ALSTOM is the successor of the TGV. It is already in service in Italy and might be selected for a California high-speed rail project that is planned to connect Sacramento, San Diego, San Francisco and Los Angeles. Other high-speed rail applications in Europe are the Eurostar train and the Pendolino, by ALSTOM, the V250 train by Ansaldo-Breda, and the Thalys train.

The TALGO is different from other trains—predominantly with regard to its wheel suspension. The wheels of this articulated train are not joined by an axle and the coaches do not run on bogies. This suspension allows passive tilting of the train into curves, thus improving passenger comfort. The tilting also allows the train to run faster on curves—especially on existing track. There are different generations of TALGO trains, including a couple of high-speed versions. TALGO is of Spanish origin but the trains run in several European countries.

A significant difference in TALGO trains is that many of them are equipped with a variable gauge mechanism; i.e., with this device the train can cope with different track gauges by adjusting the wheels accordingly—to a closer or wider pitch. This allows throughput, for example, in cross-border traffic between countries with different track gauge, such as Spain and France. Indeed, much of the Iberian Peninsula’s gauge is different from the rest of Europe. For the TALGO 350, the top operational speed at Spanish state railways RENFE is 330 km/h (205 mph). The design top speed is 350 km/h (ca. 220 mph), but the speed is restricted to 330 km/h due to the present-gauged lines (Ref. 7).

**Axle loads and bearing bore dimension.** Compared to other applications, axle loads for current high-speed vehicles are rather moderate. A reason for that is that with most high-speed applications, the traction force is distributed along the entire train instead of using push-pull technology as in the earlier days of high-speed traffic. The Siemens VELARO trains, for example, are of the EMU type (Electric Multiple Unit). With the VELARO-CN project, every second bogie of the train is driven, and the Russian-version VELARO-RUS has a similar concept. The axle loads of such applications are about 17–18 tons, depending on the train version. Based on axle load, the journal diameters are specified either as 130 mm (5.12 inch) or 150 mm (5.9 inch); these are also the bore diameters of the corresponding rolling bearings. With EMU concepts, the journal dimensions, and thus the bearing size, are kept identical for the entire train configuration. They can, however, vary between different versions within one train family. In push-pull applications like the German ICE-1 and ICE-2 trains, the axle loads are different for the power heads

and the coaches. For the ICE-1 and ICE-2, the power head axle load is 19.5 metric tons. The axle load of the passenger coaches in between these power heads is 16 metric tons. The newer-generation ICE-3, which is an EMU arrangement, has maximum axle loads of 16 metric tons throughout the entire train.

**Rotational speeds.** With wheel diameters of 830 mm (33 inch), a common diameter of the worn wheel and vehicle velocities of 350 or 380 km/h (218 or 236 mph), the rotational speed of the bearings of such high-speed applications results in 2,200 and up to more than 2,400 rpm. For a bearing the size of the described journal bearings, this is a rather high rotational speed and is not attainable using previous designs without modifications.

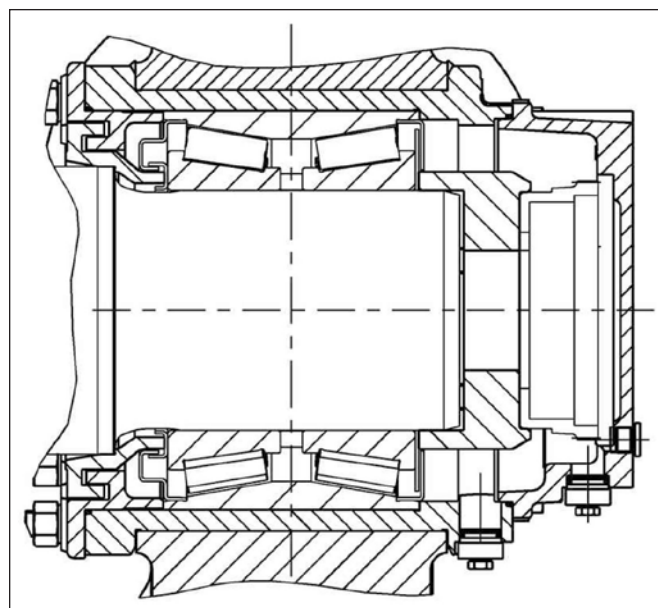


Figure 8—Bearing principle example of a high-speed train.

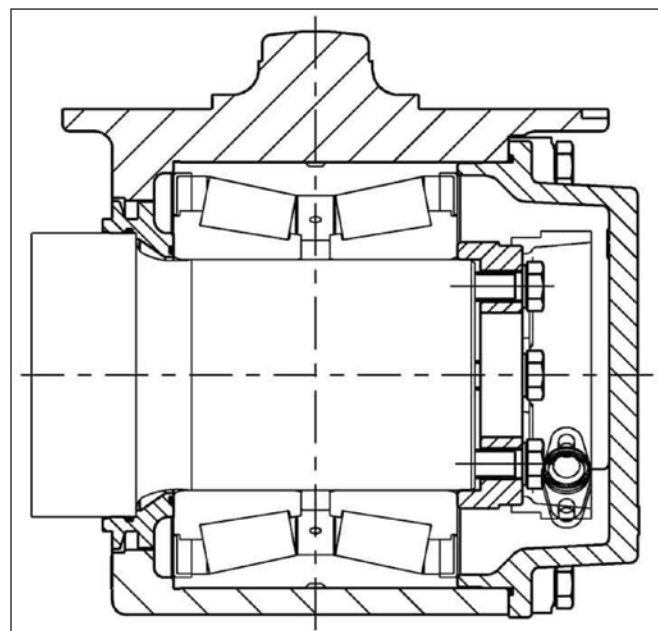


Figure 9—High-speed bearing with alternative sealing design.

**Bearing arrangements.** From the axle box bearing viewpoint there are two main concepts used for high-speed applications: cylindrical roller bearings and tapered roller bearings.

Two-row tapered roller bearing units (Fig. 4) dominate the high-speed market at the moment. The bearings are usually designed as so-called “cartridge bearings.” Per definition (Ref. 4), these are rolling bearings with two or more rows of rolling elements within a single outer ring, greased and equipped with integral seals. Besides the bearings of the tapered design there are also cylindrical roller bearings used in railway axle boxes (Fig. 5). These journal bearings are cartridge bearings with cylindrical rolling elements, usually arranged in two rows. They are supplied as greased-and-sealed units, as are tapered cartridge bearings. Such bearings are often used in European locomotives for push-pull trains with non-driven coaches. The cylindrical bearing unit design, for example, is also used for floating bearings on the middle axle in three-axle bogies of heavy locomotives.

### European Standards and Regulations

This part of the paper describes the most important standards that bearing manufacturers have to follow during the development, design, production and testing of railway rolling bearings. In addition to the standards directly referring to bearing issues, there are standards dealing with components around the axle box bearing, such as the axles themselves. Details of these often are important for certain parts of the rolling bearing design as well. Besides some rather general

standards for rolling bearings, there are three railway-specific standards in Europe (European Norm):

The first one is probably also the most important: EN12080 (Ref. 4)/Railway Applications: Axle Boxes/Rolling Bearings. Some important information on this standard is given in the Quality Assurance section of this paper.

Next in the range of standards is EN12081 (Ref. 8) for lubricating greases. This standard covers items like consistency, traceability, packaging and, most of all—the approval process for greases.

The last is EN12082 (Ref. 9), which describes the performance testing of axle boxes. Since the testing defined here is much different from other testing methods (e.g., the AAR method), there is a short description of important characteristics under the topic Product Validation.

These mentioned standards all relate to the axle box bearings themselves. However, in the project work and design phase of an axle box arrangement, some other standards and regulations have to be taken into account.

There are also standards for the axles of railway vehicles:

EN13103 Railway Applications: Wheels Sets and Bogies/Non-Powered Axles/Design Method (Ref. 10).

EN13104 Railway Applications: Wheel Sets and Bogies/Powered Axles/Design Method (Ref. 11).

In both standards the details shown in Figure 6 are used to specify the axle design. An important standardized fact is that the edge on the axle journal (A, Fig. 6) has to meet the hardened and ground part of the bearing inner ring bore some distance away from the spot where the bearing bore runs over into the chamfer. This is shown in detail in Figure 7, where 1 points to the start of the bearing chamfer or to the end of the cylindrical bearing bore, and 2 marks the distance of this spot to the edge on the axle journal. The reason for this requirement is to prevent axle fracture. When the inner ring’s transition to the chamfer contacts the cylindrical part of the journal outer diameter, there can be an indentation formed under the influence of high loads and bending under rotation. Compared to the hardened bearing inner ring, the axle journal material is much lower in hardness. Thus the indentation can lead to a serious problem as it can mark the start of a surface crack. The crack can then expand continuously from the influence of the bending under rotation and finally cause a fracture of the axle. With the specified arrangement (Fig. 7) the axle journal is prevented from damage by the bearing chamfer.

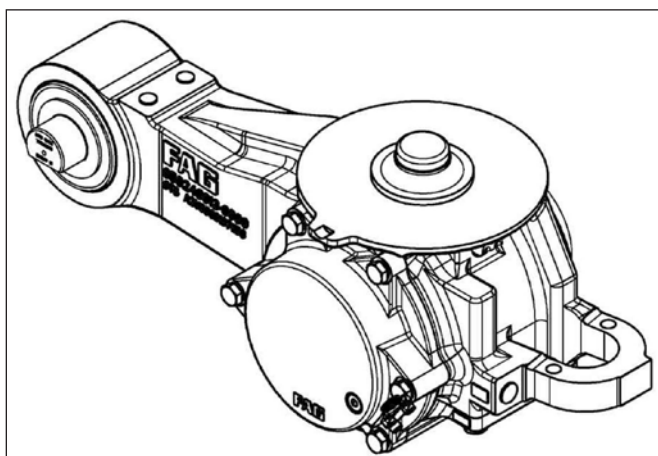


Figure 10—Housing example.

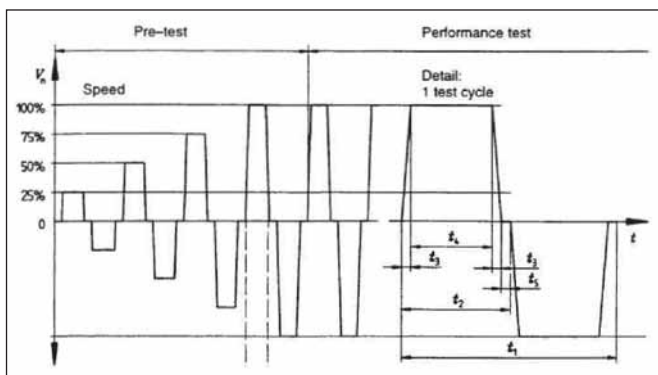


Figure 11—Alternation of test cycles (EN12082).

### Enhanced Material Properties

Material cleanliness has always been a key factor of any bearing component involved in rolling contact. Non-metallic inclusions inside the material that are filtered out in the liquid phase of the steel-producing process have to be minimized and kept as tiny as possible. Such inclusions are mainly oxides and sulfides, and they undermine rolling bearing life by allowing the initiation of fatigue failures. Under the influence of high loads—which stresses the surface and subsurface of the raceways—fatigue-based modifications of the material structure take place and lead to a reduction of bearing life. This failure mechanism is incorporated into the classic lifetime calculation by a material factor. This material factor would be higher

when using special material qualities with further minimized inclusions. Steel that is perfect—completely free of any inclusions—does not exist, given the current state of technology. But for particularly demanding applications it is sometimes necessary to increase the fatigue lifetime of the bearings. This can be done by selecting bearing steel with advanced cleanliness requirements, meaning that the bearing manufacturer specifies an improved material compared to the standard axle box bearing quality. This is often done in combination with a more sophisticated heat treatment.

