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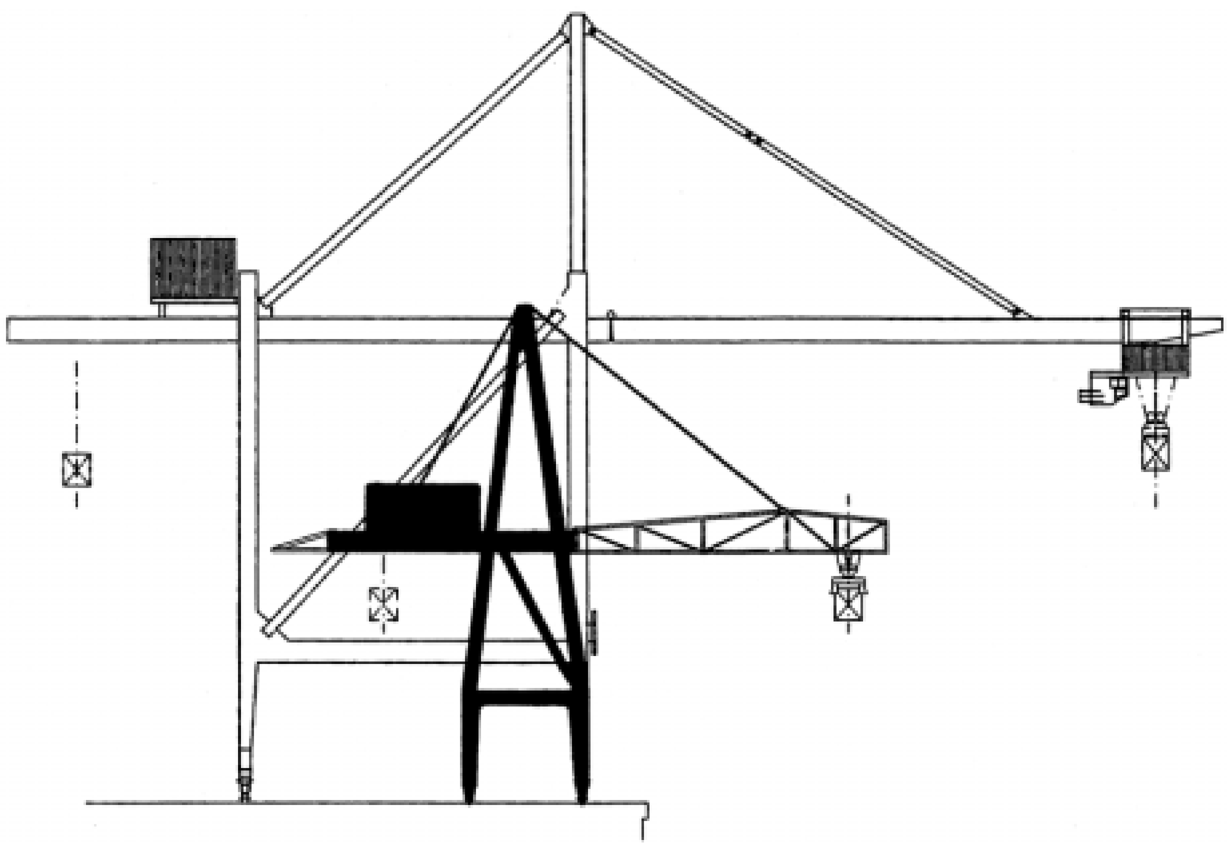

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ROPE-TOWED TROLLEY OR MACHINERY TROLLEY - WHICH IS BETTER?

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INTRODUCTION

Recent decisions by APL and Port of Singapore Authority to order a large number of post-panamax cranes with machinery-on-trolley have generated much interest in the shipping industry. These world leaders have favored the traditional rope-towed trolley cranes, until now.

This paper will discuss the evolution of container cranes with respect to trolley systems, how the two systems differ, and the reasons for APL's decision to select the machinery trolley for their dockside container handling cranes.

