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NEW CONTAINER CRANE CONCEPTS

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INTRODUCTION

During the thirty-five years since the Matson dockside container cranes were designed, the size and lifting capacity of container cranes have doubled. Many new concepts have been developed to meet special needs, improve safety, increase productivity, and improve economic performance.

This paper describes some of the new concepts developed for A-frame and low profile cranes and discusses the elevating trolley girder concept originated and patented by C. Davis Rudolf III and Anthony J. Simkus, Jr. of Virginia International Terminals.

A-FRAME CRANES

VIT ELEVATING TROLLEY GIRDER

The Concept:

VIT pioneered the concept for this crane from experience with the elevating platform, dual hoist crane, experience with state-of-the-art single hoist cranes, and research to determine the optimum crane type for the VIT North Yard Terminal expansion. Although the dual hoist, elevating platform container crane was a significant jump in container handling capacity from the older generation single hoist cranes, it still has a number of shortcomings. It is roughly 50 to 75 percent more expensive than a single hoist crane, and there is a significant increase in the complexity of the electronics, the number of drives, the hydraulics, and other mechanical aspects. It requires two operators vice the one operator for a single hoist crane. Along with this is the challenge of the single hoist crane: to eliminate, or at least reduce to an acceptable level, the sway characteristics of a crane in trolleying from inshore to offshore and vice versa.

The sway characteristics of the newer, single hoist cranes are aggravated by the fact that the post-panamax size positions operators as high as 112 feet. This, coupled with the higher speeds of hoist and trolley, made sway a significant problem requiring reduction.

Over the years, reduction in sway has been attempted in a number of ways including hydraulic methods, automation systems incorporating an anti-sway solution, and robotics systems. All of these attack the symptoms and not the real cause: a container hanging, like a pendulum, from wires extending down from the trolley.

For years, VIT has worked to come up with a method to eliminate the pendulum action of the load hanging from the wire. At first, some type of a level luffing crane where the container could be hoisted tight up against the end of the boom and then moved vertically through a rotation of the crane itself from waterside to landside was considered. A type of rigid steadying device that could be extended from the trolley, such as a scissors mechanism, was also considered. Both proved to be theoretically possible, but physically impractical.

About a year ago, VIT hit on an idea which would involve a type of low profile crane where the boom rolls out and back on rollers. The boom is mounted on hangers. If these hangers could be lowered or raised, the boom could be brought down to the lowest level at which the crane needed to work. This way, with very little hoisting, the container could be brought up tight against the trolley and then moved back and forth with high speeds and accelerations. Since the load is tight against the trolley, the cause of sway is virtually eliminated. VIT subsequently investigated this with Liftech Consultants Inc. Liftech refined the concept to show that a conventional style crane would be preferable to a low profile type because of the wheel loads, and an entire upper structure attached to the trolley girder could be raised and lowered. The Liftech crane would also have a conventional stowable boom. Once Liftech determined this type of crane was feasible, they performed a simulation study to compare the new crane with the conventional single and dual hoist variety. The simulation showed the new crane to be comparable in productivity to the dual hoist, while requiring only one operator. Examining the potential cost of such a crane also showed that it would be significantly less expensive than a dual hoist crane, but 20 to 25 percent more expensive than a conventional single hoist container crane. The details of the raising, lowering, and stopping mechanisms for the crane are currently being developed by McKay International Engineers. VIT, Liftech, and McKay feel that this crane has a potential in the industry for fast, economical, and efficient container handling.

The Crane:

The VIT elevating trolley girder crane, figures 1a and 1b, consists of two large elements, the gantry frame and the upper works including the elevating trolley girder and its stays, struts and masts. See figure 1c. [1]

