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MACHINERY TROLLEY CRANES

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In 1996, APL bought twelve machinery on trolley (MOT) container cranes for their new Port of Los Angeles facility from the German manufacturer, Noell. This decision was a major break from convention as APL had not purchased a crane without a rope-towed trolley before, and very few MOT container cranes were in operation in the United States. At the same time, the Port of Singapore Authority decided to buy twenty-four MOT cranes from Mitsubishi Heavy Industries. The PSA cranes are the largest and stiffest container cranes in the world.

Because few MOT type cranes had been ordered outside of Europe , APL and PSA's decision to buy MOT cranes was a pioneering move. It is the thesis of this paper that APL and PSA's decisions are the start of a trend rather than isolated incidents. Their choice reflects the evolution of the container crane. Due to the increased size of container cranes, the governing conditions have changed, the original solutions have been outgrown and new solutions are needed. The new conditions make a strong case for selecting machinery on trolley post-Panamax cranes.

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WHARF WHEEL LOADS GOVERNED THE DESIGN OF THE FIRST CRANES

The first container-handling crane, built for Matson Navigation Company by Pacific Coast Engineering Company, Paceco, in 1959, was designed to operate on timber pile supported crane girders. Due to the limited strength of this wharf structure--common in the world at that time--minimizing wheel loads was a key design criterion. Placing the hoist and trolley drive machinery in the machinery house near the landside legs, rather than on the trolley, reduced the weight of the trolley, which in turn reduced the wheel loads.

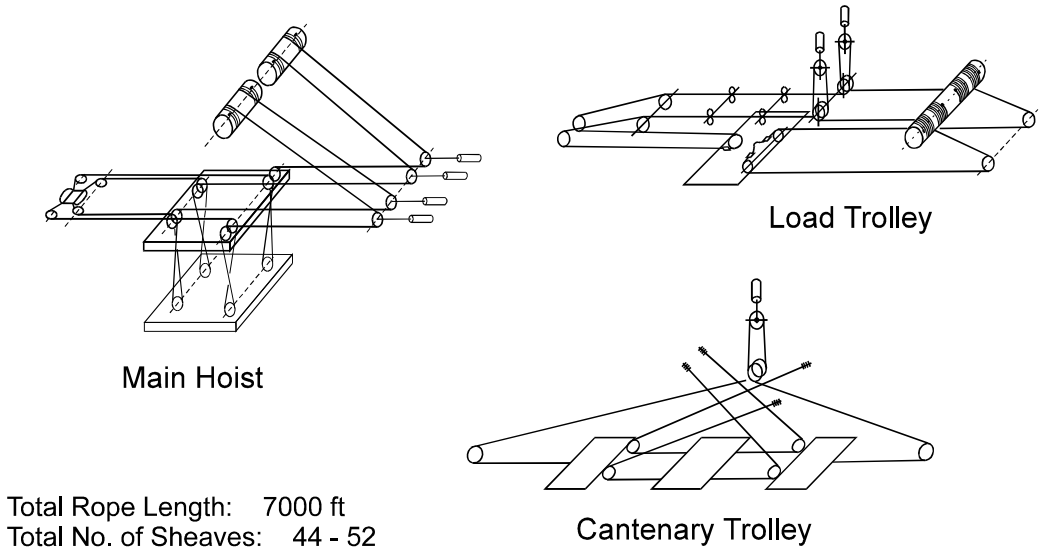

Figure 1: Reeving diagram for rope-towed trolley

Since the machinery in the machinery house tow the trolley and hoist the load by a system of wire ropes, this system is called a rope towed trolley system (RTT). The trolley tow ropes run from the machinery house to the sheaves at the landside of the crane, through the trolley to the tip of the boom, and back to the house. The main hoist ropes run from the machinery house to the landside of the crane, through the trolley and head block, and usually dead end at the waterside tip of the boom. These systems create a lightweight trolley, a heavy machinery house, thousands of feet of wire rope, and nearly fifty sheaves. Since the ropes must span nearly 300 feet, catenary trolleys or other complex rope support systems are required. Although the RTT produces minimum wheel loads at the wharf, the crane can be more costly to maintain. By reducing the wheel loads sufficiently to allow the crane to operate on existing wharves, the

RTT helped make containerization successful. Crane manufacturers, worldwide, adopted the RTT. The roped towed trolley system remains the most popular trolley system today.

THE GROWTH OF CONTAINERIZATION AND TRADE HAS CHANGED THE CRITERIA

With the success of containerization, the volume of containerized cargo has grown enormously. Ships and the terminals have grown dramatically. To keep up with the larger ships and the increased traffic, today's container cranes are three times the size of the crane built in 1959.