EVOLUTION OF CONTAINER CRANE TROLLEY SYSTEMS

The first dockside container handling crane, built by Paceco for Matson Navigation in 1959, utilized a rope-towed trolley. The main hoist equipment was in a machinery house on the gantry frame. This crane, that would reduce ship turnaround time from three weeks to eighteen hours, was conceptualized by Matson engineers for operation on the existing wharf. The wharf was supported by timber piles with limited load carrying capacity. This was common in 1959. A light weight rope-towed trolley with the machinery on the frame kept wheel loads within the wharf capacity. The concepts developed for the Matson crane were generic and met the limited capacity requirements of many other existing wharves. The minimization of wharf loads was the primary factor favoring the rope-towed trolley cranes for other existing facilities.

The Paceco crane designs became the model for the next generation of container handling cranes for most ports in the world, except for a few European ports.   Container cranes continued to increase in size, but the original Matson/Paceco design philosophy remained virtually unchanged. When post-panamax ships required greater outreach and longer trolley travel, auxiliary catenary trolleys were added to support the ropes. The larger cranes, about twice the size of the original Matson crane, required better load control, so hydraulic sway damping systems were added. These rope-towed trolley cranes have provided excellent service over the years and, with proper maintenance, have exhibited high reliability. The resulting maze of ropes, sheaves and trolleys, however, have become complex.

Some European crane manufacturers adopted the machinery trolley design concept for most of their cranes. The machinery trolley is self-driven and contains the main hoist machinery. Kocks introduced the first European machinery trolley container crane in

1968 and have since used the same basic philosophy for most of their cranes worldwide. Recently, Noell, also from Germany, has introduced their machinery trolley cranes.

A hybrid of the two systems, commonly known as a fleet-through machinery trolley, has been adopted by some manufacturers and crane operators. For the fleet-through machinery trolley the main hoist machinery is placed on the gantry frame, but the trolley is self driven.

Most of the Asian manufacturers followed the Paceco concepts and became experts in building the rope-towed and, to some extent, the fleet-through machinery, trolley designs. Recent orders for machinery trolley cranes by APL and the Port of Singapore Authority, however, should generate more interest in machinery trolley cranes.

New cranes require more outreach, more speed, and better load control. Typical post-panamax crane characteristics follow:

Rated Load	50 LT.
Rail Span	100 feet
Outreach	150 feet from face of wharf, 16 wide
Backreach	50 feet
Lift above rail	110 feet
Antisway system	Electronic

COMPARISON OF MECHANICAL SYSTEMS

See Table 1 on page 3 for a summary of the components of the mechanical systems discussed below.

Trolley and Reeving Systems

The rope-towed trolley has a shallow, light frame, carries the main hoist sheaves and rides on idler wheels. Machinery located in the machinery house on the frame tows the trolley.

The machinery trolley has a heavy, underhung frame with the main hoist equipment and trim/list/skew/snag device on the lower platform. All four wheels are driven for the machinery trolley with separate brake/motor/reducer.

Reeving systems for the two trolleys and respective components are shown in Table 1 below and Sketches 1 and 2 on page 4.

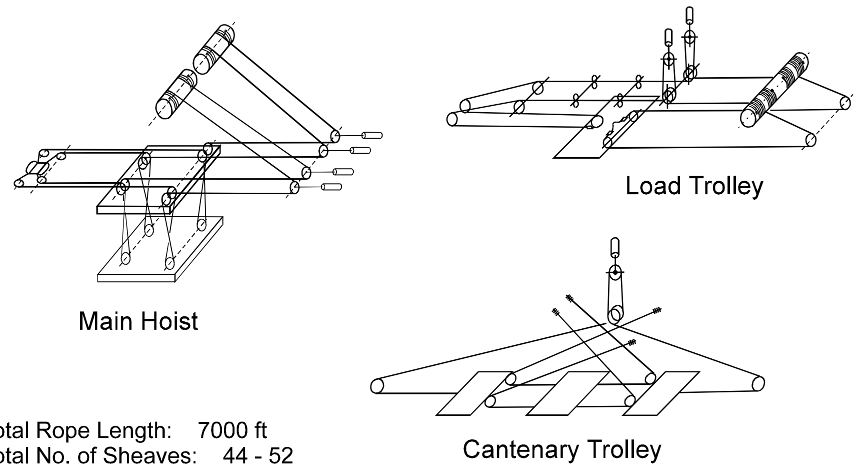
	Rope-towed Trolley (RTT)	Machinery Trolley (MT)	Advantage
Reeving Assemblies	Main Hoist Trolley Drive Catenary Trolley Drive	Main Hoist	MT
Trolley Positioning	Movement due to trolley travel rope stretch	Movement due to skidding	MT
Festoon	Spreader power only	Power for main hoist[1] , trolley drive, and spreader	RTT
Trolley Accelerations	2 ft/s^2	2 ft/s^2	---
Rope Lubricant	Exposed to environment. Oil spillage on ground.	Enclosed, spillage contained	MT