Material and/or surface and precision improvements are the most effective measures in creating higher-quality bearings for high-speed applications; special surface coatings are another option. A further improvement in material cleanliness exists in vacuum re-melted steel. However, energy consumption is much higher with several of its melting steps and there is a certain scrap content with any step. Furthermore, the lower quantity in tons feasible for the re-melting processes makes it a very costly production. These factors all contribute to a considerably higher material cost for re-melted steel in comparison to the current standard for axle box rolling bearings.

Figures 8 and 9 are examples of complete arrangements of journal bearings together with housings for high-speed trains.

### Bearing Lubrication

The grease quantity inside the bearing must be adapted to the relatively high rotational speeds, and consistency needs to be suitable for high-speed traffic.

Also, environmental conditions in the area where the train is operating have to be taken into account when selecting a suitable grease type. Base oil type and thickener are only two aspects to be considered when forming a bearing lubricant. An adjusted selection of additives is important and requires a lot of experience. The determination of grease viscosity and grease amount is also largely influenced by the specific operating conditions of the application. The grease viscosities for high-speed operation usually are somewhat lower than those of other applications. Grease suppliers and bearing manufacturers typically share their knowledge for the development of greases with outstanding performance.

Most challenging in terms of lubrication is the definition of the appropriate grease quantity for a specific application. Although theoretically there is space enough to put some reserves of grease into the bearing in order to reach long service intervals, high-speed bearings are extremely sensitive to overgreasing. Too much grease creates a temperature rise caused by the churning motion of the grease when it cannot escape from the raceway area to nonrotational sections of the bearing. This is a rather well-known finding. However, with higher speeds this aspect is even more critical. The performance test criteria described in this paper's Quality Assurance section can only be fulfilled with an elaborate consideration of the grease amount and grease distribution inside the bearing. The currently valid edition of EN12080 requires that the grease distribution has to be agreed upon and documented between customer and contractor, in addition to the designation and quantity of the grease.

### Quality Management

The Association of American Railroads (AAR) issues a separate manual—the M-1003—as part of their series of manuals of Standards and Recommended Practices that deals exclusively with quality management issues.

The AAR rules and approvals are not only used in America but also in other parts of the world. However, these rules are mainly for freight applications and thus neither suitable nor sufficient for high-speed passenger traffic systems.

There are different international standards for quality management systems, as most readers are well aware—ISO 9001, ISO9004 and TS16949, for example. And yet, none of these cover special railway topics. Thus within the last few years there was a new quality management standard developed especially for railways: IRIS (Ref. 12). The International Railway Industry Standard has its roots in Europe but is applicable worldwide, as the name indicates. IRIS is issued by the Association of the European Rail Industry; it is a globally recognized standard—unique to the railway sector—for evaluation of management systems. Its main objective is to improve the quality in the rail sector by reduction of efforts and costs (Ref. 13).

IRIS is based on the ISO 9001 structure and adds railway-specific requirements, especially on project management, design, RAMS (reliability/availability/maintainability/safety) and LCC (life cycle costs). The standard contains both mandatory and optional requirements. The audit results are scored, thus it is more robust than a pass/fail system. One might recognize some sort of analogy to ISO/TS16949, though IRIS exceeds the requirements in many ways. The second edition of the standard was issued in June 2009 and replaces the 2006 version. Many suppliers to the rail industry are certified according to IRIS. As of June 2009 there are 244 companies certified in 23 countries on five continents (Ref. 6).

Continual improvement is a basic tenet of IRIS that encompasses the entire railway business sector.

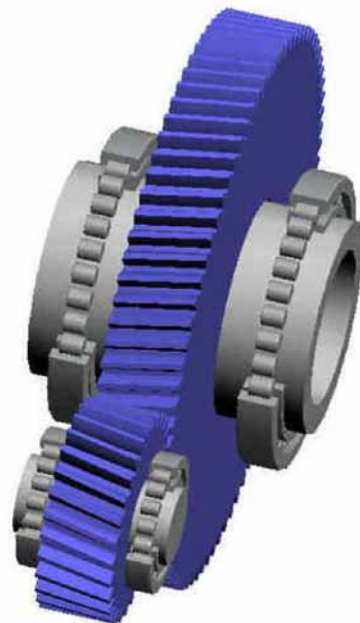


Figure 12—Transmission example with hollow shaft.

## Quality Assurance

While this paper has dealt with quality management and related systems, following is some information about actual quality assurance measures carried out on journal bearings. As already mentioned, EN12080 is the main normative instruction for axle box bearings in Europe. Although this European standard affords much leeway to project-specific agreements between customer and supplier of railway axle box bearings, there is a variety of mandatory requirements when bearings are ordered and produced according to this standard.

Extensive, non-destructive testing is carried out on all journal bearings per EN12080. This includes 100%-ultrasonic testing of the rings so that any subsurface defects in the material can be detected, and a crack inspection to detect surface fissures. Rollers are 100%-eddy-current-tested and there are hardness tests on rollers and rings for random samples. For all assembled bearings the axial clearance (bench lateral) is measured and all inspection results are 100%-documented.

## Housings

The housing is an essential component of the axle box system. Bearings in low-speed applications (especially freight cars) often run with housings connected to the bogie solely by open adapters, or the housings are of a rather simple design that does not give full circumferential support. Full-bore housings (Fig. 10) allow the use of through-hardened bearing rings made of chromium steel—the most widely used material for rolling bearings in Europe.

Without the use of full-bore housings, the bearing outer rings are not equally supported on the entire circumference and the load distribution at the outer rings is less favorable. Bearing rings are then subject to distortion, and through-hardened rings can break under the influence of such deformation. This is why high-speed applications are equipped with full-bore housings or with split housings that supply the same function as full-bore housings when the split parts are mounted together. Split housings enable the dismounting of the wheel set without removing the wheels from the axle.

## Validation and Performance Testing

The European Standards series for axle boxes also covers testing and validation. EN12082 standard (Ref. 9) deals with this topic and requires that any new axle box design undergo extensive performance testing with demanding test conditions. Unlike the durability testing according to AAR, the EN12082 rig performance test applies a relatively high lateral load (in axial direction) to the journal bearings. The standard uses the terms “axial force” and “radial force.” Bearings that undergo the AAR durability test are loaded only in the radial direction (vertically). Whereas the radial force is constant, the axial force applied during EN testing is alternating in two directions. The test cycles consist of acceleration from zero speed to test speed, running with test speed for some time and then decelerating to a stop; the next cycle then starts in the op-

posite direction (the sense of rotation is changed). Figure 11 illustrates the alternation of test cycles and shows how the speed is progressively increased during the pre-test phase.

There is a reference vertical load  $F_0$  calculated as:

$$F_0 = (1/j) \cdot m_{max} \cdot g$$

where:

$m$  is the vehicle mass and  $j$  is the number of wheel sets (axles)

Then the radial force is defined as:

$$F_r = 0.6 \cdot (F_0 - m_0 \cdot g)$$

and the axial force as:

$$F_a = 0.255 \cdot (10^4 + F_0/3)$$

With a sample vehicle load of 64 tons (common for high-speed passenger coaches with 16-ton axle load) and a wheel set mass ( $m_0$ ) of 1.7 tons, the radial load calculates as 84 kN and the axial (lateral) force as 15.9 kN. For this example the axial load on the bearing is about 19% of the radial load.

Since the axial load is only applied at speeds above 20% of the nominal test speed, and it is zero for a couple of seconds when the direction is changed from one side to the other, it makes this performance test a very daunting one.

The mileage of performance testing depends on the degree of change from existing, already-tested designs. For a completely new bearing design it is 600,000 km (373 miles) when the vehicle speed is up to 200 km/h (124 mph), and 800,000 km (about 500,000 miles) for high-speed vehicles above 200 km/h. When the modification from previously tested designs is not substantial, the test mileage can be reduced to 100,000 km (62,000 miles). This has to be agreed upon between the contracting parties (customer and supplier), as the standard gives some leeway in this respect. With certain preconditions defined in EN12082, the reduced 100,000 km test can be substituted, but this is not a must; the parties can agree on the full mileage.

## Onboard Monitoring

On most railway lines there are alarm systems alongside the tracks; e.g., infrared hot-box detection systems are the most widely used alarm systems; acoustic detectors are used in North America and China. The drawback with all of these systems is that they only consider certain positions along the track—leaving the conditions between these detector positions unattended and undetected. Continuous safety monitoring can only be done on the train itself, which is why onboard monitoring has been introduced. Using sensor bearings, the bearing temperature—the most critical indicator of bearing problems—can be monitored continuously. Other available sensor types record the sense of rotation and speed and/or acceleration acting on the bearing as well.

## Traction Motor Bearings

The propulsion of rail vehicles is mostly carried out either by diesel-electric or pure-electric traction drives. Most high-speed trains use electric propulsion today, where the traction motor is the key propulsion element within the bo-

gie. The power supply is either continuous-current (DC) or three-phase-current and sometimes classic alternating-current (AC). Three-phase traction drives prevail in high-speed traffic, their advantage being that three-phase asynchronous motors can be efficiently controlled by powerful frequency converters. The main bearing concept for traction motors has not changed much within the last decades. The rolling bearing details, however, have changed a good deal and thus have remarkably enhanced bearing performance. Typically, there is a cylindrical roller bearing serving as a floating bearing on the drive side and a deep-groove ball bearing or another cylindrical roller bearing serving as a locating bearing on the non-drive side of the motor shaft. The new concepts of traction motor control mostly require that both bearing sides be equipped with current-insulated bearings. Such bearings have a ceramic insulation layer applied to the outer ring to prevent current flow through the raceways and rolling elements. Current flow via the rolling elements seriously damages the raceways and leads to premature failure of traction motor bearings.

### Transmission Bearings

There are different bearing types in use other than journal bearings for transmissions used in railway vehicles, and the lubrication system is completely different from that used in axle boxes. While grease lubrication is used in axle box bearings and most traction motor bearings, transmission bearings are oil-lubricated. The lubricant for the bearings usually is the same as for the gearing, as this facilitates the design of the transmission housing. The fact that lubricants that are superior for the gear tooth system are not necessarily ideal for the lubrication of the rolling contact of the transmission bearings is another issue—far beyond the scope of this paper. The number of reduction stages inside a transmission can vary; for railway bogies there are both single-stage and double-stage transmissions. Figure 12 shows an example with four cylindrical roller bearings and a hollow output shaft.


**Input shafts.** While with other rail applications the rotational speeds of input shafts are roughly about 4,000–5,000 rpm, input shafts of high-speed vehicles rotate up to 6,000 rpm. Due to their suitability for high rotational speeds, input shafts are often introduced with ball bearings and cylindrical roller bearings. A typical arrangement on this fast-rotating shaft is a cylindrical roller bearing, together with a four-point-contact ball bearing on one side, and a single, cylindrical roller bearing on the other. The four-point contact ball bearing takes all of the axial load coming into the shaft and is kept free of radial loads by design measures. All radial loads onto the input shaft are supported by the two cylindricals.

**Intermediate shafts.** Intermediate shafts, if used, usually have two cylindrical roller bearings or there are two tapered roller bearings mounted in an x-arrangement. The axial loads almost compensate one another and the radial loads are moderate enough so as not to present a daunting challenge. Speeds are not an issue at this bearing location, either.

**Output shafts.** At the output shaft location we find predominantly one-row tapered roller bearings with some application-specific modifications. These bearings are often based on standardized catalogue types from a dimensional point of view, but there are several modifications necessary to empower such bearings for high-speed use in railways. One major aspect is the cage that is of a reinforced design for the output shafts, due to the shock loads and vibration influences acting on these bearings. Improved surface finish is another feature, and often there are retaining grooves in the outer rings to keep the rings from moving in the circumferential direction.