These developments have changed the basic premises of crane design. First, because of the wide acceptance and growth of containerization, new wharves are designed to suit the cranes instead of cranes being designed to suit the wharves. Second, the rope towed trolley system, which works well on smaller cranes, is stretched to the limit of its effectiveness on larger cranes.

On an RTT crane, the length of rope required to move the trolley and raise the load increases when the lift height, outreach, or backreach is increased. The longer the ropes, the more the sag and stretch. This reduces the accuracy and responsiveness of the load control system. Hydraulic rope tensioners control the sag of the trolley ropes. Catenary trolleys reduce the sag of the main hoist ropes. But the total system becomes more complicated.

The required increase in crane size and in productivity to service large ships places greater demands on speed and load control. This makes the reduced responsiveness of the RTT on large cranes significant.

The changed conditions do not favor RTT cranes from the perspective of load control and maintenance.

The alternative to the rope towed system is the machinery on trolley crane. The apparent advantage of the MOT is that less wire rope is used and fewer moving parts are required. The disadvantage is that the crane weight and wheel loads are higher, festoon cables are heavier, and trolley wheels and rails may experience increased wear.

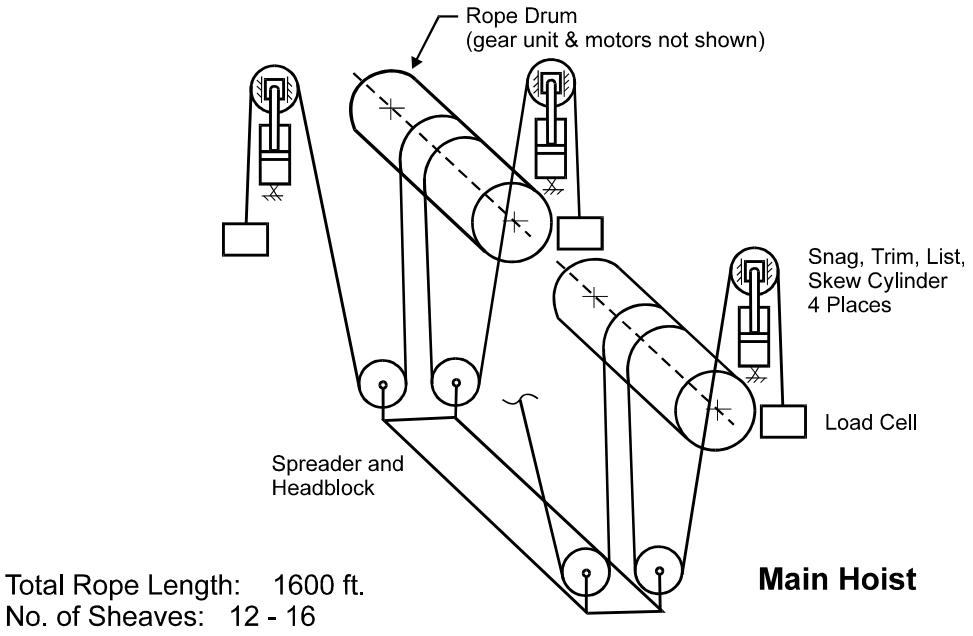

Figure 2: Reeving diagram for machinery trolley

Since the wheel loads at the wharf are less of an issue for new terminals, the MOT appears to be a promising, if not the best, alternative. However, since the machinery trolley system is less widely used, especially in the United States, it is not clear that all the problems have been discovered, or that the machinery trolley actually achieves the promised productivity and reduced maintenance.

The following description of the MOT system outlines some of the advantages and disadvantages of the system that were considered by APL when they decided to purchase MOT cranes.

ADVANTAGES OF THE MACHINERY ON TROLLEY SYSTEM

Until recently, MOT cranes were primarily a European phenomenon. The German manufacturer, Kocks, introduced the first MOT crane in 1968. Recently Noell, Mitsubishi Heavy Industries, and ZPMC have introduced their first MOT cranes.

Typically, MOT cranes have a mono girder boom. The trolley is suspended below the boom on a heavy frame. The frame supports the trolley drive and main hoist machinery. The weight of the machinery

and the frame makes the machinery trolley more than three times as heavy as the RTT.

The apparent advantages of the MOT system compared to the RTT system are:

1. Reduced maintenance cost.
2. Reduced environmental and safety concerns.
3. Improved load control.
4. Improved operator comfort.

Maintenance Cost

The newest and largest MOT cranes use about 1600 feet of running wire rope. A comparable RTT crane uses about 7000 feet of rope. With less rope in the system, performance is improved, and replacement cost and maintenance time is reduced.