[1]Including trim, list, skew, and snag device

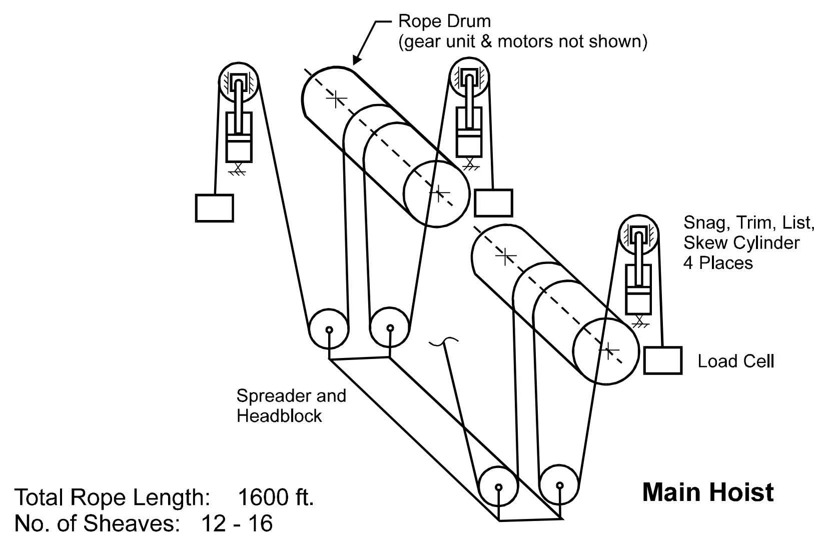
Table 1: MECHANICAL SYSTEMS

Machinery House

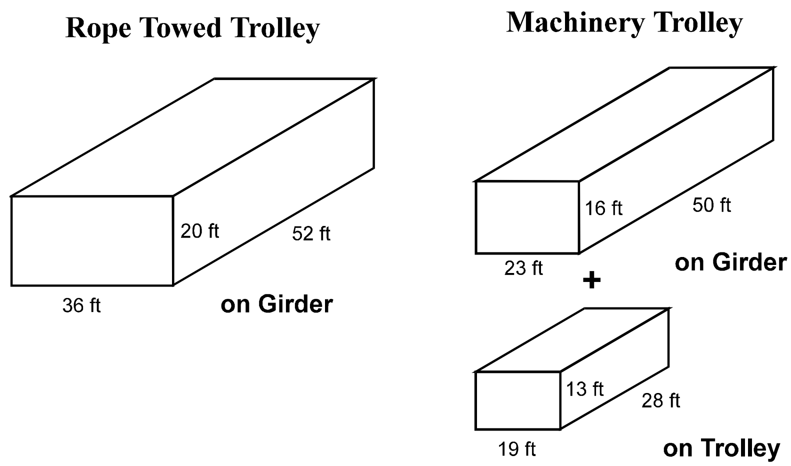
The frame mounted machinery house for the rope-towed trolley consists of the main hoist machinery, trolley travel equipment, boom hoist machinery and the climate controlled electrical room. For the machinery trolley, the main hoist is moved to the trolley, and the trolley travel machinery is eliminated. See Sketch 3 on page 5.



Sketch 1: REEVING DIAGRAM FOR ROPE-TOWED TROLLEY



Sketch 2: REEVING DIAGRAM FOR MACHINERY TROLLEY



Sketch 3: MACHINERY ENCLOSURES

Festoon

The festoon system for the rope-towed trolley carries the power and control cables for the spreader. The festoon system for the machinery trolley carries, in addition to the power and control cables for the spreader, the power cables for the main hoist machinery, the trolley motors, and the trim/list/skew/snag device. Since the trolley speeds are high, and the additional cables add weight, the festoon system design requires careful consideration. Some manufacturers have recently introduced powered intermediate festoon trolleys to reduce the shock loads on the festoon system.

