DOING THE HEAVY LIFTING

How modern cranes make the lifting of colossal construction loads possible By Virginia Hughes

"Graceful" may be the last word you'd think of to describe the elements of a typical building construction site: jagged chunks of raw material; piercing noises; flying debris; rough-and-gruff construction workers. Perhaps the one exception—poised well above the fray, like the bird that shares its name—is the crane.

Hundreds of thousands of construction cranes are used throughout the world—for assembling heavy manufacturing equipment, for unloading freight from cargo ships and, of course, for building.

A replica of a crane originally built by the Romans, noted for their innovative engineering achievements, now stands in Bonn, Germany, above.

Tower cranes are used to transport heavy loads to the top of ever-rising construction projects. Below, a crane lowers rebar as construction workers guide it into position.

Major cities are prime nesting grounds for many of the world's construction cranes. More than 125,000 tower cranes are in operation throughout the world, and industry experts cautiously estimate that 15 to 25 percent of them are in use in the city of Dubai, according to a report from the organizers of the Conmex construction machinery exhibition and *Gulf News*. New York City's Buildings Department estimates that 175 tower and mobile cranes are in use there on any given day.

But, the same is true for less populated regions. "It's not unusual to go into a small crane rental company and see 30 to 40 cranes that they rent to just that local area," says Matt Burkart, a civil engineer and president of Aegis, Corp., an engineering consulting firm in Southampton, Pa.

"Even on small sites, three- to four-story buildings, cranes are used quite frequently," he says. "And you can't build a high-rise without a tower crane."

The world's largest cranes can lift as much as 19 tons (38,000 pounds). But that's not, by any means, an upper limit. "If you need something bigger, you can make it,"

says Richard Smailes, professor of building construction at the University of Florida. "It's not a complicated process. It's all just a matter of leverage."

HISTORY

Crane design and operation is not a rapidly changing technology. "You're looking at an ancient technology that hasn't changed in thousands of years," says Smailes. "The physics involved in lifting something hasn't changed, nor has the way we've gone about it."

Historians trace crane technology to the ancient Greek civilization, as far back as the sixth century B.C. Before that, the large, unskilled labor force that constructed buildings pulled objects vertically using ramps. (It takes less effort to pull an object upward on a ramp, or inclined plane, than lifting it straight up, though you must pull it a greater distance.)

But starting around 515 B.C., the Greeks replaced ramps with wooden pulleys—wheels with a grooved circumference—allowing one person to lift loads up to several hundred pounds.

A pulley system works like this: A rope attaches to a heavy load at one end, and then wraps around several pulleys. The wrapping gives "mechanical advantage," allowing someone at the other end of the rope to lift the load with much less effort. The Greeks used men or donkeys to pull the ropes through simple pulley systems.

The Romans lifted much larger loads—up to 6,500 pounds per person—using treadwheels, in which two men would walk inside of a giant wooden wheel. "As they're walking, they're turning an axle attached to the wheel, and a rope starts winding around the axle," Smailes explains. The rope, then looped through several pulleys, would be pulling a heavy load at the other end. "Now we have a diesel engine to do it, but back then they essentially put two guys in a hamster cage," he says.

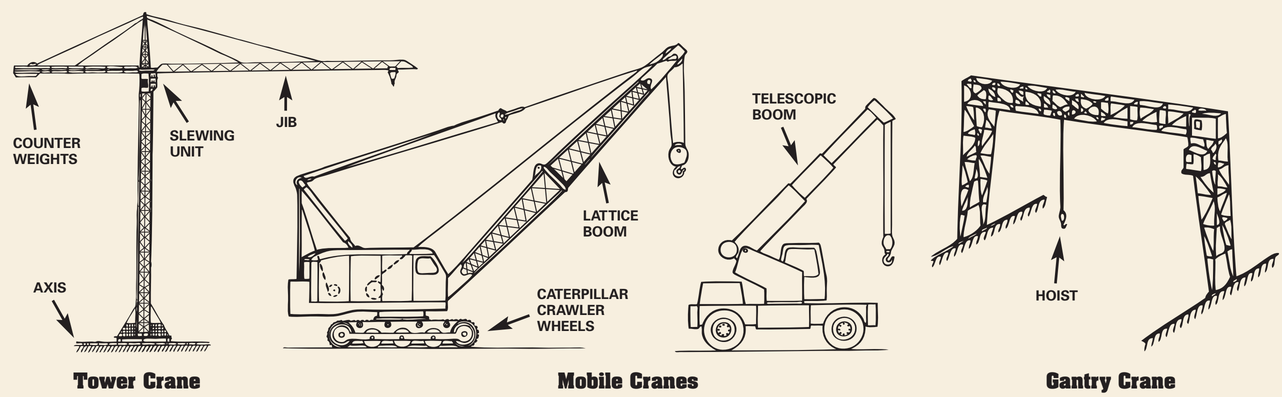
A thousand years later, medieval architects also used treadmills attached to wooden cranes to lift the heavy stone and glass pieces that made the enormous European cathedrals.

