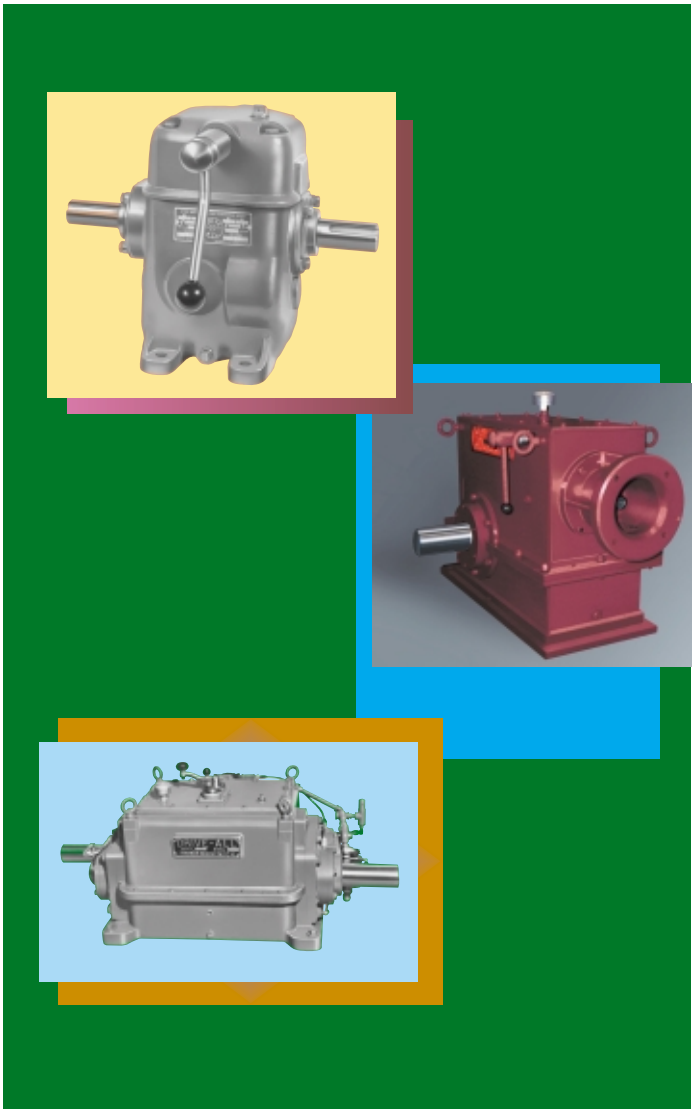
Understanding the Application: A Key to Economical Gearbox Purchases

Charles D. Schultz, PE



Above photos courtesy of Drive-All Manufacturing Co. of Harbor Beach, MI.

ON A HIGHWAY, A COMPACT PICK-UP TRUCK STRUGGLES TO TOW A 30-FOOT BOAT UP A STEEP GRADE. INSIDE THE PICK-UP, THE OWNER CURSES HIMSELF. HE SAVED MONEY LEASING A SMALLER TRUCK BUT SEES NOW THAT HE REALLY NEEDED A BIGGER, PRICIER VEHICLE, ONE SUITABLE FOR THIS JOB.

In industry, a buyer/specifier of gearboxes faces situations every day in which he must weigh the price of a unit against its suitability for an application. He also needs to avoid the truck owner's mistake; his choices will last a lot longer than a 36-month lease. So he has to carefully consider the long-term needs of his application. To make a successful choice, a great gearbox at a fair price, the buyer needs to take the time to prepare a complete and accurate specification before sending out requests for quotes.

Various trade and technical associations have done a good job of developing specifications for some applications. If a buyer's equipment must comply with API, AGMA, AISI or similar standards, he'll find most of the hard work has already been done. Still, if he hasn't reviewed the current versions of these standards, then he might be surprised at what is or isn't "in there" today. Technical, regulatory, and legal requirements change over time and more than one buyer has found out too late that "they don't make them like they used to."

In the absence of an established third-party specification, a buyer has to know the gearbox requirements for his application and has to be able to describe them to possible suppliers. For critical equipment, the buyer may want to engage a consulting engineer familiar with his industry to develop a custom specification, identify qualified suppliers and evaluate their responses.

Regardless of how a buyer creates a specification, it should address the following questions:

1. What's the application?
2. What's the prime mover?
3. What's the duty cycle?
4. What are the external connections?
5. What's the desired service life?
6. What's the operating environment?
7. What quality assurance system does the supplier use?

These questions and their answers influence the gearbox that will be provided for a specific project. Getting the right gearbox involves more than meeting a target service factor. Certain applications, for example, have typically been served by specific types of gears for reasons that may not be readily apparent to a new buyer/specifier of gearboxes.

A buyer needs to know and be able to describe an application in detail. He needs to provide a framework for identifying key elements that will make a "traditional" gearbox successful and for evaluating proposals that may seem a bit out of the ordinary.