Spreader Power Cable

The baloney cable for a rope-towed trolley is generally stored in a basket on the head block. The power cable for the machinery trolley is stored on a cable reel located on the trolley.

Performance

Trolley and hoist speeds and accelerations are about the same for both types of trolleys. Since there is no trolley tow rope with the associated rope stretch, and hoist ropes are much shorter, the machinery trolley may provide better load control. The long main hoist ropes in the rope-towed trolley absorb part of the energy in case of snag. For the machinery trolley, the snag protection device needs to absorb more energy.

While wheel skidding is not an issue with the rope-towed trolley, there is a perception that wheels on the machinery trolley skid. However, detailed calculations and observations do not support this. Detailed traction calculations show that powering into a 40 mph wind with an acceleration of 2 ft/sec^2 with a 50 LT container requires an average coefficient of friction of 7%. Even considering the uneven load distribution between the front and rear trolley wheels during trolley acceleration, a friction coefficient of 10% is required to keep the lightly loaded wheels from slipping if they are providing the same traction as the heavily loaded wheels. In icy conditions, the trolley may experience skidding for the first pass.

Trolley Rail Joint at the Boom Hinge

The location of the boom hinge relative to the trolley rail joint and the rail support at the joint requires careful consideration to provide a smooth trolley ride and a maintenance free joint. Since the trolley wheel load is heavier, this is much more important for a machinery trolley.

Maintenance

The machinery for the rope-towed trolley crane, located in the machinery house, at the boom tip, and at the landside end of the trolley girder, is easily accessible. The trolley idler wheels require little maintenance and are also easily accessible.

The overall width of the machinery trolley is limited. The trolley drive and main hoist machinery must be confined to relatively tight quarters, and the equipment is not as easily accessible as with the rope-towed trolley. However, the maintenance of the boom tip equalizer platform, the landside turning sheaves, the catenary trolleys, the rope tensioners, the deflector sheaves, and the slap blocks is eliminated. And, since there are no tow ropes and the main hoist ropes are much shorter, rope maintenance is reduced.

OPERATOR PREFERENCE

The properly designed heavy machinery trolley should give the operator a more comfortable ride, since there is much less difference in the weight of the loaded and unloaded trolley. Hoist response will be more rapid with shorter hoist ropes and the trolley direct drive. Proper design requires a smooth rail joint and good sound insulation.

If the trolley does not travel smoothly by the boom hinge, the operator is likely to reduce trolley speed when approaching the joint.

STRUCTURAL SYSTEMS

Generally, for recent rope-towed trolley cranes, the trolley rails are on twin trapezoidal girders. Generally, for machinery trolley cranes, the trolley rails are on rectangular or trapezoidal monogirders. In a relatively few cases, some manufacturers have built rope-towed trolley cranes with monogirder booms.

A properly designed monogirder boom crane weighs less than a properly designed twin girder boom crane for both rope trolley cranes and machinery trolley cranes. The eccentric lifted load applies additional load on one side of the twin girder booms and forestays, resulting in bigger sections. For monogirder booms, the eccentric lifted load causes torsion in the boom. Since the torsion does not increase the axial stresses of the monogirder boom or the forestays, the sections do not need to be increased. Eccentric loads are not considered for fatigue, so this is not a factor if fatigue stresses govern the design.

The most significant advantage of a rope-towed trolley over a machinery trolley is the rope trolley's lower weight. This result in a lower moving load and a lower fatigue load. See Table 2 below.

	RTT	MT
Trolley weight (electronic anti-sway)	45,000 lbs	140,000 lbs
Moving load Trolley + spreader + HB + 50 LT container + impact	230,000 lbs	335,000 lbs
Moving load for fatigue damage	150,000 lbs	250,000 lbs
Fatigue damage	1.0	4.63
Total crane weight 100 ft gage, post-panamax	1050 MT	1200 MT
Wheel loads	33 k/ft	38 k/ft

Table 2: STRUCTURAL SYSTEMS

The higher moving load for the machinery trolley will increase the strength requirements for those members controlled by the moving load: the boom, trolley girders, forestays, and trolley girder support beams. The fatigue strength requirements will have the greatest effect. The fatigue damage will increase by a factor of 3 to 5, resulting in a weight increase of about 75 to 100 tons. But the machinery house on the frame is lighter, so the net increase in overall crane weight is only about 50 to 75 tons.

