EPRI ELECTRIC POWER RESEARCH INSTITUTE

Electric Cable Reel Rubber-Tired Gantry Cranes: Costs and Benefits

Executive Summary

This case study explores the economic and environmental issues surrounding the adoption of cable reel electric rubber-tired gantry (RTG) cranes by seaports. Diesel RTGs can represent a large percentage of a port's total fuel consumption depending on port size and equipment usage. Electric cable reel RTGs, relatively new to the U.S. market, may reduce port operating costs associated with RTGs due to lower energy costs and higher energy efficiencies. Existing diesel RTG cranes can be converted to electric cable reel at a cost of approximately $250,000, allowing ports to take advantage of electric equipment operating benefits. In addition to the economic benefits, electric cable reel RTG cranes—both new and converted—save thousands of gallons of diesel fuel and associated emissions every year.

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Introduction

Increasing focus on air quality control by local, state and federal government has caused many U.S. ports to consider cleaner equipment technologies—including electric—for their equipment needs. Port equipment manufacturers have responded by creating a variety of cleaner equipment, and making more electric equipment available to ports. Included in this equipment is the rubber-tired gantry (RTG) crane, which was historically available only with a diesel engine.

Gantry cranes are large mobile cranes in widespread use at ports around the world. They are used land-side to stack and move containers around a terminal. The gantries on which the cranes are mounted move either on rails or rubber tires. RTG cranes typically ride on 16 wheels. At busy container ports, RTG cranes can be run almost around the clock; it is common to find RTG cranes working 4,000–5,000 hours per year. In the U.S., RTG cranes can represent up to 50% of a port's total fuel consumption depending on port size and equipment usage.[1]

At ports or terminals having such heavy usage and reliance on RTG cranes, any improvement in RTG crane operating efficiencies has a potentially enormous impact on a port's financial bottom line. The RTG crane, currently at an average purchase price of $1–2 million, has until recently been used in the U.S. as diesel equipment. The increasing price of diesel fuel, along with pressure on ports to reduce equipment emissions, has prompted cleaner, more efficient RTG cranes, including:

- Electric cable reel systems
- Electric hybrid drives

[1] Conductix-Wampfler marketing literature: "Drive-In Electric RTGs Make Green Ports a Possibility." May 2009.

- Use of regenerative braking
- Improved internal combustion engine efficiencies

These technologies, particularly the cable reel electric system, have allowed RTG cranes to become not only cleaner but also more energy and cost efficient.

A diesel crane idles as much as 30–40% of the time, consuming diesel fuel and emitting pollutants as it idles.

Electric Cable Reel RTG Cranes

Electric cable reel RTG cranes operate using a plug-in electric feed system in place of a diesel engine to power the equipment. The electric feed cable can vary in length with a maximum running distance of up to 4,000 feet, depending on need and voltage. The cable is typically stored in a cable reel located on the RTG, although some vendors use different storage mechanisms. In some cases, the power cord used for electricity delivery may restrict the crane's movement. The electric cable reel RTG crane draws power only when it is needed for moving or lifting, giving this equipment a major energy efficiency advantage over the diesel RTG crane. A diesel RTG crane idles as much as 30–40% of the time, consuming diesel fuel and emitting pollutants as it idles.[2]

Electric cable reel RTG cranes typically use a voltage supply of 13,800 volts, but voltage can vary by port. These cranes may operate for several thousand hours each year, consuming approximately 400,000 kWhs of electricity annually.[3]

Past concerns about operational flexibility—how far an electric RTG crane can travel and whether it can negotiate turns as necessary—have been addressed with various cable technology options that allow for additional crane flexibility and mobility. Technology options include:

- Cable reel carrier system
- Extended cable lengths
- Trenching
- Mounted reel

Commercial Availability

Although some crane manufacturers such as Kalmar and Konecranes have sold electric cable reel RTG cranes in Europe for several years, the U.S. market has been less robust. Interest in them in North America is due in part to the current regulatory environment in the U.S. encouraging cleaner technologies. Kalmar's first electric cable reel RTG, called the "zero emission" RTG, was delivered to the Port of Oslo, Norway in 2002.[4] The system maximizes energy efficiency by allowing the crane to reuse accumulated energy. Kalmar estimates its zero emission RTG crane energy costs to be roughly 20% of hybrid diesel-electric.[5] RTG crane energy costs—themselves much lower than diesel energy costs—depend on the comparative costs of electricity and diesel fuel.