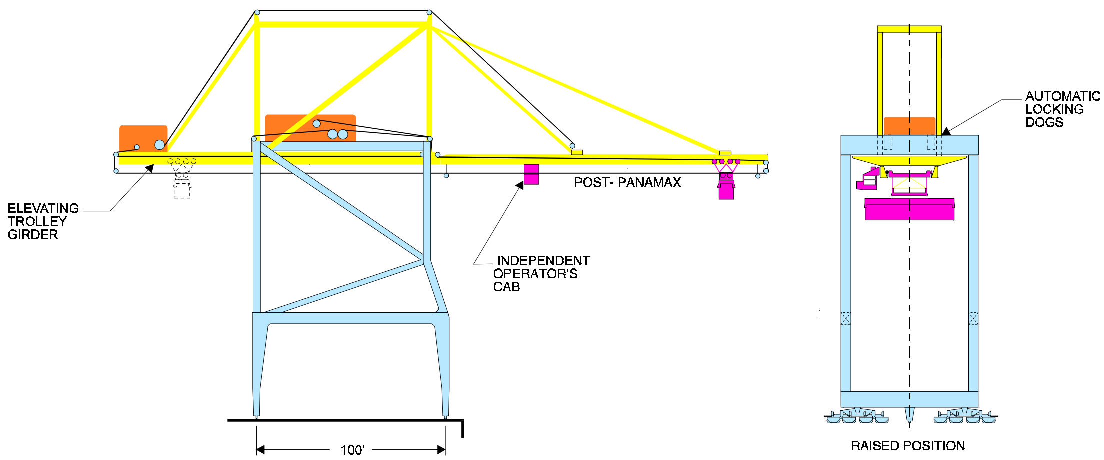

Figure 1a: GENERAL ARRANGEMENT RAISED
Virginia International Terminals Concept
VIT/Liftech - McKay 1993

The upper works is supported vertically by four masts which extend through the deep trolley girder support beams of the gantry frame. Hydraulic cylinders, located on the support beams, dog off the upper works during operation and provide safety locks at all times during raising and lowering.

The upper works is elevated by an upper works hoist located in the machinery house on the gantry frame. The hoist includes two drums, geared together to share the load and provide redundancy. Each drum is driven by independent motors and gear reducers. Each drive has independent brakes. The hoist ropes have a factor of safety of eight.

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[1]The nomenclature on the figures:

"VIT/Liftech-McKay", indicates that this is a VIT project and that Liftech and McKay are the consulting engineers. In all cases, except where noted in the text, Liftech provided the detailed structural design and McKay provided the mechanical design.

Panamax indicates that the crane services ships that can pass through the Panama canal.

Post-panamax indicates that the crane services ships, such as APL's C- 10's, which are too broad to pass through the canal. The outreach for post-panamax cranes is about 150 feet. The height of the spreader above the wharf is more than 100 feet.