### Conclusion

Most of today's high-speed trains are still based on the classic wheel-rail system. As for rolling bearings, their use is enabled by reliance upon bearing concepts that follow proven designs and implement the modifications necessary to cope with the higher requirements.

But, ever-increasing speed requirements are a challenge for all components in the bogie—including rolling bearings. It is simply a matter of time until the 400 km/h (ca. 250 mph) limit will be exceeded by a train in regular service. And it will again be established with rolling bearings, whose development continues to evolve. 

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# Improved Performance for Hydraulic Seals from Thermoplastic Polyurethane

Rolf Galle-Gutbrecht, Holger Jordan and Renate Brielmann

(This paper was first published at the 2011 52nd National Conference on Fluid Power and is reprinted here with the kind permission of the National Fluid Power Association.)

## Management Summary

Seal design engineers and end users are continually seeking improved sealing systems and materials. This paper describes the potential of a new thermoplastic polyurethane (TPU) material to deliver improvements in pressure, speed and temperature capability, which are presented as comparisons to proven industry standard materials. Performance is demonstrated by virtue of test bench results of seals made from MDI-, PPDI- and NDI-based materials.

Laboratory results of temperature scanning stress relaxation (TSSR) testing will be reviewed to show that this high-performance TPU can compete with cured polyurethanes while utilizing existing TPU technology and tools to maintain a commercially competitive product.

## Introduction

Thermoplastic polyurethane has been established for more than 30 years as a standard material for dynamic seals in hydraulic systems. TPU's outstanding mechanical properties—in combination with its straightforward thermoplastic molding process—have ensured this market position. Furthermore, the variety of available polyurethane chemistry allows an adjustment of the material properties to meet a range of different requirements.

Most commercially available TPU materials produced by reputable seal manufacturers are based on MDI. (*Editor's Note: MDI (diphenylmethane diisocyanate) is a polyurethane resin used as spandex fibers and for bonding rubber to rayon. It is used in the production of polyurethane lacquers, foam plastics, rubbers, thermal insulators and glues.*) One specific seal manufacturer is offering TODI-based (3,3'-dimethyl-4,4'-biphenyldiisocyanate) TPUs as standard materials.

The temperature range specified for MDI materials, except for special types, is usually 35–110°C—a temperature range that is suitable for use with many standard hydraulic oils.

However, the demand to increase power density in hydraulic systems has led to higher pressure requirements and has driven the temperatures up in hydraulic cylinders, along with OEM and end user requirements for longer life. Temperature capabilities for sealing materials are now required to be within 120–130°C.

## Diisocyanates for comparison:

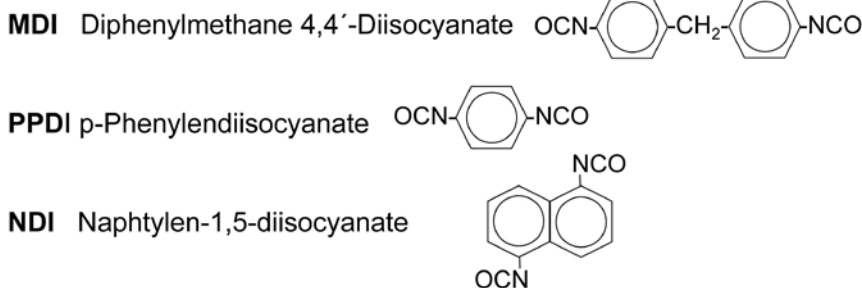


Figure 1—Comparison of isocyanates used in construction of thermoplastic polyurethane.

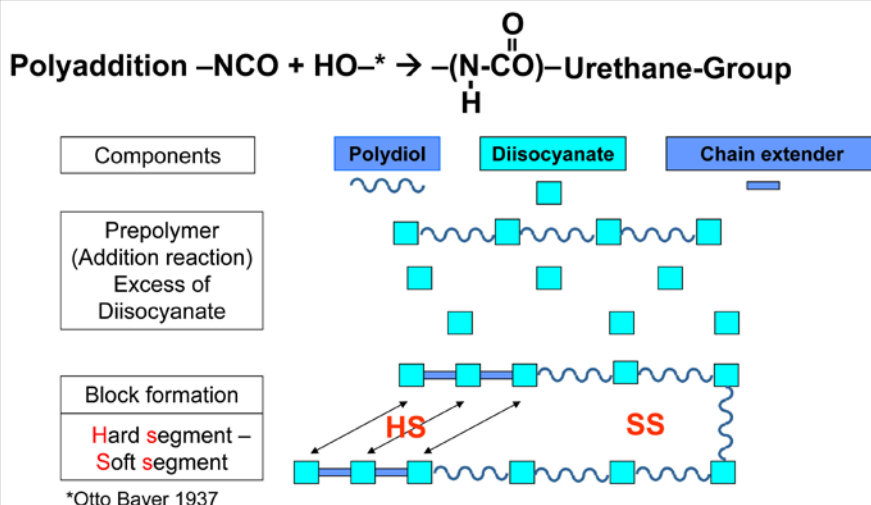


Figure 2—TPU synthesis via pre-polymer process.



With this in mind, can this temperature requirement be satisfied with an MDI-based material or must you go to a material based on PPDI (p phenylenediisocyanate) or NDI (naphthylene-1,5-diisocyanate)? The specified continuous temperature application limit of the NDI-based material is 135°C (higher for short periods); NDI is commercially available.

Or is it necessary to develop a material with an alternative diisocyanate optimized for sealing applications? A major problem with that approach is that the price for such a material would be several times higher than an MDI.

**Ingredients of TPU material.** Figures 1 and 2 show the basic raw materials for TPU synthesis as well as the diisocyanates used for the reference materials discussed in this paper. TPU consists of 3 basic ingredients:

Polydiol = HO-R<sub>1</sub>-OH (long chain)

Diisocyanates = OCN-R<sub>2</sub>-NCO

Chain extender = HO-R<sub>3</sub>-OH (short chain)

**TPU materials tested.** Four materials were produced and tested:

- A proven, standard hydraulic TPU based on MDI
- A novel, high-performance TPU for hydraulic seals, also based on MDI
- A commercial material based on PPDI
- A commercial material based on NDI

Test sheets and seals in an RU9 U-Cup profile were produced for testing in a size to suit a 50 mm diameter rod.

*(Authors' Note: See Appendix, Table 1, for physical properties of these four materials.)*

**Test equipment and method.** Figure 3 shows an outline of the test arrangement with service conditions that are specified to test the limits of the seals in order to obtain a good understanding of their capabilities. To protect pumps against high temperatures, low-viscosity oil—Shell Tellus 6—was chosen over the more common ISO VG 46. **Oil condition was carefully monitored due to the high time temperature load to ensure always same test conditions.**

Note that pressure is cycled with the stroke, meaning that seals at positions 1 and 4 are exposed to a pressurized in-stroke, whereas seals at positions 2 and 3 are exposed to a pressurized out-stroke. For this reason seals at positions 1 and 4

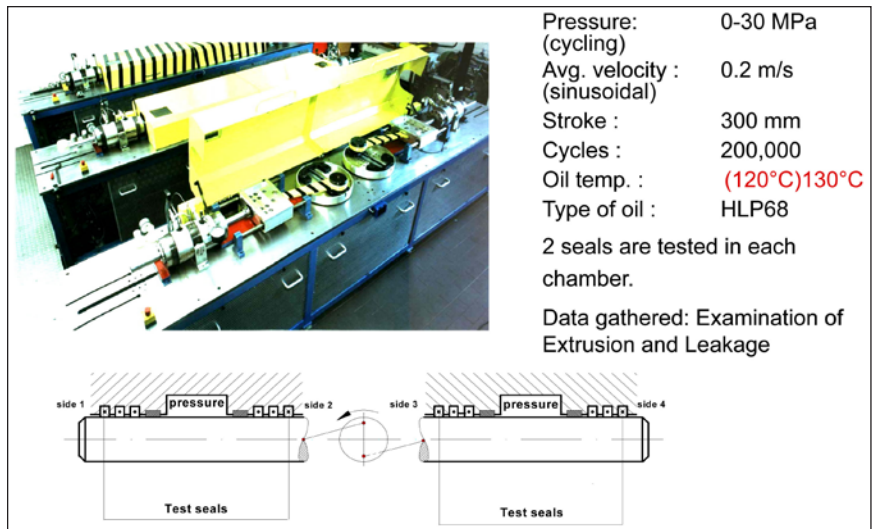


Figure 3—Test arrangement for cycle testing of hydraulic seals.

### Endurance Test ST-MDI @ 120°C

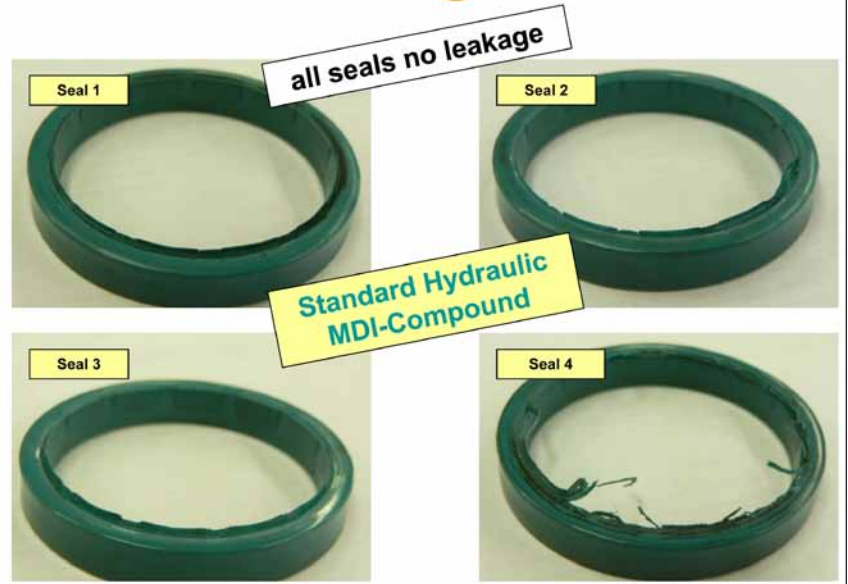


Figure 4—Standard MDI compound, 120°C.

### Endurance Test @ 120°C

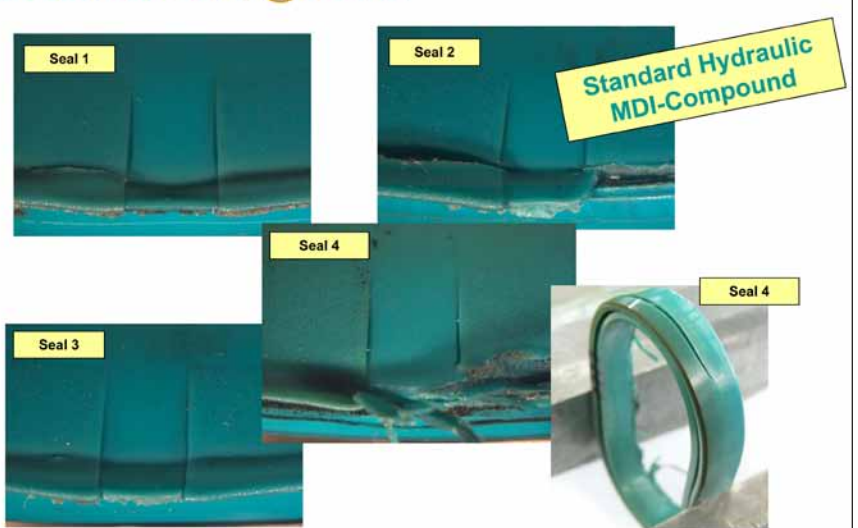


Figure 5—Details from Figure 4.