Historians think that stationary harbor cranes—those that are fixed permanently on a dock and then pivot to move freight on and off a ship—were developed in the Middle Ages.

In the 18th century, cranes were powered with the newly developed steam engine. At the turn of the 19th century, the Industrial Revolution brought the mass production of steel, making cranes much stronger and larger than the previous wood versions.

MECHANICS OF TOWER CRANES

The steel revolution also led to the development of tower cranes, the tall T-shaped structures found on urban building sites.



TYPES OF CRANES

Littered across big-city skylines, **tower cranes** are likely the most familiar type to the layman. But they are by no means the only way that engineers have configured pulleys and levers to lift enormous amounts of weight.

The most common type of crane is one that sets on top of wheels—whether trucks, railcars or caterpillar crawler wheels—called a **mobile crane**. "The big advantage of the mobile crane is that it doesn't sit there all the time—when it's done with one thing, I can put it on another job," explains longtime construction engineer Cliff Schexnayder.

Mobile cranes have one of two kinds of booms (arms). One, called a **lattice boom**, "looks like a bunch of Tinker toys put together," Schexnayder says. The lattice work, though locked into a fixed height, is extremely sturdy, and can lift much more than tower cranes. "Lattices are very expensive," he adds, "but they're useful, say, when you're building petrochemical plants and have to pick up a very large, heavy load."

The second type of mobile crane boom is a **telescopic boom**. Telescopic booms hold a series of smaller tubes, nested one inside of another like stacking Russian dolls. Hydraulic pumps are used to pull the sections out, thus extending the length of the boom.

Gantry cranes—found at ports and railroads to move cargo on and off ships or railcars—are a type of overhead crane. With this type, a long, steel rail is mounted high off the ground, between two sturdy steel legs that straddle the load. A trolley, which holds pulleys and the hook (called a hoist), runs horizontally from one end of the rail to the other. The crane operator drops the hoist vertically from the trolley to the load, hooks it on to the load, lifts it back up, and then moves it horizontally along the rail to the destination.

Tower cranes—which can rise, unsupported, 250 feet in the air, reach just as far horizontally, and weigh several hundred tons—rely upon pulleys and another simple machine: the lever.

The first step in building a tower crane is to bolt its upright steel tower firmly to a cement foundation on the ground, so that it does not tip over while lifting. This cement "pad" is huge—up to 30-by-30-by-4-feet, and 400,000 pounds, or 200 tons. "That [horizontal] axis is your counterweight, like a tree with its roots spread out," explains Cliff Schexnayder, eminent scholar at the Del E. Webb School of Construction at Arizona State University.

On top of this tree trunk rests the "slewing unit," a box that consists of the gears and motors that allow the crane to rotate. (In this unit, steel cables wrap around a drum, much like the ropes wrapped around a wooden axle in ancient times.) On top of that sits the cab, which holds all of the sensors and electronics that a trained crane operator needs to safely move the crane.

A horizontal beam—the part that makes the lever of this lever machine—also sits atop the tower. Most of the beam extends in front of the tower, leaving a short arm sticking out behind it, much like an unbalanced seesaw. The long arm, called the jib, holds the heavy load. The short arm holds counterweights that prevent the whole crane from tipping over.