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[2] California Air Resources Board. presentation: *Cargo Handling Equipment Idling Emissions*, September 16, 2009. http://www.arb.ca.gov/ports/cargo/idle/presentations/091609present.pdf.

[3] Based on modeling using EPA's NONROAD model using a load factor of 0.20. This load factor is, we believe, in line with this crane's usage and profile.

[4] Kalmar Corporate Marketing Material. *Kalmar RTG: Zero Emission*.

[5] Ibid.

Photo 1. Konecranes cRTG

Konecranes markets its electric cable reel RTG crane, called the "cRTG" (photo 1).[6] The cRTG is also electrically fed, utilizes a cable reel, a feeding cable, and a transformer station to provide power. The cRTG running length can be a maximum of 4,000 feet, depending on feed point location. An auxiliary diesel generator unit is fitted to power the crane as it moves from container stack to stack, where the crane is then reconnected to another feed point using a plug and receptacle. cRTGs offset their power use through reuse of accumulated energy, with the energy generated during container braking actions fed back to the grid. As a result, the terminal may draw less power from the power grid.[7]

Because the electric cable reel RTG crane is so new to the U.S. market, cost information is preliminary and is largely dependent on the configurations and demands of specific ports. Cost per unit for electric cable reel RTG cranes may be marginally higher when compared to diesel units, with costs expected to be equalized after market demand allows electric equipment to be produced on a large scale. As stated above, current RTG crane pricing for a typical unit is $1–2 million.

[6] KoneCranes Marketing Material. *Low Emission Concept: When Less is More.*

[7] Cranes *Today* Magazine. *Going for Green*. September 15, 2009. http://www.cranestodaymagazine.com/story.asp?storycode=2054118.

Infrastructure Requirements

Infrastructure upgrades may be necessary in order to effectively service new electric equipment at a port terminal. Every port has its own electric needs. Therefore, a cost estimate for any electric infrastructure upgrades necessary to service electric equipment, new or converted, will depend on current infrastructure and the local area electric utility. Newer ports or terminals that have ample electrical capacity and infrastructure in place may have minimal infrastructure upgrade needs in order to serve new electric cable reel RTGs added to their fleets, while other ports may need to make an initial investment in order for these RTGs to be effectively serviced. Many ports, like the Ports of Houston and Savannah, for example, have already made electrical infrastructure upgrades for their fleet of electric ship to shore cranes—an increasingly common piece of equipment at ports—and may, as a result, have only minor additional upgrades to be made for electric cable reel RTGs added to their fleets.

These electric cable reel models typically use electric power from the shore with an electrical service requirement ranging from 4,160 to 13,800 volts depending on use and specifications. Electrical infrastructure that may need to be added can include:

- High voltage source and switchgear infrastructure
- Electrical power from substation to crane switchgear infrastructure
- Cabling from switchgear infrastructure to the crane vaults/pits

Because of the relatively long useful life of the typical RTG, even an older diesel RTG converted to electric cable reel can offer economic benefits.

Equipment Retrofits

Several ports have recognized the potential benefits of electric equipment, and are investigating equipment conversions. These ports include Los Angeles and Long Beach, which have provided funding for their tenants to retrofit existing diesel RTG cranes with electric cable reel systems. Other ports are also starting to consider electric cable reel RTG cranes. A recent announcement indicated that Hong Kong International Terminals would convert 81 diesel cranes to electric cable reel by this year.[8]

Converting an RTG crane to electric cable reel involves replacing the diesel engine with a transformer, cable and electric components. This retrofit can cost between $200,000 and $300,000 and requires electrical infrastructure to support the cranes. Whether or not the conversion offers an economic benefit depends on such factors as existing electrical infrastructure, the remaining useful life of the crane and how much the RTG is used. Because of the relatively long useful life of the typical RTG—as much as 25 years—even an older diesel RTG converted to electric cable reel can offer economic benefits over the remaining life of the equipment.

Electric cable reel RTG conversion vendors such as Konecranes, Conductix-Wampfler and Paceco can utilize one of several technologies for power system conversions on the cranes, including:

Conductix-Wampfler E-RTG

The Conductix-Wampfler E-RTG™ uses one of two electric power systems on its conversions depending on the needs of the port: the motorized cable reel or the conductor rail.