A good example of a non-traditional gearbox that wasn't right for its application: the initial failure of carburized and hardened gearboxes from the late 1970s/early 1980s that were used in pumpjack service. Demand for pumpjacks was booming and was being met as much as possible, as fast as possible via the manufacture of through-hardened double helical and herringbone gears.

Buyers, however, needed so many gearboxes that they sought new sources to meet the supply crunch, and a European company was ready with modified versions of its very successful carburized parallel shaft reducers. The "new" drives easily met the service factors established over the years with much smaller, lighter, and less costly packages. The "old style" boxes were roughly the size of an office desk, their replacements were closer to the size of an extra large suitcase.

Unfortunately, the new reducers couldn't accommodate the extreme cyclic loading of the familiar "rocking horse" pumpjack mechanism. There was nothing intrinsically "wrong" with carburized and hardened gearing in a cyclic load situation. Careful consideration of the system dynamics, however, could have prevented the failures and saved lots of time and money. The application needed every bit of the higher strength capacity built into the through-hardened gears. Once the carburized reducers were selected for similar strength service factors, they were

CHARLES D. SCHULTZ IS CHIEF ENGINEER AT BRAD FOOTE GEAR WORKS INC., LOCATED IN CICERO, ILLINOIS, NEAR CHICAGO. IN THE GEAR INDUSTRY SINCE 1971, HE CURRENTLY DESIGNS CUSTOM GEARBOXES AND MODIFIES STANDARD ONES, BOTH FOR INDUSTRIAL APPLICATIONS. HE'S ALSO OVERSEEN THE REPAIR AND REFURBISHING OF SEVERAL HUNDRED GEARBOXES FROM MANY DIFFERENT MANUFACTURERS. SCHULTZ IS AUTHOR OF THE BOOK *AN INTRODUCTION TO GEAR DESIGN* AND OF THE TECHNICAL PAPER "GEARBOX FIELD PERFORMANCE FROM A REBUILDER'S PERSPECTIVE," PRESENTED AT THE 1999 AGMA FALL TECHNICAL MEETING.

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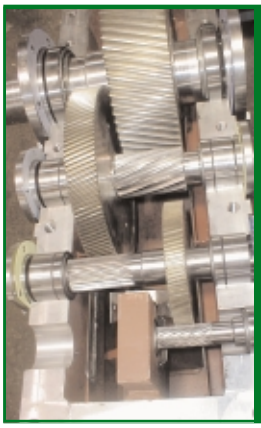
used successfully in pumpjacks. The new specification, however, increased their size and brought their overall costs closer to the traditional gearboxes.

Today, through-hardened gears remain in strong demand for pumpjacks.

Changing technology may occasionally make it worthwhile to investigate "new" approaches to a problem, but a buyer needs to make certain that innovators prove the suitability of their gearboxes for his particular application.

Likewise, the buyer needs to know and communicate aspects of a common application that his company is doing in new or different ways. Without such knowledge, he and his supplier can't adjust properly while selecting a gearbox.



1. WHAT'S THE APPLICATION?
2. WHAT'S THE PRIME MOVER?
3. WHAT'S THE DUTY CYCLE?
4. WHAT ARE THE EXTERNAL CONNECTIONS?
5. WHAT'S THE DESIRED SERVICE LIFE?
6. WHAT'S THE OPERATING ENVIRONMENT?
7. WHAT QUALITY ASSURANCE SYSTEM DOES THE SUPPLIER USE?

The pumpjack example illustrates a key point in defining the intended use of a gearbox: System dynamics, the relationship of tooth load to position in the rotational cycle, must be understood to properly specify a gearbox. Specifying isn't just a horsepower/speed/ratio problem. The pumpjack's mechanism consistently put a high peak load on the same spot on the gear. This load put a premium on tooth strength.

Other applications may place a premium on positional accuracy. Still other devices, notably multi-cylinder pumps, could have several peak loads during a rotational cycle. Also, batch processing equipment may have a load profile that changes over the course of operation because of work done to the raw material. A buyer needs to know about these dynamics and describe them to suppliers so they can use their experience with similar devices to tailor a gearbox to match a buyer's application characteristics.

Following directly from system dynamics is the prime mover. A buyer should understand the prime mover to be used in a particular application. It makes a difference whether the prime mover is a fixed-speed electric motor, a variable-speed AC drive, or a variable-speed DC drive. It also makes a difference whether the AC or DC drive is computer-controlled. The advent of computer-controlled, variable-speed drives makes it possible for companies to fine tune their processes to a degree unheard of even five years ago.

A buyer needs to specify the prime mover because, in the case of the computer-controlled drives, gearbox suppliers would have to discard many assumptions from their experience with the non-computer-controlled drives. For example, they couldn't simply assume 200% starting torque and move on to the next question. The computer-controlled drives, their torque diagrams and acceleration curves require close attention, as do their dynamic braking characteristics. Also, internal combustion engine drive packages behave differently since the adoption of computer controls, and suppliers have to rethink many long-held assumptions concerning their use, too.

