

■ Cooper Compression's redesigned C-Force compressor is especially well suited to compressed natural gas (CNG) applications because of its small footprint, light weight and innovative tandem cylinder offerings.

THE REINVENTION OF THE SUPERIOR C-FORCE COMPRESSOR

*Cooper Compression's Aggressive Redesign
Based on Customer Input*

By Phil Burnside

The last 18 months have been busy for Cooper Compression as new product developments continue to roll out of Houston, Texas, U.S.A., with a regularity that could only be dreamt of by many manufacturing firms. During that period, the company has introduced a new integrally geared centrifugal fuel gas booster in the MSG Alpha (COMPRESSORTech™ June 2004) and a completely new frame design in the Axis reciprocating compressor (COMPRESSORTech™ April-May 2005). The company also unveiled a significantly updated version of its Superior compressor products, which are targeted to the CNG and gas transmission markets. In addition, the company has made significant enhancements to its venerable Ajax integral compressor line and opened a new call center that enables company employees to answer inquiries on a 24/7 basis for its aftermarket customers.

Earlier this year Cooper also, and without a great deal of fanfare, released a redesigned version of its balanced, couple-free C-Force reciprocating natural gas compressor for the compressed natural gas fuel market.

Meeting the company's aggressive launch goals for new and redesigned products and other initiatives presented challenges, according to Bob Rajeski, president of Cooper Compression (COMPRESSORTech™, January 2005), but he said that the company's successful achievements are a direct result of the synergies achieved through the merger of the Cooper Energy Services and Cooper Turbocompressor businesses.

"We also continued our focus on utilizing Six Sigma technology to improve our performance and customer satisfaction," he said.

Part of the new product development process at Cooper involves collecting data from customer surveys to identify their likes and dislikes about the company's products and reciprocating compressors in general. That

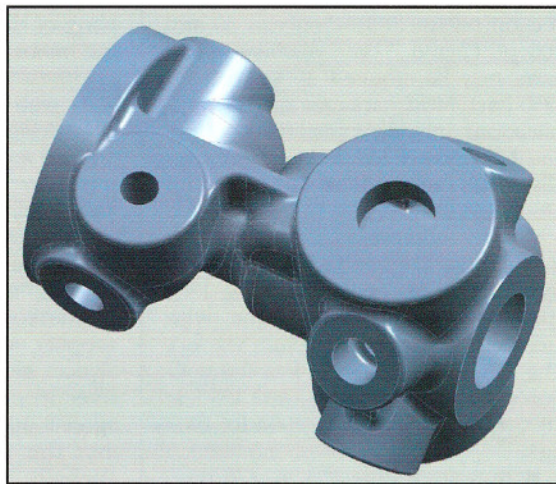
data is then filtered through a Six Sigma tool known as Quality Function Deployment (QFD) to determine its validity and importance. The end result is a prioritized summary of the collected data.

During discussion of Cooper's original C-Force compressors, customers said they liked the couple-free, low vibration design that had been achieved by incorporating opposed connecting rods, and that made the C-Force ideally suited to compressed natural gas applications. The design was also well suited to offshore applications in which much of the engineering time in developing platforms revolves around reinforcing the structure to take vibration moments into account.

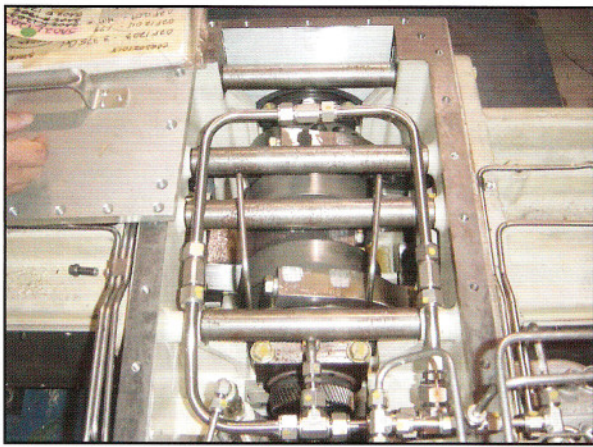
They did, however, identify limitations in the existing cylinder offerings and other design features. The moment-free design was easy to package they said, but they also indicated that a lack of tandem cylinders put limits on useable suction pressures.

Cooper's answer was to develop new tandem cylinders that enable higher pressure ratios to be achieved in fewer crank throws while offering much easier maintenance by permitting the pistons to be serviced from the outside while the cylinders remain attached to the frame.

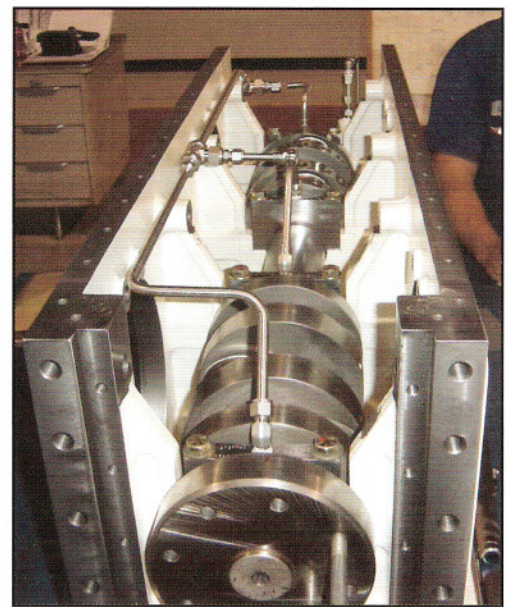
The new C-Force design continues to utilize connecting rods that lie directly across from one another, rather than the more conventional staggered configuration. In a C-Force compressor, one piston is supported by a single, wide connecting rod. The opposing piston is supported on two narrower connecting rods attached to



■ A new tandem cylinder design locates the larger piston on the head end of the cylinder, with the smaller bore piston on the inboard, or crank end, of the cylinder, which allows both pistons to be removed without removing the cylinders and associated interconnecting piping. Cylinder design made outstanding use of solid modeling, according to the company.