The motorized cable reel system involves the mounting of a cable reel onto the crane. Customers can choose one of two technologies with this system: a motorized cable reel with permanent

[8] China Real News, June 3, 2008, Hong Kong International Terminals Plans to Cut Carbon Dioxide Emissions by 7,000 tons.

magnetic coupler or a frequency controlled motorized cable reel. Conductix-Wampfler estimates that the payback period in most cases for their RTG crane conversion is 12–18 months.[9]

An alternative to the cable reel is Conductix-Wampfler's rail system (Photo 2). With this system, it is not necessary to manually plug the RTG into the current collector trolley of the conductor bar system. Instead, the current collector trolley is automatically steered to the guide rails of the steel structure when the RTG enters the aisle, and the current collector is safely guided into the conductor bars. This "drive-in" solution saves time and energy, increasing the efficiency of a terminal while reducing its environmental burden.

Paceco Electric Cable Reel Carrier

The Paceco electric cable reel carrier (CRC) system uses a cart that travels alongside the crane and holds the power cable. This electrification method is simple in that it eliminates the need for complex guidance mechanisms or ground modifications. One of the challenges of crane electrification is that RTG cranes can stray significantly from straight line paths, which complicates the matter of drawing and laying down power cables in their fixed enclosures. The CRC addresses this challenge with a separate rolling cart, which follows a cable guide channel. The CRC is mechanically linked to the RTG crane so that it can remain alongside the crane to supply power.[10]

Benefits of Electric Cable Reel RTG Cranes

There are many potential benefits to using electric cable reel in place of diesel RTG cranes, including

- greater energy efficiency
- reduced operating and maintenance costs
- longer equipment life
- reduced emissions
- no need for refueling

Photo 2. Conductix-Wampfler Conductor Rail System

[9] E-RTG™ RTG Electrification, Conductix-Wampfler marketing literature.

[10] "Paceco marketing material. Electrified RTG Cable Reel Carrier. http://www.pacecocorp.com/prertgcrc.shtml.

Economic Benefits

The economic benefits of electric cable reel RTG cranes are a result of increased energy efficiency, lower energy costs, and less maintenance and downtime compared to a diesel RTG.

Operating Costs

Electricity costs are lower and more stable than diesel fuel in most parts of the U.S. Using an average industrial rate of $0.08 per kWh[11] compared to off-road diesel fuel at an average of $2.30 per gallon, running RTG cranes on electricity is more economical.[12] For example, a 650 horsepower diesel RTG crane operating 4,000 hours per year uses about $72,000 worth of diesel fuel annually (priced at $2.30/gal). By comparison, an electric crane utilized the same number of hours uses about $32,000 worth of electricity annually, assuming 407,000 kWh at $0.08 per kWh (see Table 1)[13].

Some estimates, such as Conductix-Wampfler's analysis of the benefits associated with their E-RTG conversion, show an even greater benefit for electric cable reel RTG crane operations.[14] Note that this example does not factor in electric cable reel RTG crane maintenance or infrastructure costs, both of which are discussed below.

Maintenance Costs

Maintenance costs for electric equipment are typically lower than for diesel equipment. Frequent oil changes, engine tuning, diesel-related failures, regular diesel engine replacements, and longer equipment down time are all common with diesel equipment. In an industry that requires its equipment to be up and running in order for operations to run smoothly, this equipment down time can affect a port's bottom line. At the Port of Savannah, for example, 25% of the port's equipment down time is directly attributed to diesel-related issues.[15]

Infrastructure Costs

Electrical upgrades and additional infrastructure may be required to run electric cable reel cranes from dock-side power. Again, every port has its own needs, so it is impossible to estimate the

Table 1. Cost Comparison Between an Electric and Diesel RTG Crane

	Diesel RTG Crane ($)	Electric Cable Reel RTG Crane ($)
Equipment Cost	1.5 M	1.65 M
Annual Operating Cost	72,164	32,573
20-Year Operating Cost	1.44 M	651,460

Assumes 20-year life, 650-horsepower diesel engine, 4,000 hours per year operation, load factor of 21%; a diesel equipment price of $1.5 million, an electric RTG crane purchase price of 1.10% that of diesel, diesel fuel cost of $2.30 per gallon, electricity cost of $0.08 per kWh.

[11] http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html.

[12] http://tonto.eia.doe.gov/oog/info/wohdp/diesel.asp. Average on road diesel fuel price is $2.80/gal; subtracting $0.50 tax equals off-road price.