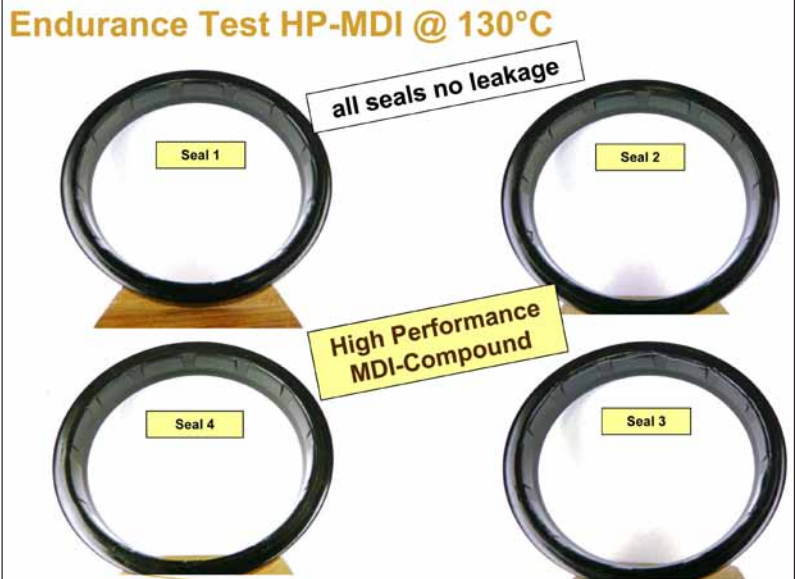


Figure 6—High-performance MDI compound, 130°C.

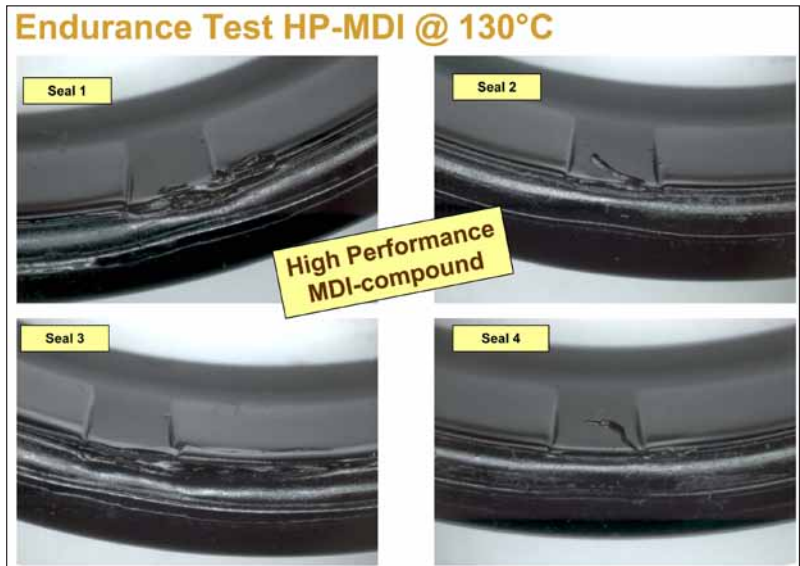


Figure 7—Details from Figure 6.

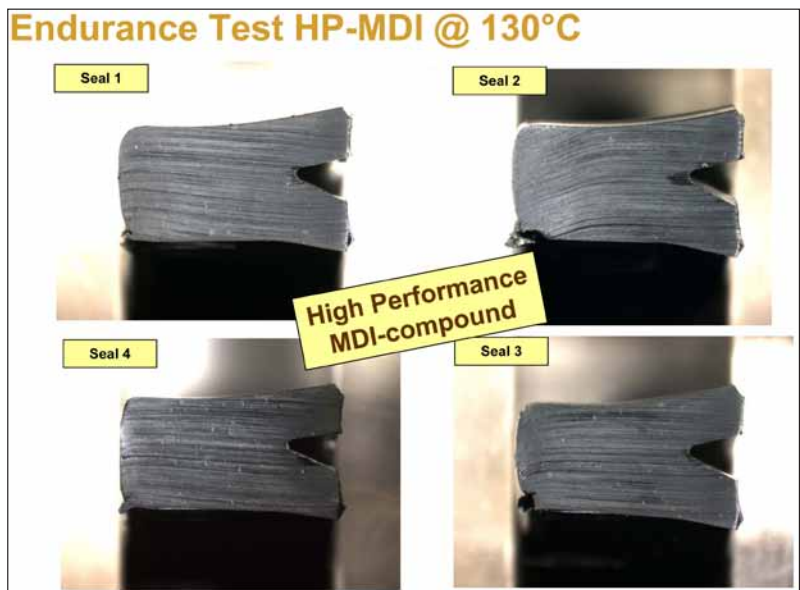


Figure 8—Cross-sections of seals in Figure 6.

are considered to be most representative of typical service conditions.

**Test results.** First we will review the results of the proven standard hydraulic TPU compared with the newly developed, high-performance TPU—both MDI based.

Figure 4 shows seals made from the standard hydraulic MDI-based material after a test run at 120°C continuous temperature (Fig. 5).

A considerable degree of extrusion is visible, especially on seal 4. Although the test run was finished without leakage, the limit of the seals is visible.

Figures 6 and 7 show the corresponding seals made from the MDI high-performance TPU after the test run, conducted at 130°C continuous temperature. Note that the close-ups in Figure 7 and the profile sections shown in Figure 8 display very limited extrusion; again, no leakage and the seals remain completely functional.

In comparing the two materials, the high-performance MDI material is clearly superior, despite the 10°C increase in test temperature. This is evidenced also by comparing the change of interference (Appendix, Fig. 17) when comparing all four TPU compounds.

After the direct comparison between standard- and high-performance MDI compounds, next is a comparison with the test results of the RU9 U-Cup from the PPDI- and NDI-based materials.

Figures 9–11 show images of seals of a commercially available PPDI compound tested at 110°C.

Another way to evaluate performance is to look at the permanent loss of seal interference after testing. This interference is vital to seal performance at both low and high pressures, and while some loss of interference is always expected, excessive loss can lead to premature failure.

By comparing the seals from the commercial PPDI compound tested at 110°C with those of the high-performance MDI compound—tested at 130°C—a comparable level for the loss of interference is visible.

Figures 13–15 contain test results of seals made of commercial NDI compound, having completed the test run at 130°C continuous temperature.

Despite its good properties profile, the commercial NDI material did not exceed the high-performance MDI material in terms of extrusion resistance—even at a high temperature of 130°C.

**High-temperature properties.** So what is the difference-maker in the performance of the sealing material?

Table 2 (Appendix) shows the physical properties of these four materials at higher temperatures, as well as the key points from the DMA analysis that are detailed in Figure 16 (Appendix).

The NDI material shows the best tensile strength values and the highest softening temperature (see Appendix, Figure 16, Onset 2). The high-performance MDI material follows with a softening point approximately 2°C lower. The PPDI material shows with 7.5°C less—a significant difference. However, the storage modulus of the high-performance MDI material in the upper temperature range is about 40 percent higher.

The DMA curve confirmed the known benefits—good visco-elastic properties—of NDI material with a very steep drop of the curve in the glass transition temperature, compared to the more gradual transition of the PPDI and high-performance MDI materials.

**TSSR testing.** Brabender TSSR testing was employed to characterize the new high-performance MDI material and to compare it with published data on other thermoplastic and thermo-setting sealing materials. (*Editor’s Note: Temperature scanning stress relaxation is an anisothermal stress relaxation test method that also enables conventional isothermal relaxation measurements.*) Figure 17 (Appendix) shows that it appears to be superior to the other thermoplastic polyurethane materials in terms of T50 failure temperature and rubber index value; i.e., a measure of stress relaxation with varying temperature. A theoretically perfect material would have a rubber index of 1.

### Summary

A comparison of endurance test shows that a high-performance, MDI-based TPU—optimized specifically to the needs of a highly-loaded hydraulic seal in regard to temperature and

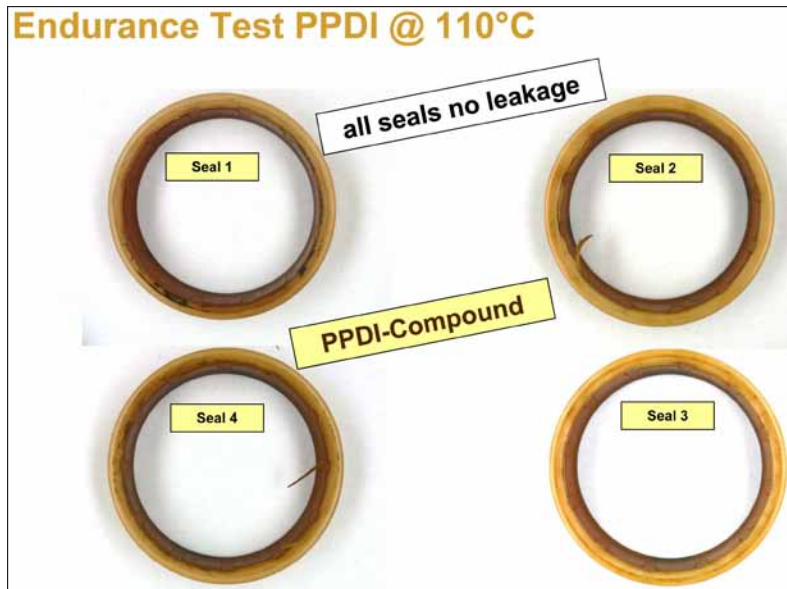


Figure 9—Commercial PPDI compound, 110°C.

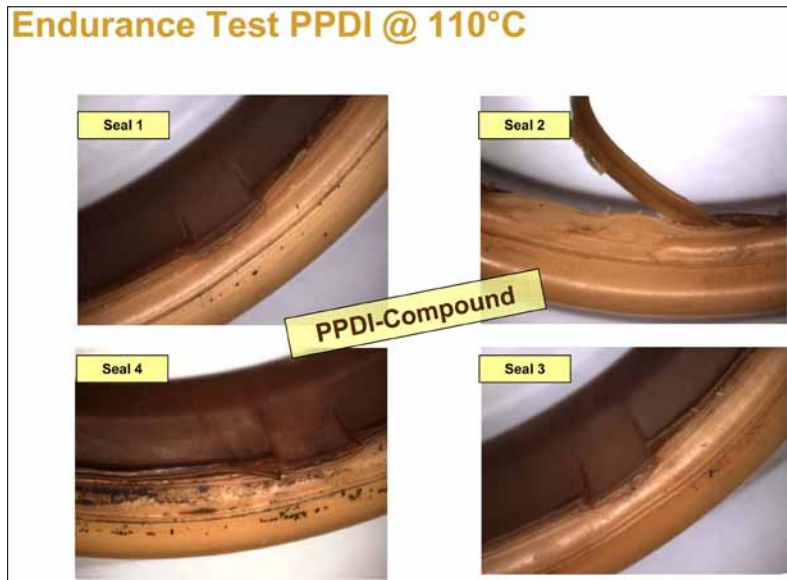


Figure 10—Details from Figure 9, partial extrusion visible on seals 2 and 4.