The MOT system has fewer moving parts. The RTT system uses as many as 52 sheaves; the MOT system requires between 12 and 16 sheaves. In addition, the MOT crane eliminates the need for catenary trolleys and rope tensioners. This simplifies the systems and reduces maintenance costs.

On the other hand, the MOT requires more and heavier cables in the festoon system to power the main hoist and trolley. The shock loads in the festoon system can cause excessive wear. To avoid this problem, both APL and PSA selected motorized festoon systems. With this system, some of the festoon trolleys are driven by small motors. The replacement cost of the motorized festoon can be three times greater than for the conventional festoon system used with the RTT.

A new inductive power supply has been developed and is being tested at Virginia International Terminals. In concept, this system uses one loop from a transformer to transmit electrical power from the crane to the trolley. The only connection to the trolley is an electromagnetic link. A communications system using a wave guide, which also needs no physical connection, has been developed in conjunction with the inductive power supply. These developments will eliminate the need for festoons or collectors.

Unfortunately, the present inductive power systems transmit only enough power to supply a rope towed trolley. So, although inductive power is expected to significantly reduce maintenance on the power supply system, it is presently only suitable for rope towed trolleys.

Since the MOT trolley is much heavier, the trolley wheels are more sensitive to misalignment and may wear more if some rubbing occurs.

Although MOT cranes have some additional maintenance problems, the overall maintenance cost for MOT cranes should be significantly less than for RTT cranes.

Environmental Concerns

Environmental concerns are important issues in selecting a crane system, particularly in the United States. A problem with the RTT system is that the exposed lubricated wire ropes, running the length of the crane, inevitably drop grease and oil onto the wharf and into the water. This may require unlubricated ropes and require more frequent rope replacement.

On the MOT crane, the main hoist ropes are contained between the trolley and the spreader. The trolley drive ropes are eliminated. So the potential for environmental problems is reduced.

Load Control

Since the main hoist ropes are shorter and there is no catenary motion, the MOT improves load control over the RTT system

The MOT eliminates the trolley tow ropes. Therefore sagging and stretching of these ropes is not a concern. Each trolley wheel is independently driven and controlled. Some concerns about traction and skidding of the MOT wheels have been raised, but detailed calculations and observations have not shown any problems under normal operations. Occasionally, skidding may occur for the first few runs during icy conditions or build-up of rust on the rail combined with moisture. But once the ice or rust is worn off, the wheels do not skid.

Operator Comfort

Since the difference in weight between the trolley with and without the lifted load is reduced, and the crane structure is heavier and stiffer, the trolley motion is smoother and the operator is more comfortable.

Improved operator comfort reduces operator fatigue and increases productivity.

DISADVANTAGES OF MACHINERY ON TROLLEY SYSTEMS

The disadvantages of the MOT system compared to the RTT system are:

1. Heavier structure and higher wheel loads.
2. Potential for unexpected operational problems.
3. Unknown reliability.
4. Operator acceptance.

Wheel Loads

The increased trolley weight increases the effect of the fatigue load by a factor of 4.5 or greater compared to RTTs. Although the mono girder boom is lighter than the twin girder for both RTT and MOT cranes, the weight of a monogirder MOT is about 15% greater than that of a twin girder RTT crane. The increase in weight results primarily from increased sections to control fatigue damage.

Increased crane weight combined with higher trolley weight results in about 15% higher wheel loads for MOT cranes than for RTT cranes.

The increased crane weight and wheel loads will increase wharf construction costs. But the cost of increasing the crane girder capacity on new wharves is surprisingly small. Even though MOT cranes are heavier than RTT cranes, their initial cost in not always higher.

Potential for Unexpected Operational Problems

The festoon system for the RTT carries power for only the spreader and cab. On the other hand, the festoon system for the MOT carries the power for the main hoist and trolley drives. This additional power demand requires heavier cables. Since trolley speeds are high, there has been some

concern that the increased inertia of the system would cause additional wear and reduce the reliability of the festoon system.

Since the main hoist rope is relatively short, potentially, the rope could come off the drum when the empty spreader is lowered at high speed and suddenly stopped. In the RTT system, the weight of the long ropes draping from the supports to the trolley maintains a greater minimum tension and holds the rope in the drum grooves. Fortunately, this has not been a problem.

There was also concern that the trolley wheels could skid during rain storms. Since ropes tow the rope trolley, traction is not a concern for the RTT system. Skidding has not been a problem on MOT cranes.