[13] Modeling assumptions include: a load factor of 0.20, a 650 horsepower pre-1990 engine, equipment usage of 4,000 hrs per year, and CO_2 was based on the carbon content of the fuel using the following equation: CO_2 EF = (BSFC * 453.6 – HC) * 0.87 * (44/12) where BSFC is from the NONROAD model and is expressed in terms of pounds per HP-hour.

[14] E-RTG™ RTG Electrification, Conductix-Wampfler marketing literature.

[15] Per communication with Rich Cox, 2009.

infrastructure investment required to support electric cable reel RTG cranes. Newer ports or terminals that have ample electrical capacity in place may not require additional infrastructure, while older facilities may need to make an initial investment. Various stakeholders—including port tenants and the local electric utility—in addition to the port itself may contribute to defraying the cost of electrical upgrades.

Cost Summary

The energy efficiency and cost savings of an electric cable reel RTG crane compared to its diesel counterpart can result in a substantial cost advantage, the specifics of which depend on the prices of electricity and diesel fuel. Over a 20-year equipment life, this savings can add up to hundreds of thousands of dollars (see Table 1).

Environmental Benefits

Emissions from port operations are increasingly being scrutinized because of environmental and regulatory pressures. As a result, diesel emission reduction programs have been established at most larger ports. These programs often include efforts to reduce diesel equipment emissions through the use of alternative fuels and electricity. Equipment that runs on electricity produces no operating, or tailpipe, emissions. The emissions associated with electric equipment are those emitted due to the generation of electricity. These emissions compare very favorably to those from diesel equipment. In the case of an RTG crane, the net reduction can amount to several tons per year of many major pollutants.

Table 2 shows an average[16] pre-1990 RTG diesel crane emissions and fuel usage profile. As shown, a typical diesel RTG crane emits annually approximately six tons of nitrogen oxides (NO_x) and 350 tons of carbon dioxide (CO_2)—about the amount of CO_2 emitted by 63 passenger cars in a year.[17]

Although there are no tailpipe emissions from an electric cable reel RTG crane, there are emissions associated with the generation of electricity used to power the crane. Depending on the source of electricity, these emissions can vary widely. A national average for carbon dioxide emissions from power plants of 1.35 lb/kWh is assumed for this analysis.[19]

Using this national average for CO_2 generation emissions, an RTG crane that is operated 4,000 hours per year will use an estimated 407,000 kWh per year, the generation of which is associated

Table 2. Annual Emissions for a Typical Diesel RTG Crane[18]

Emissions (T/yr)				
NO_x	HC	CO	PM	CO_2
5.8	0.4	1.6	0.2	354

NO_x: nitrogen oxide; HC: hydrocarbon; CO: carbon monoxide; PM: particulate matter; CO_2: carbon dioxide.

[16] Based on 650 horsepower pre-1990 engine, and equipment usage of 4,000 hrs per year.

[17] Assuming vehicle emits 25 lbs per year of NO_x and 5–6 tons per year CO_2. Environmental Defense Fund, Tailpipe Tally.

[18] Modeling is based on RTG crane load factor of 0.21 and EPA's NONROAD model; assumptions include: a 650 horsepower pre-1990 engine, equipment usage of 4,000 hrs per year, and CO_2 was based on the carbon content of the fuel using the following equation: CO_2 EF = (BSFC * 453.6 - HC) * 0.87 * (44/12) Where BSFC is from the NONROAD model and is expressed in terms of pounds per HP-hour.

[19] http://www.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/e-supdoc.pdf.

Table 3. Annual CO_2 Emissions Associated with a Diesel and Electric RTG Crane

Equipment Type	Annual Energy Use at 4,000 hr/yr	CO_2 Emissions
Diesel Crane	31,376 gal	354 typ (tailpipe)
Electric Crane	407,000 kWh	275 typ (power plant)

with 275 tons of CO_2 emissions. This estimate represents a decrease of approximately 22% compared to a diesel crane.

Conclusions

Due to lower energy costs and energy efficiencies, the electric cable reel RTG crane can offer energy savings compared to its diesel counterpart. Existing diesel RTG cranes can be converted to electric cable reel at a cost of approximately $250,000, allowing ports to take advantage of several electric equipment operating benefits. In addition to the economic benefits, electric cable reel RTG cranes—both new and converted—save thousands of gallons of diesel fuel and associated emissions every year.

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