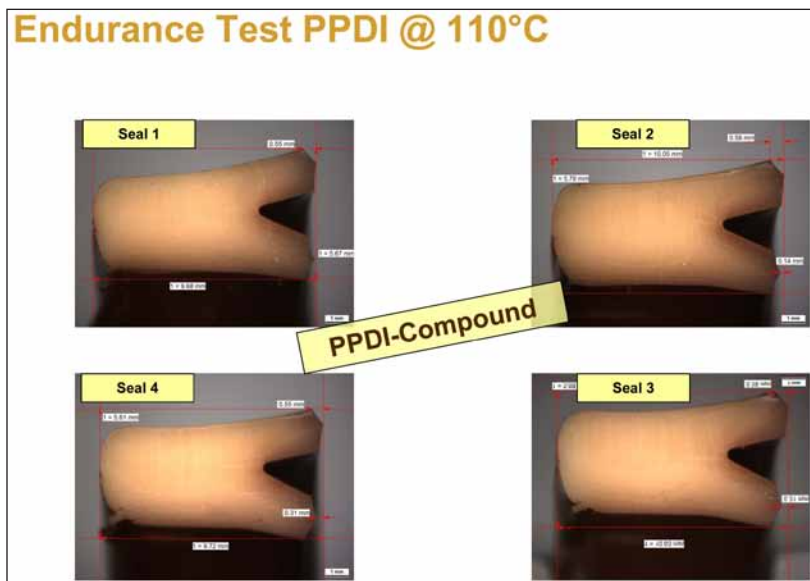


Figure 11—Cross-sections of seals from Figure 9; again, extrusion is clearly visible.

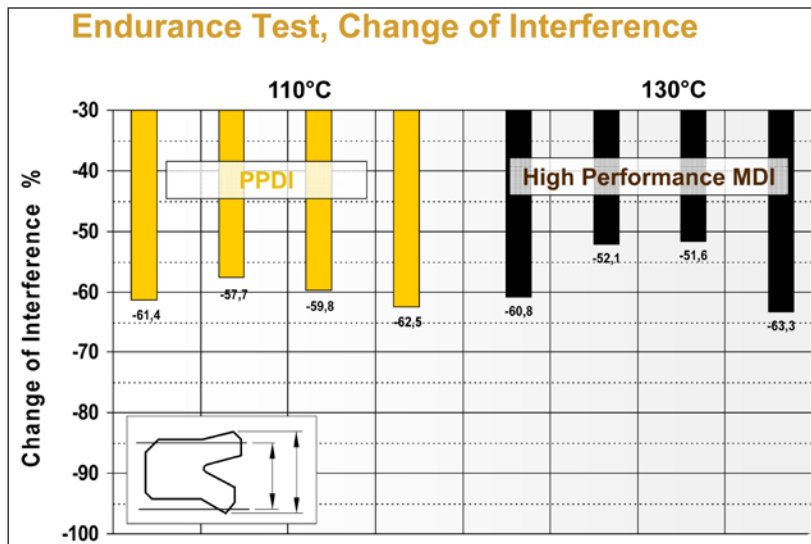


Figure 12—Comparison of the change of interference between PPDI and high-performance MDI materials.

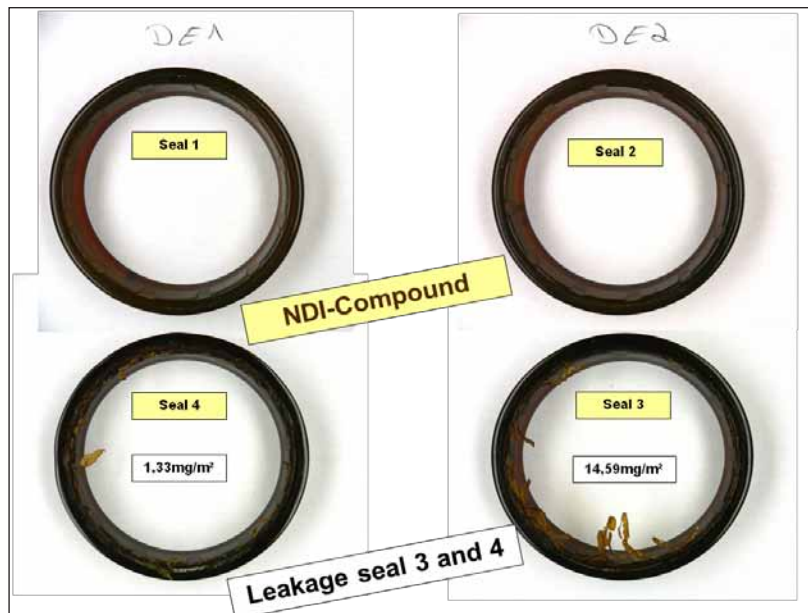


Figure 13—Commercial NDI-based material, 130°C; note the thick, broken extrusion on seals 3 and 4.

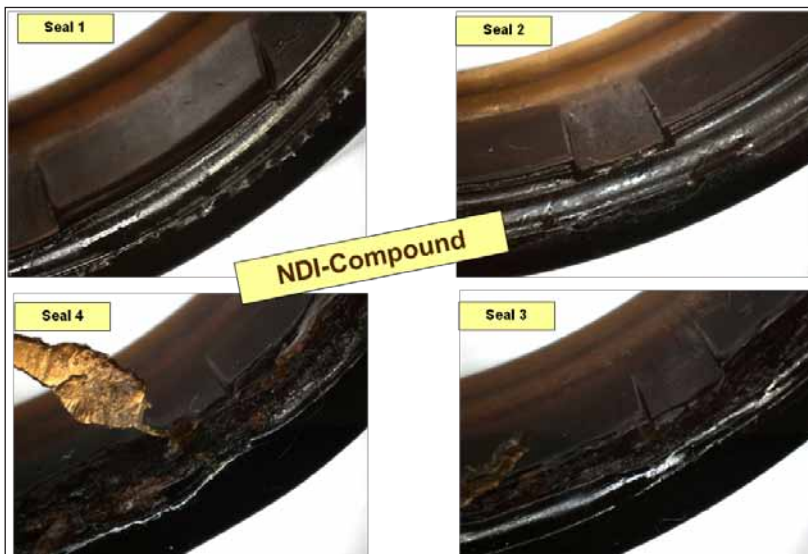


Figure 14—Details of thick extruded sections shown in Figure 13.

pressure—can out-perform a range of common TPU seal materials, including conventional MDI and commercially available NDI- and PPDI- based TPUs.

As a final comparison—Figure 18—shows the change of interference of test seals from all four materials run at specified temperatures in the study. Once again the high-performance MDI material shows its superiority—even when tested at temperatures higher than the others.

The high-performance, MDI-based material also showed benefits in extrusion resistance, storage modulus and TSSR performance. As a value-added benefit, the MDI material can be processed by using the same tools and methods as the standard MDI material—thus enabling a simple seal upgrade for high-temperature applications.

### Conclusion

It has long been assumed that NDI-based materials were required to ensure the stable, high-temperature performance of polyurethane hydraulic cylinder seals. But with out-of-the-box material design—and evaluation methods that closely replicate real-world working conditions—it has been demonstrated that a specially developed, MDI-based material can perform extremely well. This in turn allows for production of commercially and technically competitive, high-performance seals.

*Acknowledgments.* The authors wish to express their thanks to Dipl.-Ing. Frank Fuchs of Brabender GmbH & Co. KG, Duisburg, Germany, for permission to use Brabender's TSSR data on comparative sealing materials.

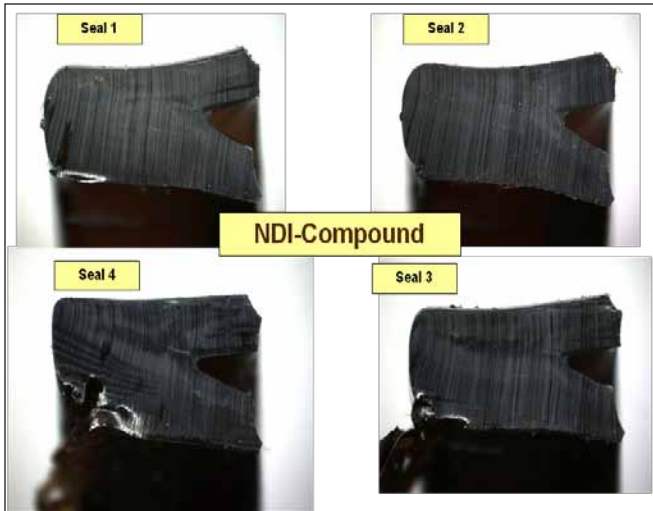


Figure 15—Cross-sections of seals from Figure 13; damage is especially evident.

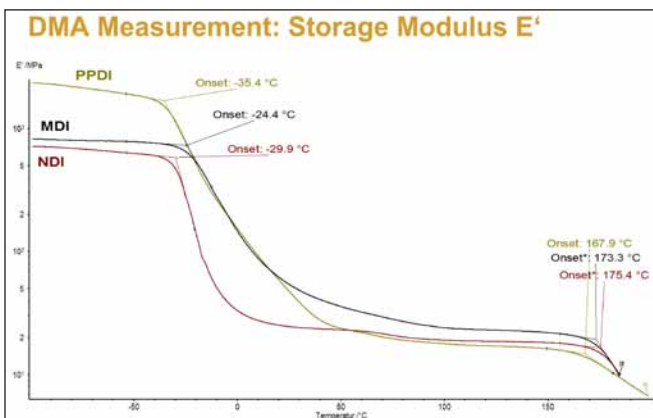


Figure 16—Comparison of change-of-interference of the four compounds after testing.

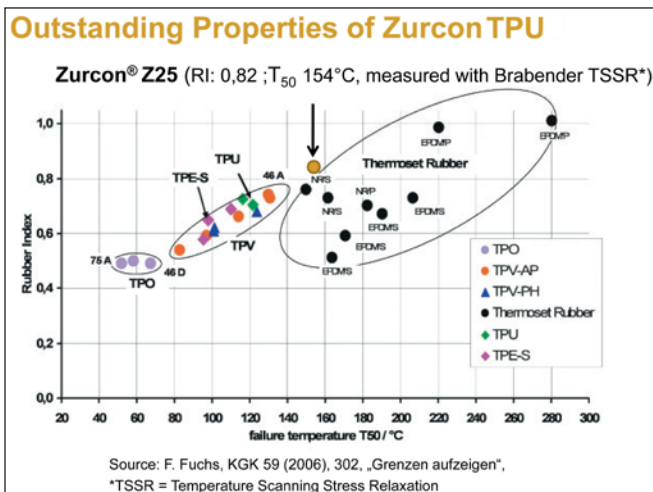


Figure 17—Dynamic mechanical analysis (DMA) measurements comparing storage modulus ( $E'$ ) of high-performance MDI material with NDI and PPDI materials.

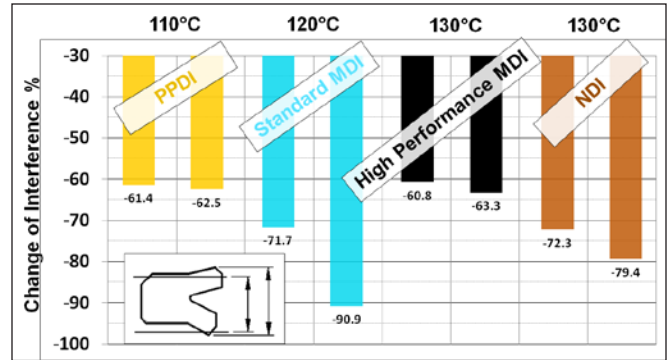


Figure 18—Comparison of TSSR results of traditional, commercial MDI-TPUs, thermoplastic elastomers (TPEs) and conventional thermoset rubber to the high-performance, MDI-based material.