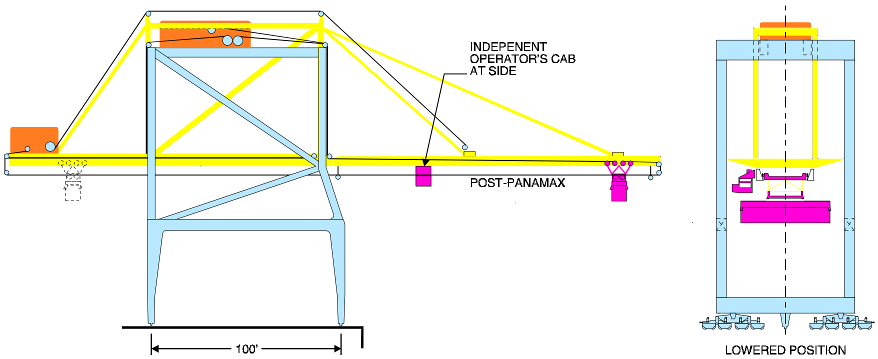

Figure 1b: GENERAL ARRANGEMENT LOWERED
VIT Concept
VIT/Liftech - McKay 1993

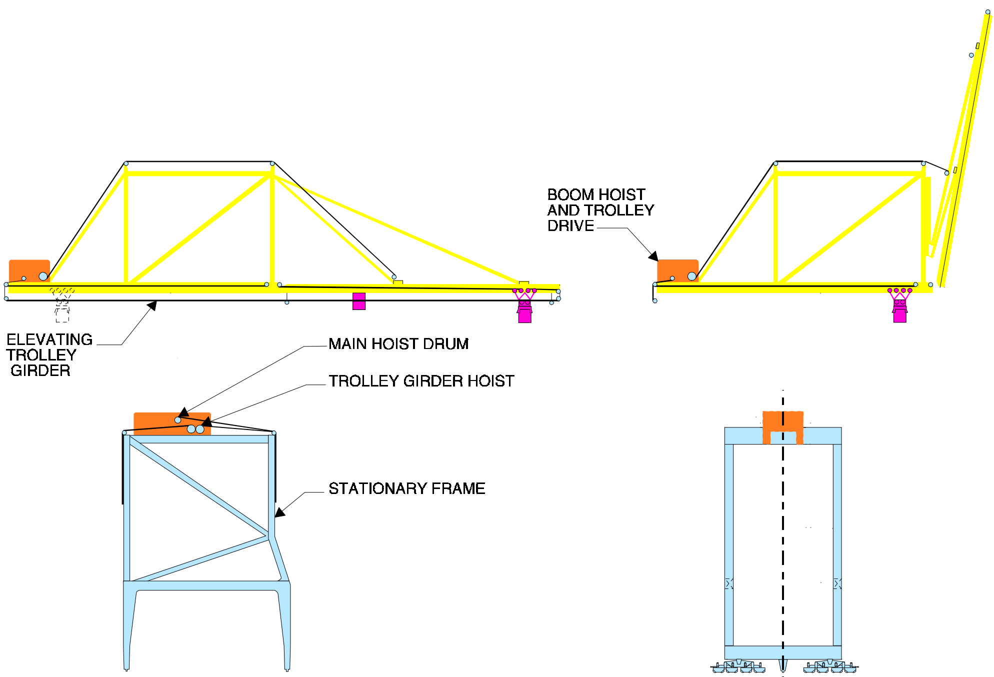

Figure 1c: CRANE COMPONENTS
VIT Concept
VIT/Liftech - McKay 1993

The system is redundant to the second degree. Power plant cranes that handle nuclear fuel need only be redundant to the first degree. The system is ultra safe. The hydraulic cylinders that normally dog off the masts can be used to slowly raise or lower the upper works, if necessary.

The main hoist is above the upper works hoist in the machinery house. The main hoist ropes run up and down between the waterside leg to the trolley girder.

The upper works is guided laterally by the gantry frame legs.

ANSALDO KAOHSIUNG CRANE

This unusual crane, shown in figures 2a and 2b, is designed to support two trolleys on the same trolley girder runway. Currently, only one trolley operates on the runway. A second trolley may be added in the future. One trolley will operate from the backreach to the waterside leg, and the other trolley will operate from the landside leg to the outreach. Containers will be deposited to and from a platform on the portal beam.

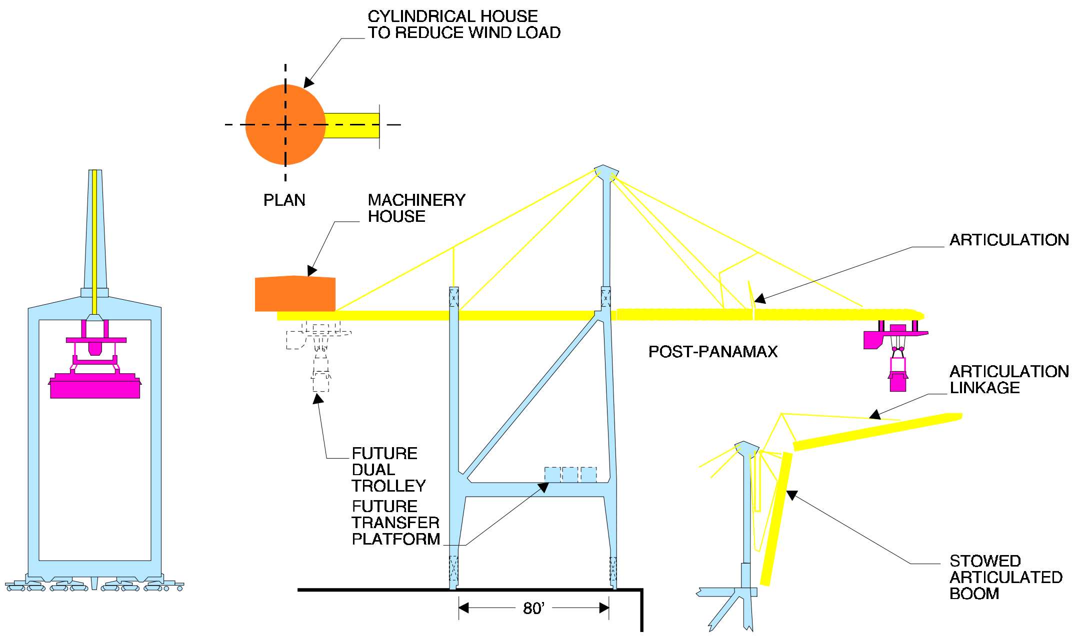

Figure 2a: GENERAL ARRANGEMENT
Ansaldo/Liftech - McKay
Kaohsiung 1990

Ansaldo has standardized on a single trolley runway girder crane. They are currently using such a scheme for the Puertos Mexicanos cranes. By nature, this design is efficient and offers a minimum wind resistance.