Reliability

The RTT system is ubiquitous in the United States. Many more crane manufacturers worldwide have produced RTT cranes than MOT cranes. Many manufacturers have never designed or built MOT cranes. The RTT is tried and tested and the bugs have been worked out. RTT cranes have a successful track record.

For many users and manufacturers, the MOT crane is a new concept. This, in itself, speaks against the MOT crane when purchasers are making decisions involving millions of dollars worth of equipment. But the high cost is also a stimulus to keep an open mind and carefully examine alternatives. It may be that MOT cranes are more reliable than RTT cranes.

Operator Acceptance

Crane operators who spend years perfecting their skills on certain types of equipment are sometimes reluctant to accept new equipment, especially new equipment with a completely different feel. If operators do not like the equipment, productivity can be severely affected. But if the new equipment is user friendly and more productive, the operators will quickly accept it.

The layout and design of the MOT trolley and cab is of primary importance. Because the machinery space is limited on the trolley, the layout is critical to maintain the same ease of maintenance. And because

the machinery is much closer to the cab, noise insulation of the cab is an important design issue for the operator.

AMERICAN PRESIDENT LINES' EXPERIENCE

APL diligently investigated alternatives. They did everything they could to make sure they made the best choice. But without a track record in an APL terminal, questions remained. Would the ropes jump off the main hoist? Would the festoon system work? Would maintenance cost savings actually be realized? Would operators accept the different trolley and controls?

With twelve Noell MOT cranes commissioned at their Los Angeles facility, eight of them fully operational for five months as of November 1997, APL now has some answers to those questions.

APL expected improved performance and reduced maintenance. Expecting lower costs, APL staffed their maintenance for the new facility at thirty percent less than for RTT cranes. This staffing has proved to be adequate.

In addition, APL is anticipating significant savings due to reduced spare parts inventory. Compared to an RTT crane, each MOT crane has approximately 5400 feet less rope and 30 fewer sheaves of miscellaneous sizes that require periodic replacement. For twelve cranes, the saving is 65,000 feet of rope and 360 sheaves.

Typically, maintenance cost, including spare parts, is three to five percent of the purchase cost per year. Assuming a twenty-year life and an interest rate of eight percent, the present value of the maintenance cost is 30 to 50 percent of the purchase cost. APL's estimated saving of thirty percent of the maintenance cost over twenty years translates into ten to fifteen percent of the initial purchase cost of the cranes.

A side effect of reduced maintenance is reduced downtime. This also reduces operating costs. In only five months, records show that the operating cranes have experienced a downtime of about one percent. For new cranes, it usually takes up to a year to work out bugs and achieve this rate.

The festoon system was a potential source of operating problems. APL selected the Wamphler system of powered festoon trolleys. These were

introduced on Noell's Algeceiras MOT cranes. This festoon system is working without problems. The system is so smooth that wear on the festoon cables is less than for a conventional RTT festoon system. The steel wheels on the motorized festoon trolleys are noisier than the conventional non-powered festoon system. This is not a problem.

Skidding of wheels or jumping of main hoist ropes have not been problems. The combination of rust on the rail and fog causes occasional skidding. APL expects that this will not be a long-term problem.

The operators are pleased with the fast operating speed of the trolley, 800 feet/min. compared to the typical RTT speed of 600 feet/min.

Productivity has been satisfactory. Currently, the terminal can support a productivity of about 25 moves per hour and the cranes achieve this without difficulty. The cranes are expected to easily achieve the current terminal goal of thirty moves per hour.

In short, the cranes have satisfied APL's expectations and the potential problems have not materialized.

Productivity, reliability, and maintenance data will vary from place to place. Labor agreements, regulations, the size of a facility, the mix of equipment, and the management approach can all affect the results. Having moved from an older facility in Los Angeles to the new Berth 300, APL's experience provides a reasonable comparison of the two types of cranes.

An important part of APL's success with their new cranes has been their active approach during the entire procurement and commissioning process. APL made special efforts to work closely with the crane supplier and all parties involved with the crane operations. Open communication lines made it possible to hear and address problems and suggestions from many points of view. Capitalizing on the diverse input of all users, the final product was a superior one.

CONCLUSION

When APL was deciding what type of crane to buy they assembled their engineering staff and a group of other crane experts and asked: If our new cranes were the first cranes and no traditions had been established, what design would be the best. The goal was to optimize efficiency, reliability,

and the combined initial and operating costs. The group chose the machinery on trolley cranes.

APL's experience supports this choice. Soon, we will know more about PSA's experience with its Mitsubishi Heavy Industries machinery trolley cranes.

Now both rope trolley cranes and machinery trolley cranes are viable.

For large super-productive cranes, the machinery trolley crane will be the choice of the future.

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