### Overview of Tested Compounds

Compound	ST-MDI	PPDI	NDI	HP-MDI
Description	Standard Hydraulic	Commercial Compound	Commercial Compound	High Performance Hydraulic
Hardness Shore A/D DIN 53 505	94 +/- 2 45 +/- 2	94 40	92 43	95 +/- 2 46 +/- 2
Density DIN EN ISO 1183-1	g/cm <sup>3</sup> 1.20 +/- 0.02	1,18	1,15	1.20 +/- 0.02
Modulus 100 % DIN 53 504	N/mm <sup>2</sup> 13,2	11,3	9,9	14
Tensile strength DIN 53 504	N/mm <sup>2</sup> 60	56,9	51,5	60
Elongation at break DIN 53 504	% 540	652	593	520
Rebound resilience (6mm) DIN 53 512	% 45	53	64	47
Tear strength DIN ISO 34-1	N/mm 90	104	90	90
CS 70h/70°C DIN ISO 815 (B)	% 22	33	29	22
CS 70h/100°C DIN ISO 815 (B)	% 38	50	36	36
Temperature range	°C -35/+110	<-45/+135	<-40/+135	-35/+130

Table 1—Overview of physical properties of tested materials

### Tensile Test at 110°C, DMA Onset

Compound	PPDI	NDI	HP-MDI
Tensile test at 110°C			
Description	Commercial Compound	Commercial Compound	High Performance Hydraulic
Modulus 100 % DIN 53 504	N/mm <sup>2</sup> 6,7	6,7	7,5
Tensile strength DIN 53 504	N/mm <sup>2</sup> 24,5	31,8	17,5
Elongation at break DIN 53 504	% 740	702	698
DMA Onset low temperature	°C -35,4	-29,9	-24,4
DMA Onset high temperature	°C 167,9	175,4	173,3

Table 2—Tensile test data at 110°C and onset temperature of DMA measurements

## Miller and Negri

### HIGHLIGHT SUCCESSFUL BSA CONVENTION

The Bearing Specialists Association (BSA) elected Linda Miller, Bearings & Drives, Inc., as president for 2012–2013. In addition to Miller, the following industry leaders were elected to serve BSA in 2012–13: James Webster, DXP Enterprises, Inc., as chairman of the board; Jack Simpson, Applied Industrial Technologies, as vice president; and Brian Negri, Jamaica Bearings Company, Inc., as treasurer. The elections were held in conjunction with the association's 2012 Annual Convention held April 29–May 1 at the Hyatt Regency Coconut Point Resort and Spa in Bonita Springs, Florida. BSA also elected the following industry leaders to serve three-year terms on the board of directors: Brian Davis, Bearings & Drives, Inc.; Mitch Bouchard, General Bearing Service Inc.; and Tom Arnold, Applied Industrial Technologies.



Linda Miller

Additionally, the BSA presented its 10th Lifetime Achievement Award to Peter Negri, president and CEO of Jamaica Bearings Company, Inc. Negri is a graduate of Boston College and the Amos Tuck School, the Graduate School of Business at Dartmouth College. The company that once employed 15 people at a single location in Jamaica, Queens, New York, now employs more than 135 people at locations in New York, Pennsylvania, Florida and California, with employees around the world, including Canada, Singapore, China, Italy, Great Britain, France and Australia.

Negri's involvement with BSA dates to his early years with Jamaica Bearings. He has chaired the Membership, Young Executives, and Manufacturer/Distributor Relations Committees, and after serving on the board of directors was elected president in 1986. Negri has served as BSA's convention chair a record four times. Beyond BSA, Negri has served his community as a village trustee, on various commissions, and in a number of roles to preserve the community's historic status. He supports Boston College as head of the Alumni Admissions Council for Long Island. Negri and his wife Kaye have been married for almost 41 years and are the proud parents of Brian, Liz and Christine, and they also have six grandchildren.

In a second presentation, BSA recognized Gus Kontonickas as an active BSA participating manufacturer for more than 20 years. Although he changed manufacturer "hats" more than once during that period, Kontonickas was steadfast in his support of BSA and the industry. Wearing his hats from Thomson and The Timken Company, he served on the Industry Communications Committee from 1989 to 1998 and the 1996 Convention Committee. He also served on the 2000

Convention Committee wearing his Loctite hat and then with NSK Limited, Kontonickas served on the Educational Services and the Long Range Convention Planning Committees from 2004–2008. He served on a third Convention Planning Committee in 2008.

## Danfoss

### WINS GLOBAL BUSINESS AWARD

Danfoss Power Electronics, a global provider of VLT drives and panels, was recently named the Silver Winner for the 2011 Global Awards for Excellence in Business Process Management (BPM) and Workflow. This prestigious award has been granted to industrial organizations since 1996, in recognition of their ground-breaking solutions leading to significant business benefits. The Awards Program is managed by Future Strategies Inc. and sponsored by *BPM.com*, Object Management Group and Workflow Management Coalition.

Danfoss Power Electronics received the award in the competitive North American region. The judges recognized the company's skilled management of interdisciplinary competencies with basic technology applications in order to springboard a process management program. As a result of the BPM project, the company significantly reduced workload in several areas; for one, the master data on shipping information, price



Martin Weightman, business application manager, and Debra Menge, customer service supervisor, accept the Silver Award for Excellence in Workflow, for Danfoss Power Electronics.

points, discounts and other variables is now far more accurate and no longer needs to be manually checked and entered, resulting in a 25–35 percent improvement in productivity for customer service personnel. The company also introduced a new, team-oriented culture aligned with the organization's value stream and developed a competency toolbox for process management.

This project was a result of an industrial research program between the two entities, aimed at solving business problems while advancing theoretical knowledge in the BPM area. Danfoss was nominated for the award by its research partner, Center for Industrial Production, Aalborg University, Denmark. For more information, visit [www.danfossdrives.com](http://www.danfossdrives.com).

## Fluid Power Industry

### GROWTH TREND

The latest data published by the National Fluid Power Association (NFPA) shows industry shipments of fluid power products for March 2012 increased 3.2 percent compared to March 2011, and increased 7 percent from February 2012 to March 2012. Mobile hydraulics, industrial hydraulics and pneumatics all showed growth in March 2012 when compared to March 2011. NFPA's industry reports, outlook surveys, forecasts, and data sources allow our members to understand trends and anticipate change with a variety of trend graphs and data analysis for fluid power products, customer markets, and economic indicators. For more information, visit [www.nfpa.com](http://www.nfpa.com).

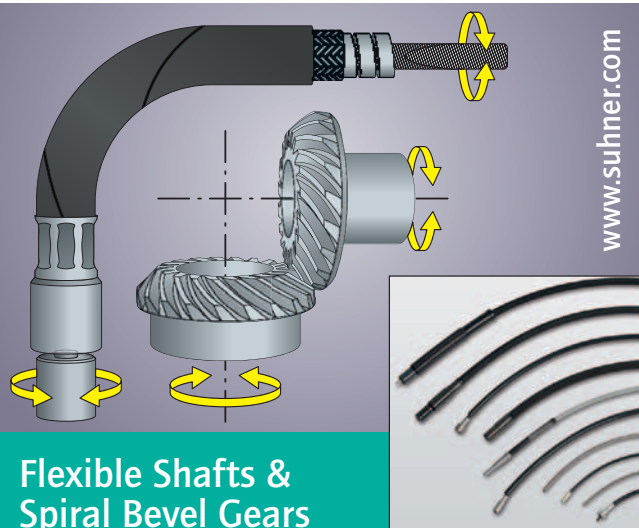
## PTDA

### WELCOMES NEW MEMBERS

The Power Transmission Distributors Association (PTDA) welcomed two new distributor members in the first quarter of 2012. Importadora Gutierrez, S.R.L. (Santo Domingo, D.N., Dominican Republic) was founded in 1979 to serve the needs of the Caribbean region's expanding agricultural industry. As customer needs evolved, so did the company's product offerings, which now include motion control products such as electric motors and frequency drives; PT components, such as gearing, bearings, belting and coupling products; and conveyor components. Although the company's main markets are the Dominican Republic and Haiti, it also fully services Central America and the Caribbean. Company general manager Ricardo Gutierrez said, "Through our PTDA membership, we are looking to expand our servicing capabilities by acquiring know-how from PTDA's training. We also hope to establish new, lasting relationships with customers searching for quality products and services in our region."

Werner Electric Supply Co. (Neeah, Wis.): A distributor with 11 branches throughout Wisconsin and Michigan's Upper Peninsula, Werner Electric Supply Co. is a wholesale distributor of products and services including industrial automation, lighting, electrical and data communication equipment, pneumatics and clean energy solutions. Founded in 1948, Werner Electric's multiple locations serve the electrical control needs of original equipment manufacturers, the maintenance and automation needs of industrial plants and

  
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## CORRECTION

In the April issue of *Power Transmission Engineering*, Eric Lanke, CEO of the National Fluid Power Association, was incorrectly identified as 'Erik' Lanke in the article "Hydraulics/Pneumatics Assessment." *Power Transmission Engineering* regrets the error.

—The Editors

commercial buildings, and the electrical needs of construction contractors. For more information, visit [www.ptda.org](http://www.ptda.org).

## Bauer

### OPENS ASSEMBLY PLANT IN CHINA

Bauer Gear Motor, part of Altra Industrial Motion, has announced the opening of its first assembly plant in China, a move to streamline the growth of localized sales and support in this expanding region. Bauer, located in Esslingen, Germany, is a European manufacturer of high-quality gear motors, offering engineered solutions to a variety of industries. As part of Altra, Bauer gear motors, including the new Series 2000, are available throughout North America. Contrary to moves by other companies, Bauer is not moving its core design and manufacturing to China. It is simply providing local availability of its products for customers that have already made the move to manufacturing in China in order to service the industrial growth in that region more efficiently. "This is one of the powerful advantages of now being part of the Altra group of global power transmission companies," says Jens Gabel, Bauer vice president global sales and R&D. "It has provided the opportunity for us to accelerate our growth plans and reduce delivery times with a large-scale assembly and distribution hub in China. This brings us closer to some of our core OEM cus-

tomers who are taking advantage of the growth in the Chinese market." Bauer gear motors are utilized in virtually every area of industry, from heavy-duty mining and marine applications to power generation, utilities, packaging machinery and many other niche sectors. Global strategic business areas include: basic metal (raw material processing and metals production); cranes, hoists & lifts, and food & beverage. For more information, visit [www.bauergears.com](http://www.bauergears.com).



Bauer Gear Motor is now providing products to the China market like the Series 2000 gearmotors (courtesy of Bauer).

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# Boston Gear

CELEBRATES 135 YEARS

This year Boston Gear celebrates 135 years in business, longer than such venerable companies as IBM, Coca-Cola, General Electric and Ford. It's been around longer than the light bulb, radio, movies, automobiles and the airplane. Boston Gear, part of Altra Industrial Motion, is a global supplier of quality power transmission products to most major industrial markets including food processing, packaging machinery and material handling. From its 193,000 square foot state-of-the-art manufacturing facility in Charlotte, North Carolina, Boston Gear offers a wide range of products. Many companies worldwide rely upon Boston Gear as their single-source supplier of motion control products.

Boston Gear was founded in 1877 as a small machine shop manufacturing gear-cutting machines. Early on, Boston Gear introduced the concepts of gear standardization and stock gears—innovations of enormous benefit to power transmission designers, specifiers and users. By 1929, Boston Gear was



established as the world's largest manufacturer of stock gears. Today, products like the new 2000 Series gear motors help Boston Gear maintain its position in the industrial field. And Boston's 700 Series speed reducers, available in both cast iron and stainless steel, have long been the industry standard for food processing and material handling applications.