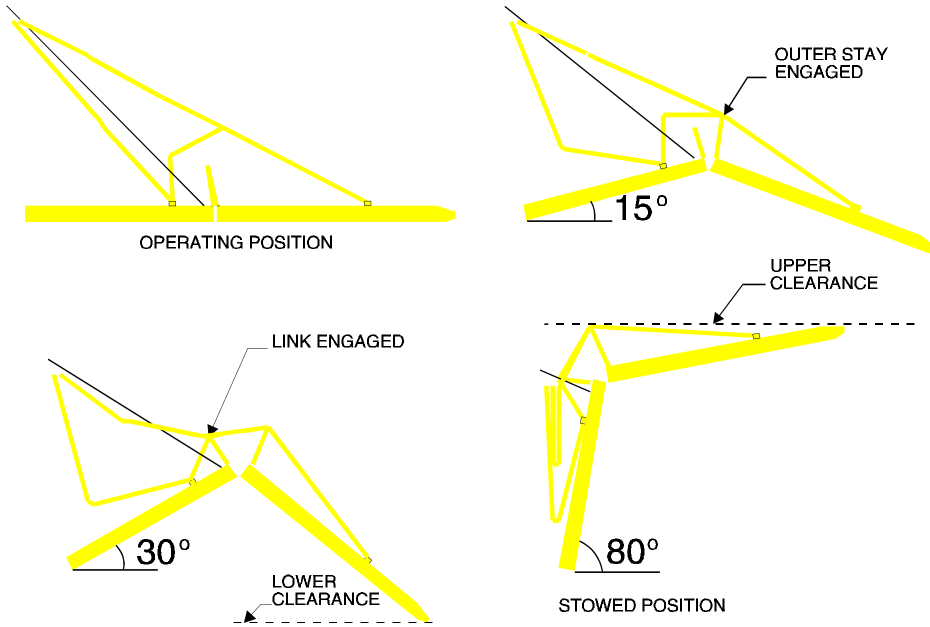

Figure 2b: ARTICULATED BOOM
Ansaldo/Liftech - McKay
Kaohsiung 1990

The standard rectangular machinery house is not nicely shaped for wind. The cylindrical house shown in figure 2a, which is nicely shaped, reduced the wind load on the house by 40 percent.

Aircraft clearance requirements mandated an articulated boom. The stowed wind speed is 225 mph at the boom tip. The weight of the double trolleys, the aircraft clearance requirements, and the wind loads made a conventional articulation reaving system impractical The solution is the boom articulation linkage system shown in figures 2a and 2b.

As the boom hoist begins to raise the boom, the tip dives down to just above the lower clearance line. Notice that the lower edge of the boom is clipped to increase the clear height.

At about 15°, the outer stay engages a mast on the boom. The mechanism, consisting of the frame, boom inner and outer, and the hoist ropes, becomes a "four bar linkage". At about 30°, the link between the inner boom and the outer boom engages, and the boom continues to raise as a rigid body. When fully raised, the boom tip clears the upper clearance line. Notice the top of the boom is clipped to reduce the overall height.

A computer program was used to develop the geometry and calculate all the member forces during all stages of raising.

This crane has a rather odd appearance but is structurally efficient and quite light, considering its capabilities.

Liftech provided the structural design of the crane including the articulation structure. McKay designed the mechanical components of the articulation system.

DEER PARK POST-PANAMAX TRUSSED BOOM

Until this boom was developed, all double forestay post- Panamax booms were plate or box girders. The special requirement here was that the out-to-out of the boom be limited to allow setting 20 foot containers close to the ship's house. See figures 3a and 3b.