Computers also affect another aspect of gearbox specification: the definition of the duty cycle. Duty cycle isn't just how many hours per day the equipment will be run or how many starts-per-hour can be expected. Sophisticated data logging devices make it possible to determine just how many rotational cycles will be run at specific load levels and speeds. This technology has helped improve reliability in many applications, most notably wind turbine gearboxes, where even a few "spikes" over the design peak loads can result in greatly shortened service life. If a company is embarking on a major redesign of a product or an upgrade to an existing process line, the company's buyer might want to obtain an instrumented test of the current setup. As an alternative, he could have a consulting engineer familiar with similar equipment prepare an estimated duty cycle for inclusion in the gearbox specification.

In some cases, typical duty cycles have been published in academic papers or trade association standards. Duty cycle information allows a supplier to perform a "Miner's Rule" calculation on

the gears to estimate their life expectancies. Similar techniques are applied in the calculation of bearing L-10 life.[1]

Bearings are a key reason that buyers need to know the external connections of their systems. Different types of couplings transfer misalignment forces to the shafts in different ways. Some bearing arrangements, particularly plain or babbited bearings on high-speed drives, are very sensitive to externally caused misalignments. Some coupling designs dampen torque fluctuations in the system to the benefit of the gears and bearings. Other couplings reduce the peak loads seen at start-up. In some cases, the weight of the coupling itself must be considered in evaluating bearing life.

There are many different types of couplings offered for commercial sale and each one has unique characteristics that can affect a gearbox. So a buyer needs to select the couplings for his gearbox or needs to know what effects he wants and doesn't want so his supplier may recommend a specific type of coupling.

Service life is a key assumption in every gearbox design but is seldom disclosed in a manufacturer's catalog. Thirty years ago, gear capacity was calculated based on allowable stresses being unchanged after the gears were used for 10 million cycles. This was less than a year's service for a 1,750 rpm shaft. In the years since, the gear industry has learned a lot about long-term serv-ice, and AGMA life curves no longer flatten out. Most new enclosed drives are designed around 10,000 hours of life at a 1.0 service factor. This is a far more reasonable value for industrial service but probably not conservative enough for very large drives that may be used for 40 or 50 years. Consequently, a buyer might want to specify 20,000 hours for most custom drives and 100,000 hours on very large units that will be grouted into place.

On the opposite side of this issue are applications where it's known that the gearboxes will be used for a very short period of time, operated only intermittently, or are expected to be replaced frequently. Designing for short service life is perhaps a more challenging task than getting equipment to last because of the size, weight, and cost constraints typically imposed. Regardless of the application, however, a buyer should know what design life to specify.

He should also ask suppliers what options they have that might be best suited to the equipment's operating environment. Beyond the usual question of ambient temperature range (which affects a gearbox's thermal rating and resulting accessories), the buyer should know about his application's exposure to the elements, including dust, sunlight, and chemical vapors. Access to the units for routine maintenance, such as oil and filter changes or gear inspection, is also important. Special paint treatments, seal materials, seal arrangements, or lube system accessories are relatively inexpensive to add when the equipment is designed but very costly to retrofit.

Options are a key area in evaluating competing bids because a buyer may find some suppliers insisting on including certain options while others may include only what is absolutely required by the specification. Initial cost saving can quickly disappear if changes have to be made after the order is placed or the equipment is delivered. For example, a buyer once purchased several gearboxes for his mill, which was built under strict requirements for automated equipment monitoring. In several process lines, each gearbox was fitted with a sensor to prevent start-up if the oil level was too low. A neighboring line was equipped with a gearbox that had no sensor. Predictably, it was the only burned-out gearbox from the commissioning process. The same day as the burnout, a very angry maintenance manager placed a rush order for oil-level sensors.

As with motor vehicles, gearbox "quality" can be judged by a variety of standards. Dimensional accuracy, material cleanliness, heat treat consistency and component robustness are critical to long-term performance. Unless the gearbox being purchased is straight out of a supplier's catalog, buyers are wise to ask about the quality system in place at the manufacturer's facility and what acceptance tests are performed. Some buyers feel most comfortable requiring bidders to comply with ISO 9000 requirements. Others prefer a more hands-on approach and want to witness the final tests. If a project has specific quality requirements (such as material certification, load tests, or lost motion checks) they can greatly affect cost and lead time. To avoid unpleasant surprises, the buyer is wise to address these requirements directly in the product specification. In the case of standard out-of-the-catalog gearboxes, buyers could do worse than follow the old Packard slogan: "Ask the man who owns one!" Successful manufacturers don't feel threatened by a potential customer asking for references.

Like the guy choosing between a larger truck and a smaller one, no buyer wants the wrong gearbox for his application. So a buyer should start his selection process with a detailed understanding of the application.

For more information, contact the editors at:
Gear Technology
1425 Lunt Ave.
Elk Grove Village, IL
60007
Phone: (847) 437-6604
Fax: (847) 437-6618

Or contact the author via the Internet at:
chucks@bradfoote.com
www.bradfoote.com

[1] L-10 life refers to the number of hours at which 10% of the bearings will have failed. Average life is represented by L-50 and is assumed to be five times the calculated L-10 life.