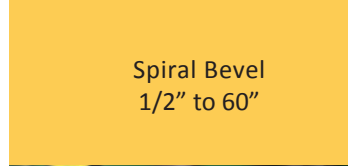
Boston Gear survived a national depression in the late 1800s, the Great Depression of the 1930s, numerous recessions, and several changes of ownership. And during World War II, the company worked round the clock, contributing to the U.S. war effort. In appreciation, the employees of Boston Gear were awarded the Army-Navy Production Award for high achievement in 1943.

More recently, Boston Gear has faced radical changes in the global marketplace. "Just 20 years ago we competed primarily with companies based in North America," said Vice President & General Manager Ed Novotny. "But now we face

## Bevel Gear Solutions



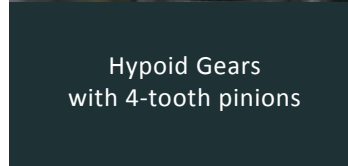
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competition from companies worldwide. This globalization has opened up many new opportunities for us.”

Carl Christenson, president & CEO of Boston’s parent company, Altra Industrial Motion, adds, “We’re an extremely customer focused company,” Christenson said. “Our associates are committed to satisfying the customer. We service the marketplace with above average industry performance standards in quality, delivery, and product innovation.”

## PTDA

### SEES STRONG GROWTH IN PT/MOTION CONTROL FIELD

The PTDA Business Index indicated that the first quarter was the eighth consecutive quarter for business growth among PTDA members, with a reading of 75.4. Compared with a reading of 67.3 for the 4th quarter of 2011, the recently released first-quarter results indicate the power transmission/motion control industry is expanding at a faster pace than before. Both distributors and manufacturers saw strong growth in the first quarter. [Note: The index reading indicates the rate of change compared with the previous period. For example, a reading of 50 indicates no change from the prior period while readings above 50 indicate growth and below 50 indicate contraction. The further the index is above or below 50 suggests a faster or slower rate of change.] PTDA members participating in the Business Index expect 2012 to be another year of growth with an average forecast of 11 percent, up from nine percent in the 4Q11 survey. For more information, visit [www.ptda.org](http://www.ptda.org).

PTDA Quarterly Business Index

	4Q2011	1Q2012
Business Activity	68.6	83.7
New Orders	72.8	80.8
Employment	65.9	74.4
Supplier Deliveries	61.9	62.5
Inventories	64.7	69.8
Prices	83.7	87.2
Backlog	55.8	66.3
Overall PTDA Index	67.3	75.4

## RIA

### ANNOUNCES FIRST CERTIFIED ROBOT INTEGRATORS

JR Automation, Motion Controls Robotics, Tennessee Rand, and Wolf Robotics are the first four robotic integrators to receive the new Certified Robot Integrator designation from the Robotic Industries Association (RIA), the industry’s trade group. “We are very excited to announce this first group of Certified Robotic Integrators,” said Jeff Burnstein, president of RIA. “In order to become certified, integrators go through a rigorous process which includes an on-site audit, safety training and hands-on testing of key personnel among other important criteria. Based on feedback from the industry, we believe that achieving certification will be valuable to integrators looking to showcase their capabilities and experience to users and suppliers alike. Additionally, the program allows integrators to benchmark their own processes against best industry practices, allowing them to identify areas in which they can improve. This also helps the industry by strengthening the overall integrator channel.”

The new RIA Certified Robot Integrator program was officially announced in late January at the Robotics Industry Forum in Orlando. Burnstein said several other integrators are in the process of becoming certified, with three already slated for audits in the next several weeks.

Each certified integrator will need to be recertified every two years. Detailed information on the certification program and the certified robot integrators can be found on a special section of [www.robotics.org](http://www.robotics.org).

“We feel the investment in this testing process is well worth the value it will provide to our customers,” says Bill Yeck, general manager, JR Automation. “The testing highlighted our ISO9001:2008 procedures; which we feel will ensure future success of our company. JR Automation believes this certification will help companies identify sources for automated/robotic equipment as well as supporting customers with their service needs.”

Scott Lang, president, Motion Controls Robotics, agreed. “At times it can be difficult to convey to a potential customer the depth of experience and qualifications of our organization. Achieving Certified Integrator status from RIA demonstrates our expertise and allows our customers to make a more informed supplier selection based on the findings of an independent third party. We are especially pleased to be among the first group of robotic integrators to earn this certification.”

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## Green Days

### Hannover Messe 2012 Focuses on Energy and Environmental Technologies

Hannover Messe 2012 generated enough buzz that the 5,000 exhibitors “will have their work cut out for them,” according to Dr. Wolfram von Fritsch, chairman of the managing board of Deutsche Messe. “Green technologies are a viable business model with the power to drive growth around the world. Industry has the solutions needed for achieving sustainability in manufacturing. And green technology can translate into higher profitability for industry.”

According to Hannover Messe personnel, one in four visitors stopped by the IndustrialGreenTec show in Hall 26 during the exhibition. The five-day event provided a ringing endorsement of the organizer’s efforts to align the event with the global megatrends of energy and environmental technologies, mobility and urbanization. “The new themes launched at Hannover Messe over the past several years are now at the forefront of interest and are energizing the entire show. This means that our long-term strategy is proving to be right on target,” von Fritsch added.

The exhibition also demonstrated that industry has embraced the outstanding opportunities created by the energy shift. “Industry has the expertise required; now it’s time to get moving on implementation,” he continued.

This year’s Hannover Messe further strengthened its position as an event for top-level decision-makers, he reported: “One out of five visitors was a CEO or company owner.” Professionals accounted for 95 percent of all attendees— a jump of five percent compared with 2008. “This mix of international participation, thematic excellence and high-caliber decision-makers defines Hannover Messe as the international bench-



The 1,040 exhibitors at the “Industrial Automation” trade fair presented a wide array of automation innovations for manufacturing and processing (courtesy of Hannover Messe).

mark for new business generation and networking in the industrial, government and research sectors,” von Fritsch added.

China as this year’s featured Partner Country showcased solutions for sustainable growth under the slogan of “Green + Intelligence.” “Here in Hannover, China has raised the bar for future Partner Countries a notch higher,” von Fritsch said. “The People’s Republic has presented itself as an equal partner and an important market and technology driver.” China’s presentation at Hannover Messe was its largest-ever industrial showcase at a foreign venue. The 500 participating Chinese companies were represented in all display sectors at the event. Prime Minister Wen Jiabao opened the event jointly with German Chancellor Angela Merkel.

Some highlights during the show included new products and innovations from companies like Bosch Rexroth and ABB and the third annual “vector awards” from Igus, offering cash prizes for technology advancements for energy chains.

#### Bosch Rexroth

Bosch Rexroth offered the Sytronix family, a combination of the company’s hydraulic pumps and electric drives at Hannover Messe. The Sytronix family provides many advantages, as the design engineer can integrate the ready-to-install, pre-configured solutions very easily and quickly in the engineering environment without having to deal with the details of programming. Additionally, Rexroth now offers new features with the IndraMotion MLC system solution for minimizing time and effort for design and commissioning. The drive and



With the control system IndraMotion MLC, Bosch Rexroth minimizes time and effort for design and commissioning (courtesy of Bosch Rexroth).

control manufacturer neutralizes specifics for the user through electrical components and software with integrated hydraulic application expertise. Rexroth's IndraMotion MLC equally controls—decentralized and centralized—hydraulic, hybrid, or electric axes. The control software comprises a wide range of predefined hydraulic control functions; therefore the parameterization of motion profiles does not require any hydraulics expertise. Rexroth is now intensifying that simplification approach for the design and assembly of fast I/Os in typical applications such as forming or metallurgy. For more information, visit [www.boschrexroth.com](http://www.boschrexroth.com).

### ABB

ABB launched its new generation 420kV Gas Insulated Switchgear (GIS) at Hannover. The new design reduces product volume by up to 33 percent (width × depth × height) compared to its predecessor resulting in a considerably smaller footprint. The compactness of the unit makes it ideally suited for installations where space is a constraint and also reduces the amount of SF6 insulating gas requirement by as much as 40 percent, making it more environmentally friendly. It is also designed to enhance resource efficiency by reducing thermal losses, lowering transportation costs and optimizing investment in infrastructure.

The new GIS can be factory assembled, tested and shipped as one bay in a container instead of multiple assembly units, saving site installation and commissioning time by up to 40 percent compared with traditional designs. Frontal access to drives, position indicators and service platforms enable easier operation, inspection and maintenance. Standardized modules and connection elements also enable flexibility in terms of configurations and building optimization.

The product features a fast single-interrupter dual motion circuit breaker and has been designed for current ratings up to 5,000 A. It is capable of providing protection to power networks with rated short-circuit currents up to 63 kA. "A compact and more user friendly design, faster on-site commissioning and lower environmental impact are some of the key features of this latest generation of Gas Insulated Switchgear," said Giandomenico Rivetti, head of ABB's High Voltage Products business, a part of the company's Power Products division. "The introduction of this 420kV GIS is part of ABB's ongoing technology and innovation focus and follows the recent launch of our advanced 245kV and 72.5kV versions." For more information, visit [www.abb.com](http://www.abb.com).

### Igus

Modern plastic energy chains ensure the safe supply of energy, data, pulses and operating media and are always in motion. They are suitable for multipurpose use in the crane and machine tool industries and in the robotics and clean room industries. Igus, a manufacturer of energy chain systems, cables and accessories, announced the results of the third global "vector award" competition during Hannover. The competition



During the five days of the show, a total of approximately 5,000 exhibitors from 69 different nations showcased their product innovations and solutions for industrial applications (courtesy of Hannover Messe).

jury included representatives from the automation association within the German central association for electrical engineering and industry (ZVEI), the tooling laboratory (WZL) of the RWTH Aachen and TÜV Rhineland. The winners received their awards at a special ceremony. The "vector award" is officially under the patronage of the Robotation Academy of the Hanover Industrial Fair. Winners in 2012 included Kuka Systems (gold), DEME (silver) and SCM (bronze). For more information, visit [www.igus.com](http://www.igus.com).

Overall, Hannover Messe was deemed a triumphant success. Planning is already underway for the next show that will be staged from April 8–12 2013. "More than 600 companies have already submitted their registrations for Hannover Messe 2013. Over the past few days many of them have even inquired about the possibility of booking bigger stands next year," von Fritsch added. "So next year's event is likely to fill the entire trade fair complex in Hannover." For more information, visit [www.hannovermesse.de](http://www.hannovermesse.de).

# calendar

## June 18–20—10th Shenzhen China International Small Motor Exhibition and Electric Machinery Exhibition.

Shenzhen Convention and Exhibition Centre. The tenth installment of this trade show features forums, general assemblies, product conferences and technology seminars taking place in eight exhibition halls. Co-located events include the International Magnetic Materials and Equipment Exhibition; the International Magnet Wired Insulating Materials Exhibition; International Electronic Equipment, Components, Photonics and Laser Exhibition; and the 18th China International Power Supply Exhibition. Exhibits cover a broad scope including motor technology, test equipment, manufacturing apparatus, parts and auxiliary products, motor control systems and devices, servo systems, digital control devices, frequency converters, switch devices and more. For additional information, visit [www.motor-expo.cn/en/dj.asp](http://www.motor-expo.cn/en/dj.asp).

## June 19–20—International VDI Congress Drivetrain for Vehicles 2012.

Friedrichshafen, Germany. Sustainable driving, lower CO<sub>2</sub> consumption, a paradigm shift towards electromobility: the automotive industry has some difficult demands to satisfy. Vehicle transmission developers and users will be gathering at this important industry meeting-point now in its tenth incarnation. The conference will be directed by Dr.-Ing. Hans-Joerg Domian, director of new products and methods, design tasks, ZF Friedrichshafen AG. Opening papers tackle the subjects of the future of driveline development, potential CO<sub>2</sub> savings and the role of electrification as well as electromobility. Alongside future-oriented transmission components for electric and hybrid vehicles, the program will also include current developments in the fields of double-clutch and automatic transmissions, manual transmissions and all-wheel drives, efficiency, components, materials and production engineering as well as clutches and operating strategies. The machines section is entirely new: here attendees can learn about, for example, technical trends in agricultural machines, new developments in construction machinery drives, infinitely variable power take-off drives or improvements in the ease of gear shifting. For more information, visit [www.transmission-congress.eu](http://www.transmission-congress.eu).