■ Superior engineers redesigned the lube system to incorporate drilled passages within the compressor frame and utilizing bent tubing to feed the oil passages, thus eliminating dozens of fittings and potential leak points. The new design is shown here on the right; the old design is illustrated on the left.



the crankshaft on either side of the wide connecting rod. This directly opposed cylinder arrangement eliminates the force-couple or moment created by the conventional piston rod arrangement. Eliminating those moments eliminates the need for a massive base plate and foundation support, and helps the machine run more smoothly and with less apparent vibration that would otherwise be the case.

Customers' need for a new line of tandem cylinders presented a challenge. But successfully meeting that challenge would enable up to two stages of compression on a single throw using both a small and a large piston on a single connecting rod, with each piston residing within its own chamber. Thus, an application requiring four stages of compression could economically be satisfied with a two-throw compressor frame.

The higher stages of compression are needed in CNG applications because of the large pressure differentials commonly involved. While typical suction pressures are between 30 and 100 psi (2 and 7 bar), discharge pressures may be required up to 3630 psi (250 bar). Most packages for CNG applications include interstage cooling, and horsepower requirements are usually small, ranging from 100 to 180 hp (75 to 134 kW).

C-Force compressors come in two models. The C-Force 32 is a two-throw frame rated 290 hp (216 kW) at 1800 rpm. The weight of the frame, with crosshead guides, is 1200 lb. (544 kg). The second version is the four-throw C-Force 34, rated 580 hp (432 kW) at 1800 rpm. Its weight is 2000 lb. (907 kg).

Both units feature a 3 in. (76 mm) stroke with a rod diameter of 1.125 in. (29 mm) and internal tension and compression values of 13,000 lb. (58 kN), net rod loads of 11,000 lb. (49 kN) and total peak-to-peak load of 21,000 lb. (93 kN). Piston speed at 1800 rpm on

both models is 900 fpm (4.57 m/s), and lube oil flow is 10 gpm (38 L/min). Sump capacity of the C-Force 32 is 4 gal. (15 L), while the C-Force 34 holds 10 gal. (38 L). Both models are operable between 850 and 1800 rpm.

According to John Bartos, Cooper's vice president of engineering and new product development, one innovative design feature of the new tandem cylinder line is the location of the high volume stage within the tandem cylinder. In the new cylinder design, he said, the larger piston is located on the head end of the cylinder, with the smaller bore piston being located on the inboard, or crank end, of the cylinder. This arrangement benefits both assembly and maintenance, because both pistons can now be removed without removing the cylinders (and associated interconnecting piping) from the machine's frame.

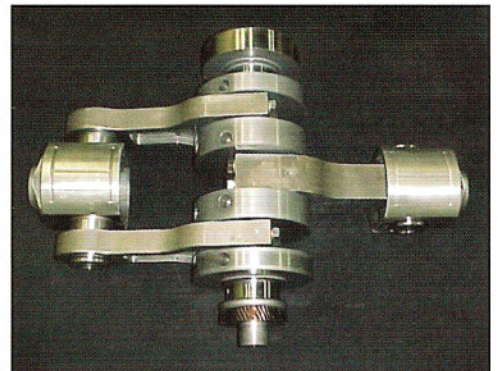
The new C-Force compressor frame also features a bell-housing mount design that permits direct close coupling of the driver, whether it is electric motor or 1800-rpm engine, to the compressor.

As with virtually all of Cooper's recent design work, the C-Force team applied solid models to develop computer prototypes and worked with casting suppliers to achieve quick realization of new designs. The initial cylinder design was modeled on the computer and simultaneously fed to a casting supplier, and the engineering analytical group. Through an iterative process, all of the teams agreed upon a final design that met the ideal parameters for strength, weight and castability. The end result was a first article casting that was acceptable on first pour and effortlessly passed through all quality checks.

Customers identified the compressor's lubrication system as

one candidate for improvement to the existing design. They wanted a design that would make the lube system simpler, more reliable and less prone to leakage. Superior engineers redesigned the oil system to incorporate drilled passages within the compressor frame and utilizing bent tubing to feed the oil passages. Those changes resulted in the elimination of dozens of fittings and potential leak points, and a much cleaner, easier to assemble and maintain design, the company said.

"In the end," explained Bartos, "all of these changes may or may not have come about if we had followed the classical engineering-driven model of new product development. But, by meeting one on one with our customers, surveying their opinions and then sharing that information throughout the teams established to meet their needs, the ideal products were developed in less than one year after the first meeting was held in a customer's office." ■



■ The heart of the C-Force balanced, couple-free compressor is the crankshaft arrangement, shown above.