Because of their expense—large tower cranes cost upward of $750,000 to build—most construction companies rent cranes, the type and size dependent on whatever their specific need at the site. The typical fee for transport, installation and disassembly of a large tower crane runs around $60,000, on top of a $15,000 monthly fee.

"All of that is decided in the planning process, before you step foot on site," Smailes says. For instance, while a high-rise building might use a tower crane in a fixed position, a small building might need just one, mobile crane. (See sidebar, page 11: Types of Cranes.)

Renovations to structures like the Tacoma Narrows Bridge in Washington State, above, would be virtually impossible without the assistance of tower cranes to do the heavy lifting.

At ports around the world, cranes are used to transfer heavy freight to and from cargo ships, below.

To do their jobs, most cranes use "lifting hooks"—sometimes as large as a grown man—to pick up the wire or chain to which the load is attached. Attached to the hook is a safety latch that keeps the load from slipping off. Two hooks—placed at opposite ends—may be used for picking up awkwardly shaped loads, to keep them balanced on the way up.

The most dangerous part of crane operation comes when tower cranes are made taller during construction, a process known as "jumping." During jumping, the vertical tower part of the crane is temporarily unhooked from its base support and is placed on top of hydraulic jacks. The jacks raise the tower while a new section slides beneath it, then they lower the tower on top of the new section.

"When it's just sitting on those jacks, it's not able to take a load or anything," says Schexnayder. The crane pieces could easily come loose during this vulnerable time. "The most dangerous time with a tower crane is when you jump," he says.

CRANE ACCIDENTS AND SAFETY

There are three main components to crane safety: crane design; the crane site's operating environment; and the crane operator's control.

Accident numbers are largely unavailable in China and Middle Eastern countries, though both China and the United Arab Emirates have a poor international reputation on ensuring worker safety.

In contrast, safety rules are uniform and fairly strict across most of Europe. In France, the installation of a crane is done by companies that specialize in safety, and cannot be done by the company that owns the crane. After installation, a separate government organization must give its safety approval before construction can begin. From 2002 to 2007, France had 10 fatal crane accidents, almost all due to weather conditions or technical failures.

By comparison, 72 workers across the United States died in crane-related accidents in 2006 (the most recent year that statistics are available), according to the federal Occupational Safety and Health Administration (OSHA).

Experts, however, are quick to point out that there are thousands of construction projects yearly that use cranes without incident. "When you talk about accidents on a work site, cranes are not going to be at the top of the list, or even close to it," says Smailes.

Still, when they do happen, crane accidents are big news. This was particularly apparent in the spring of 2008.

On March 15, in New York City, seven people died when a 6-ton piece of steel—and the enormous tower crane it was supposed to hold up—plummeted 18 stories during a jump.

Ten days later, at a high-rise building site in Miami, a 7-ton section of crane fell on a house, killing two people.

On May 30, two more New Yorkers died when a tower crane's cab and boom fell away, falling into a nearby apartment building.

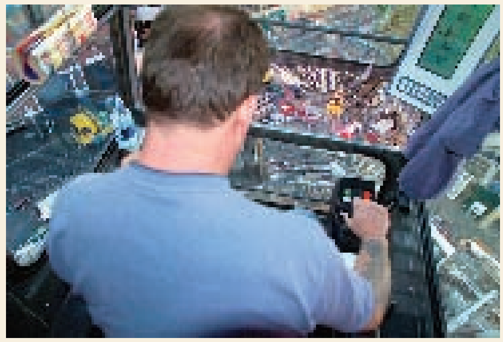
On June 11, in Dallas, a cable snapped from a crane hook, killing one.

How exactly these accidents occurred is still under investigation by the cities' district attorneys, but the blame is generally placed on routine equipment failures, rather than operator error.

With the recent, highly publicized crane accidents, many lawmakers are considering stricter regulations of crane operators, including more pre-construction planning meetings and mandatory licenses.