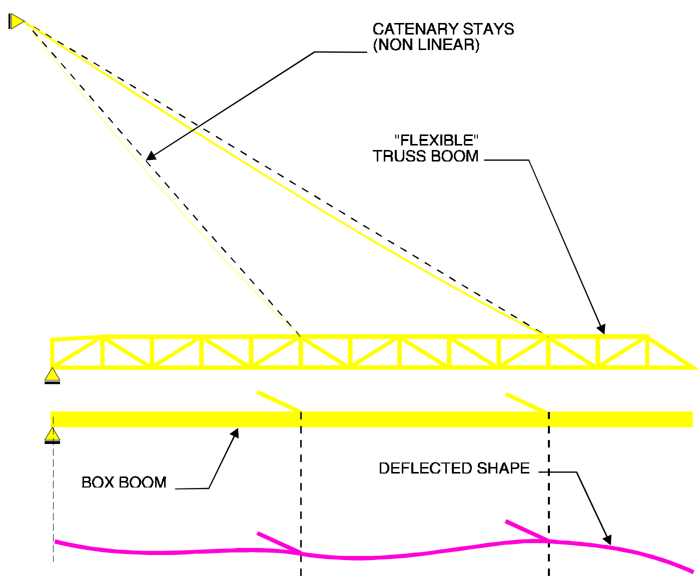

Figure 3a: ELEVATION
Deer Park/Liftech
Melbourne 1991

The manufacturer wished to use an overriding trolley rather than an underhung trolley. An underhung trolley could have met the out-to-out requirement, but this would have required a complete new design of the manufacturer's standard product.

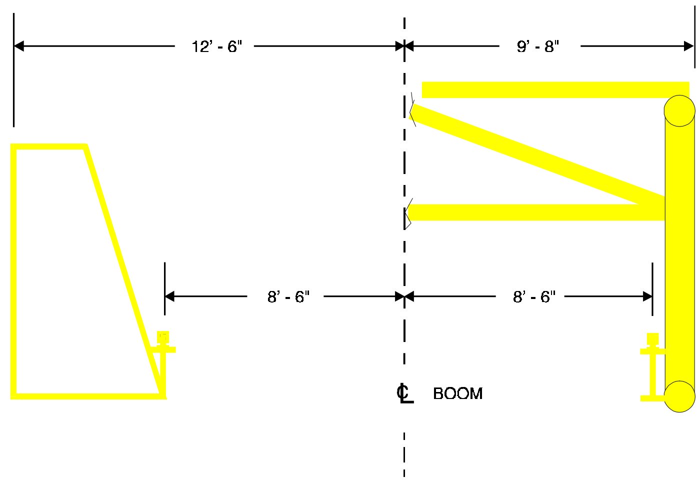

Figure 3b: FLEXIBLE TRUSS BOOM
Deer Park/Liftech
Melbourne 1991

Since the forestay stiffness is nonlinear (because of the catenary curve), the boom should be flexible enough to favorably distribute the load to the stays. A shallow plate or box girder boom is suitable. A traditional trussed boom is not suitable, since it is stiff and would cause too much load to go to one stay. A single stay boom would be too heavy.

The shallow boom met the performance requirements and was, according to Deer Park, easier to build. This design is by no means a breakthrough, but it is another approach to a typical problem.

LOW PROFILE CRANES

The first low profile container cranes were constructed in the 1960's. The Paceco standard panamax design is shown in figure 4. The boom is supported by a hanger system including support trucks and wheels. The boom rides on the wheels at all times.

For the Paceco standard, all machinery and electrical equipment is on the boom. The machinery travels with the boom and causes significant increases in the wheel loads. For post-panamax cranes, the machinery on the boom approach causes extremely high wheel loads requiring unusually strong runways.

Some new design concepts have been developed for post-panamax low profile cranes which reduce the weight of the crane and the wheel loads.