Many factors affect the cost of the crane. The lightest crane may not be the most economic. Typically, the fabricators have a standard design that they have learned to build. For them, their standard design is the least costly and the most reliable. For some fabricators, the monogirder design is best. For others, the double girder design is the best.

DOCK LOADING

The operating wheel loads for a machine-trolley crane are about 15% higher than for a rope-towed trolley crane. See Table 2 above. These are unfactored service loads.

SUPPLIERS

There are many experienced manufacturers of reliable rope-towed trolley cranes in Asia and Europe. The experienced suppliers for properly executed, reliable, machinery trolley cranes are limited to German manufacturers. Others will catch up rapidly because of the new interest in the machinery trolley design.

APL SELECTION PROCESS

Just about two years ago, APL concluded negotiations with the Port of Los Angeles for construction of a new port facility at Berth 300. APL elected to design the dock with a maximum crane rail allowable load criteria of 40 kips per foot of rail to accommodate future technological advances which will require increased dock load-carrying capabilities.

With the help of Liftech Consultants Inc. and McKay International Engineers, APL developed a new post-panamax crane specification. The specifications were written for the traditional rope-towed trolley design. Proposals were solicited for the purchase of twelve shoreside gantry cranes. Although the new specification allowed bidders to offer alternatives to the base specification, APL stipulated a preference for proposals which would focus on the base specification.

Bids were received from many international crane manufacturers. A number of them submitted alternatives to the base specification, but APL concluded that it was best not to deviate from their initial request, and APL focused on bids based on the base specification.

But one manufacturer, Noell Inc. of Germany, offered a design of a machinery-on-trolley. At first, APL did not consider changing from the traditional rope trolley. Perhaps this was because, even though the commitment from the beginning was to have an open mind, the traditional design was familiar and worked well. But taking a second look, after some creative encouragement by Mr. Manfred Kohler of Noell, the design began to intrigue the evaluation team.

APL's in-house evaluation team looked at it this way: If no container cranes had ever been built and there were no dock wheel load constraints, would the team recommend a crane with a rope-towed trolley system or as a machinery-on-trolley system? Interestingly enough, the group was inclined toward the machinery-on-trolley design.

As a next step, APL invited a small group of crane experts to join the evaluation team in an informal workshop to brainstorm the merits of the two designs. Joining our in-house team of Mr. Rab Puri, Mr. David Olsen, Mr. Pat Nuroet, and Mr. Julius Kerenyi were our consultants, Mr. Mike Jordan of Liftech Inc., Mr. Larry Wright of McKay International Engineers, and Mr. Norbert Beising, of Beising Engineering. As a preamble to the discussion, the team was asked to keep in mind the basic criteria: that no container crane had ever been built, no design constraints exist, and the goal is to optimize efficiency, reliability and maintenance of the crane. The interesting result of that session was how easily the group concluded that, with this criteria, the machinery-on-trolley design was the logical choice.

Prior to making the final decision, the APL team visited sites where Noell had installed similarly constructed cranes. The newest were at Algeceres, Spain. The input from Mr.

Steve Hessenauer, Maintenance Supervisor and Mr. Ken Valdez, Crane Operator, both from APL's San Pedro Terminal, was invaluable.

Why was the machinery-on-trolley system chosen?

Depending on the design, approximately 5,400 ft. of wire rope is eliminated from the main hoist, trolley drive, and catenary trolley.

Approximately 36 sheaves of various sizes are eliminated.

Hydraulic rope tensioning devices are eliminated.

The spare parts inventory is reduced.

The intensity of maintenance is reduced.

Up-time reliability is increased because of the reduced number of crane components.

Wire rope lubrication is reduced.

CONCLUSION

Both types of trolley systems - the rope-towed and the machinery-on-trolley - have beneficial site specific applications. For each crane purchase, the owner will need to evaluate each design and then choose the design which best suits the site and the all-round operational needs.

ACKNOWLEDGEMENTS

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