This summer, in fact, New York City Mayor Michael Bloomberg proposed legislation to increase regulatory oversight of construction sites, including increased fines for violations. In September—taking both union members and industry officials by surprise—his administration enacted new, stricter crane regulations meant to prevent crane accidents like the ones in March and May. The regulations dictate, among other things, that manufacturers give city inspectors a detailed outline of how they plan to raise sections of the crane as a building gets higher (jumping.) The city must certify the plan before work begins.

But as Schexnayder points out, "New York already has the



HOW TO BECOME A CRANE OPERATOR

Tower crane operators are in constant communication with workers on other parts of the site. "Sometimes the operators can't even see the load, so they have to find out information from the radio or from hand signals from somebody on the building or on the ground," says Cliff Schexnayder, eminent scholar at the Del E. Webb School of Construction at Arizona State University.

Crane operators learn their trade not in school, but in an on-the-job apprenticeship. "You might come out of high school and start work at a construction company as what's called an oiler," says Richard Smailes, professor of building construction at the University of Florida. An oiler cleans the crane, and keeps the gears greased properly. As an oiler gains more experience and becomes more comfortable around the equipment, a crane operator will slowly teach him or her to use the crane.

With the exception of a few states and municipalities, no special license or certification is required of crane operators.

However, most construction unions require that crane operators meet both written and practical exams before they're allowed to run the crane solo. "You have to prove that you understand the machine, that you can read the books and interpret what the rules and regulations are," Schexnayder explains. "But then you also have to get in that seat and show you can do it."

In Western Europe, most crane operators have specialized training and a certification degree. All operators are required to take and pass a safety course and, before starting work on a new site, must pass a medical inspection.

Tractors built with front-end loaders use a telescopic boom to extend their reach. They are often used to lift less cumbersome loads like lumber on this construction site in Los Angeles, Calif., left.

A low-angle view accentuates how this mobile crane can effortlessly support the structure of this warehouse in Fuzhou City, China, below.

strictest regulations in the country. The rules don't do any good unless you follow them."

TECHNOLOGICAL UPGRADES

Though the underlying physical principles haven't changed, crane technology has seen a few upgrades in the past few decades.

"There are always small innovations, always developments," says Burkart. "They have significant amounts of electronics on them now that have made them more reliable, safer, and I dare say they will continue to develop."

"In the old days, a crane was strictly a mechanical type thing," Schexnayder says. Friction clutches, controlled by the operator, operated the drum and caused the cable to move. But today, most of that movement is done by either hydraulic or electric motors. A dashboard of gauges and sensors in the cab tells the crane operator exactly where every piece of equipment is located, how much more weight it can handle, and even how close it is to electric wires. "Now it's just a lot easier for the crane operator," he says.

In the next decade, Schexnayder thus predicts "more emphasis on safety education," both from unions and crane manufacturers.