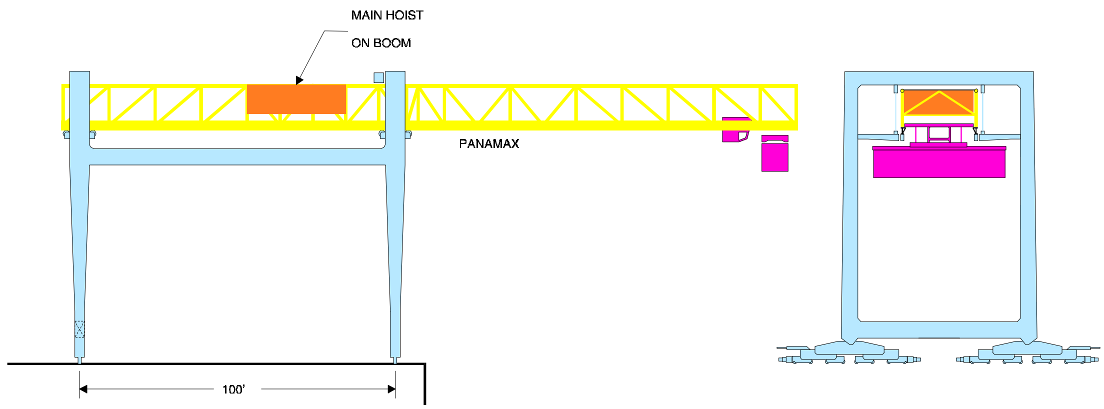

Figure 4: GENERAL ARRANGEMENT PACECO STANDARD
Paceco/Liftech
Boston, Genoa, Elizabeth, NJ,
Oakland, Hong Kong Circa 1970

KOCKS OAKLAND LOW PROFILE CRANES

This post-panamax low profile crane, shown in figure 5, operates on crane runway girders designed to support Paceco standard Panamax cranes. Wheel load limitations required some new concepts.

Typically, post-panamax low profile booms travel about 170 feet. Compare this to a panamax boom which travels about 125 feet. The weight of the post-panamax boom is, therefore, extremely important. The Kock's boom weight was reduced by placing the main hoist and electrical components on the frame.

The main hoist motors and gear boxes are in machinery houses at the side of the boom, "saddle bags", and the main hoist drum is placed directly over the boom. The main hoist ropes run along the top of the boom to turning sheaves at the landside end, then to the trolley, and from the trolley to turning sheaves at the waterside end. The ropes dead-end at sway control cylinders mounted on the frame waterside of the main hoist drum. Because of this reaving, there is no net horizontal force to the boom.

In the full outreach operating position there is no backreach. For intermediate positions, when the boom is not fully extended, there is some backreach.

Liftech and McKay provided the design concept and detailed preliminary analysis to demonstrate that the crane could be built to perform as desired and Kocks provided the final detailed design. Although not required to do so, Kocks used the Liftech-McKay concept.

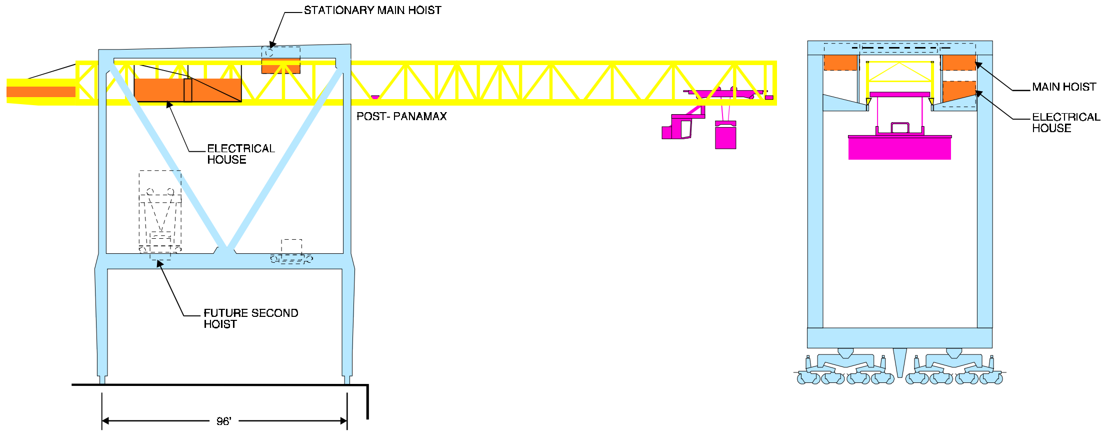

Figure 5: GENERAL ARRANGEMENT
Oakland Low Profile
Kocks/Liftech - McKay
Oakland 1990

SAMSUNG HEAVY INDUSTRIES LOW PROFILE PORT EVERGLADES CRANE

This low profile crane, shown in figure 6a, was the only design submitted in response to Port Everglades RFP that met the specified wheel load requirements. The concept that significantly - on the order of 30 percent - reduced the weight was moving the landside boom support 28 feet landside of the landside gantry rail.