## June 23–27—National Leadership and Skills Conference (NLSC).

H. Roe Bartle Hall Convention Center, Kansas City. The National Leadership and Skills Conference (NLSC) boasts 16,000 high school and college students that meet key decision-makers in vocational-technical and school-to-work education and leaders from business and industry. SkillsUSA TECHSPO is held in the midst of the SkillsUSA Championships, where 5,400 students, America's best entry-level workers, compete in 96 hands-on skill and leadership contests. On the cutting edge

of technology, these contests are run with the help of industry, trade associations and labor organizations. And it's all open to the public. SkillsUSA TECHSPO includes a Career Fair, where students and company representatives can exchange information and talk about employment opportunities. For more information, visit [www.skillsusa.org](http://www.skillsusa.org).

## June 25–28—Siemens Automation Summit 2012.

Washington D.C. The theme of this year's Summit, "Community. Experiences. Productivity," builds upon the "wingman concept," as the event will cover the complete spectrum of automation—from process and discrete to motion control and drives. The Summit will feature Version 2.0 of the popular Connect Event, where attendees can network in-person and virtually with Siemens employees, solution providers, integrators, distributors and end users. Siemens will offer hands-on training sessions, featuring work stations with equipment, led by technical experts, and will provide updates on recent product enhancements, including the *Totally Integrated Automation (TLA) Portal, Simotion Version 4.2*, and the recently released *PCS 7 Version 8*. Certificates will be distributed to those individuals completing training courses, which may then be submitted for professional development hours. Classes may include firewalls in automation security, automation with Siemens, programming safety logic using safety matrix, energy management using intelligent motor control solutions and others. More than 40 breakout sessions are scheduled featuring best practices and topics such as energy and asset management, improving productivity through the application of automation technology, maintenance and operations, novel approaches to problem resolution and safety and industrial security. For more information, visit [www.usa.siemens.com/summit](http://www.usa.siemens.com/summit).

## June 26–29—Expo Pack Mexico 2012.

CentroBanamex, Mexico City. Expo Pack will showcase the latest solutions in packaging and processing machinery, materials, containers and other related goods and services. It offers direct access to the packaging and processing industries in Latin America, attracting buyers from throughout the region, including professionals from the food, beverage, pharmaceutical, personal care, graphic arts, medical, chemical and automotive industries. Expo Pack Verde, returning for a third year, will display sustainable packaging technologies, and the Procesa pavilion will feature the latest developments in processing machinery and technology. The Containers and Materials pavilion will include innovations that increase visual impact, enhance convenience and maximize shelf life. For more information, visit [www.expopack.com.mx](http://www.expopack.com.mx).



### August 6-9—CAR Management Briefing Seminar.

Grand Traverse Resort and Spa, Traverse City, Michigan. The Center for Automotive Research (CAR) presents its traditional summer gathering for the automotive industry. This year's scheduled sessions will focus on global manufacturing strategies, tooling technology, money matters, surviving the skills shortage and many more. The briefing seminar is a networking opportunity for manufacturers and suppliers, purchasing and marketing executives, energy representatives, financial analysts, government and education representatives, information managers, labor leadership, media members and plant managers and superintendents to share thoughts on the changing automotive industry. Speakers include Joseph Bakaj, vice president, powertrain engineering, Ford Motor Company, Jay Baron, president and CEO, CAR and Erik Berkman, president, Honda R&D Americas Inc. For more information, visit [www.cargroup.org](http://www.cargroup.org).

### August 27-30—Power Transmission Principles.

Indianapolis. IDC University's Power Transmission Principles course (PTP) is a four-day intensive study into the world of power transmission. PTP provides students with confidence in themselves, their company and the power transmission products they represent. This course is designed for inside and outside sales people from beginners to seasoned employees. Throughout the course, major power transmission products are displayed, discussed, and selected until each student knows how and why specific products help their customers. For more information, visit [www.idc-usa.com](http://www.idc-usa.com).

### September 10-15—IMTS 2012.

McCormick Place, Chicago. The 29th edition of the manufacturing technology show boasts more than 1,100 exhibiting companies that will occupy 1.1 million net square feet of exhibit space. The show attracts 82,000 buyers and sellers from more than 116 countries. Leading manufacturers will display their equipment in pavilions including Metal Cutting, Tooling and Workholding Systems, Metal Forming and Fabricating/Laser Processes, Gear Generation, Industrial Automation and many more. The IMTS 2012 Conference brings the industry together, under one roof and at one time, to discuss revered technologies, business development and optimization, plus workforce efficiency and productivity. Special emphasis will be placed on maintaining focus on short- and long-term goals during a tough economic environment. For more information, visit [www.imts.com](http://www.imts.com).



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# The Painful Birth of the DC Electric Motor



Defined in rudimentary terms, an electric motor is a device that uses electricity to create mechanical force. But in 1834, when our story takes place, most people would have trouble understanding the ramifications.

That was the year that one of the earliest DC electric motors was invented—by a blacksmith. It's true. Thomas Davenport (1802–1851), a Vermont smithy, constructed the first American DC electric motor. He went on to produce literally hundreds of motors.

One of a dozen siblings—his father died when he was 10—at age 14 Davenport began serving a seven-year indentureship for a local blacksmith. His indentureship completed, in 1823 Davenport settled in Brandon, Vt. and opened his own blacksmith shop.

The genesis of Davenport's curiosity in electricity and magnetism was news that a nearby ironworks was using a new method for separating crushed ore. Developed by Joseph Henry, it used magnetized spikes secured to a rotating, wooden drum that attracted the purest of the iron content from the crushed ore. As it happens, this was quite timely in that the expansion of the railroads was spiking the need and demand for quality iron.

His interest piqued by the news from the ironworks, the uneducated Davenport read everything he could find on electricity and magnetism. Lacking money, Davenport asked his brother, a drummer, for help. They proceeded with a fire sale of sorts in that they unloaded most of the brother's wares, conducted some further horse trading, and secured enough money to buy one of the electromagnets.

Back in his shop, Davenport eagerly deconstructed the magnet as his wife, Emily, recorded each step. He then started his own experiments, building two magnets of his own design. One problem: insulated wire was required, but there wasn't any. Problem solved—Emily cut up her silk wedding dress into strips—you just can't make this stuff up—to provide the insulation required for maximum windings.

The electricity source used was what was known as a "three-cell Grove battery."

Davenport mounted one magnet on a wheel; the other was fixed to a stationary frame. The two magnets powered the rotor to turn one-half revolution. He then discovered that by reversing the wires to one of the magnets, the rotor would rotate another half-turn. Next, he devised what is now commonly known as a brush and commutator. Wires from the frame supplied current to a segmented conductor, thus supplying current to the rotor-mounted electromagnet. The result was reversal of the polarity of the rotor-mounted magnet—twice-per-rotation—resulting in non-stop operation.

The motor was capable of powering equipment in Davenport's shop, but he was looking beyond horseshoes. He sought to find a power source for railroads that could replace the steam locomotive, which at that time suffered frequent, deadly boiler explosions.

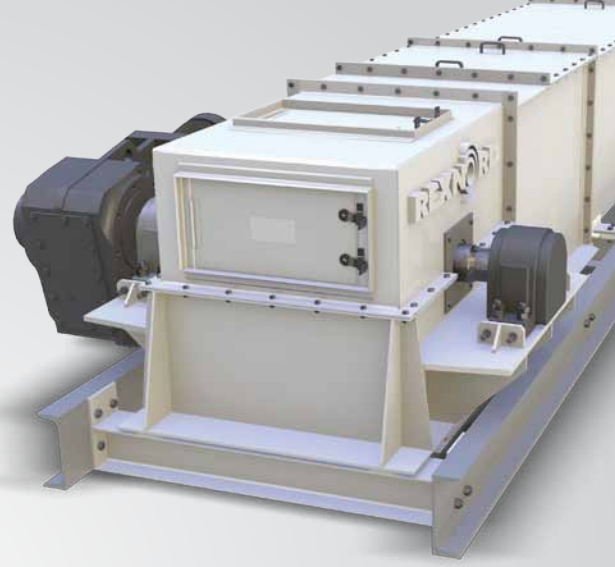
Davenport's solution: an electric locomotive. He even demonstrated it with a small-gauge model train car on a short section of track, thus anticipating—knowingly or not—the electrification of passenger transport; e.g., streetcars. The "train" operated on a circular track with power supplied by a battery fixed to the locomotive and using the rails as conductors to transmit the electricity. Encouraged, Davenport traveled to Washington to obtain a patent. His application was rejected, due largely to ignorance of electric equipment (evidenced by the fact that there were no existing patents for electrical machinery of any type).

But the scientific community and the media responded—with enthusiasm. Benjamin Silliman, founder of *Silliman's Journal of Science*, wrote that "A power of great but unknown energy had unexpectedly been placed in mankind's hands." The *New York Herald* reported it with practically transcendental fervor: "The occult and mysterious principle of magnetism is being displayed in all of its magnificence and energy as Mr. Davenport runs his wheel."

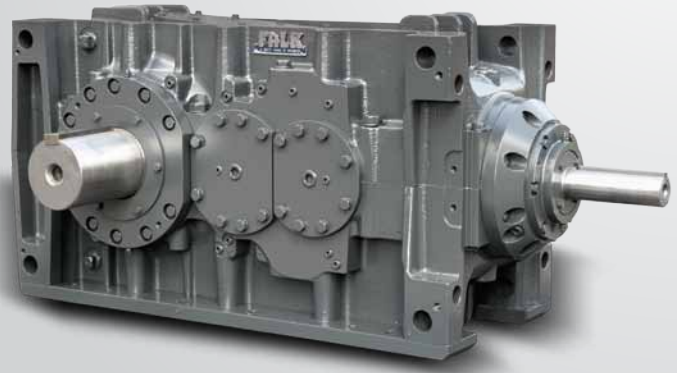
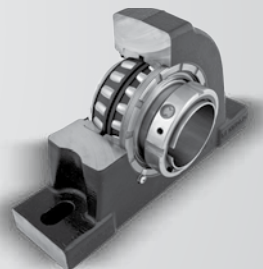
Encouraged anew, Davenport returned to the patent office, armed this time with testimonials and—most importantly—a working model. Alas, the model was destroyed by fire before examination. He built yet another. Finally, in 1837 the first patent on any "electric machine" was issued to Davenport for his electric motor.

The motor was a technological success—and a dismal commercial failure. Just like the folks at the patent office, there was then a dearth of knowledge of how, for example, to predict energy strength in a chemical battery. But most of all, battery-powered motors could not begin to compete with steam engines. Funds were promised him, which were unfulfilled, so Davenport retreated to Vermont with hopes of writing a book on his work and vision for his electric motor. He died broken—financially and in spirit—in 1851 at the age of 49, his book never completed.

On a happier note, there is a patent office model of Davenport's motor in The Smithsonian Institution. (Sources: "The Inventions of Thomas Davenport," by Franklin L. Pope—*Transactions of the American Institute of Electrical Engineers, Vol. 8, 1891*; *edisontechcenter.org*; "The Blacksmith's Motor," by Dr. Frank Wicks—*Mechanical Engineering magazine, July 1999*.)



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