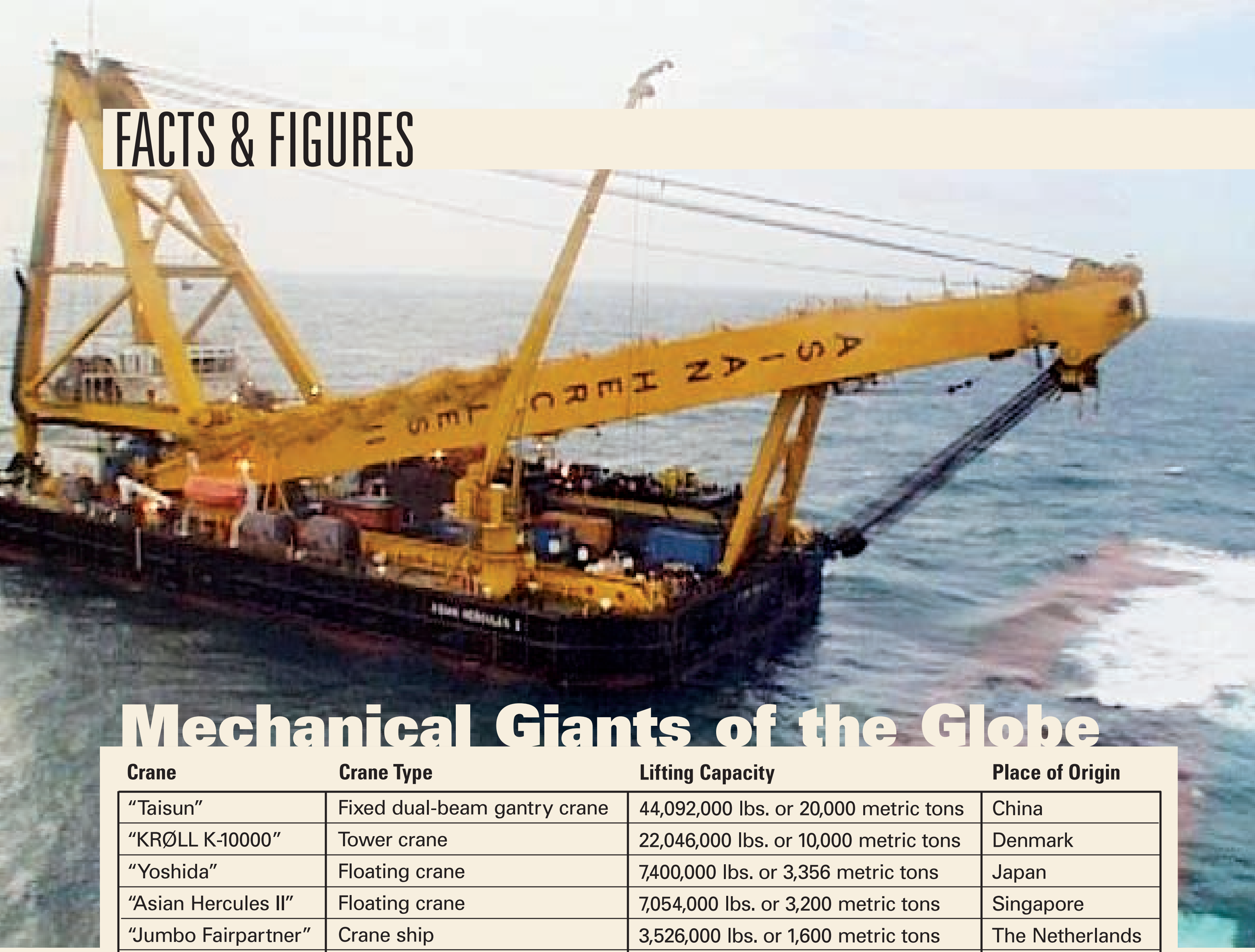
Dixon and Cranes

The following Dixon products are used in the construction industry:

Boss stems and clamps
Boss Holedall
Air King
King Combination nipples
Suction couplings
Air hammer couplings
Ball valves
King cables
Safety shut-off valves
Air receiver manifolds

He also predicts that, thanks to climbing gas prices, people will be driving less and will be less keen to life in the suburbs. "With people moving to the city to get out of driving their automobiles, I can visualize a lot more crane use and more vertical building," he says.

With this increased use, technological advances will come in curbing carbon emissions from the machines. "Manufacturers will be working to make cleaner cranes, and lots more of them," Schexnayder says.



Mechanical Giants of the Globe

Crane	Crane Type	Lifting Capacity	Place of Origin
"Taisun"	Fixed dual-beam gantry crane	44,092,000 lbs. or 20,000 metric tons	China
"KRØLL K-10000"	Tower crane	22,046,000 lbs. or 10,000 metric tons	Denmark
"Yoshida"	Floating crane	7,400,000 lbs. or 3,356 metric tons	Japan
"Asian Hercules II"	Floating crane	7,054,000 lbs. or 3,200 metric tons	Singapore
"Jumbo Fairpartner"	Crane ship	3,526,000 lbs. or 1,600 metric tons	The Netherlands
"MoMo"	Mobile crane	3,526,000 lbs. or 1,600 metric tons	The Netherlands
"Kockums"	Gantry crane	3,306,000 lbs. or 1,500 metric tons	Sweden

Sources: www.darkroastedblend.com; http://www.bbc.co.uk; www.towercranes.com; www.turbosquid.com; www.gcaptain.com.

Above: Asian Hercules II, Below: Yoshida