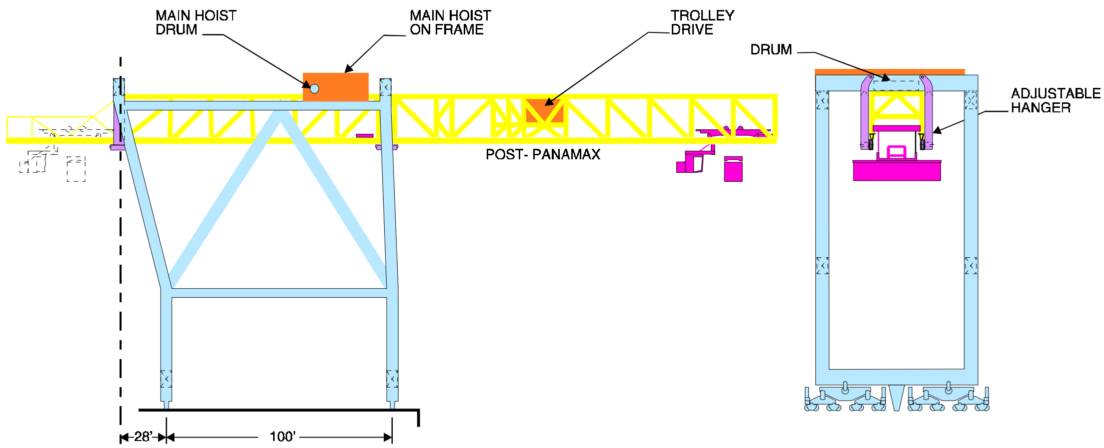

Figure 6a: GENERAL ARRANGEMENT
Samsung Heavy Industries/Liftech
Port Everglades 1993

The increased support dimension reduced the moving load shear and hanger reactions by 28 percent and the stowed wind load boom moments by 23 percent. These reductions compounded: less load required less structure, less structure caused less load.

The Everglades aircraft clearance was about 20 feet above Oakland's, so the machinery house could be located above the boom, a simpler and less expensive solution.

The hanger system is new. See figure 6b.

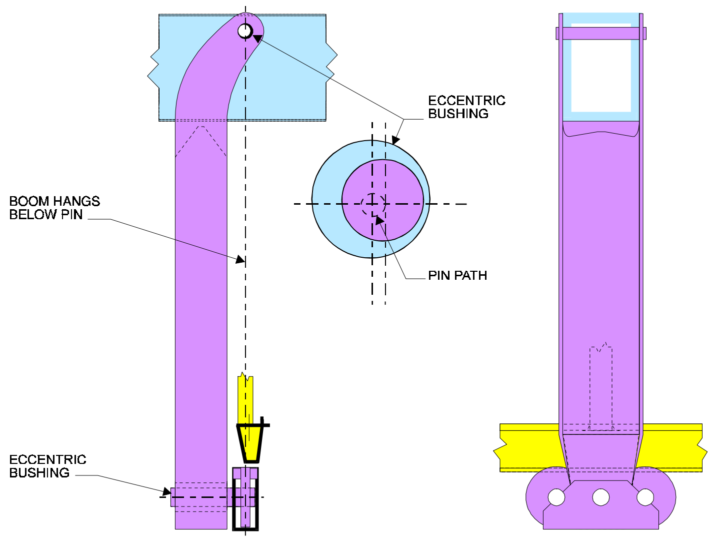

Figure 6b: HANGER
Samsung Heavy Industries/Liftech
Port Everglades 1993

When the boom or the trolley moves, the loads on the boom supports vary from a maximum to zero. As the hanger load varies, the frame deflects and the legs spread. The design of the support system needs to account for the relative movement between the boom and the frame.

The Everglades wind loads are notorious. The boom wind loads are carried by horizontal bracing in the plane of the upper chord. The cleanest load path is directly from the upper chord to the frame.

The boom support wheels may not be perfectly aligned. This causes the boom to crab during boom shuttling.

The hanger system overcomes all these difficulties. The hanger connects to the support beam directly above the applied vertical load. Statics forces the hangers to be perfectly vertical. The hanger is not connected to the legs, so leg movement is not important.

The lateral loads are taken by side rollers supported by the frame and pressing against the upper chord (not shown on the figure for clarity). This is efficient and allows the structure to deflect during hurricanes.

The orientation of the boom support wheels is adjustable. Eccentric bushings at strategic pins provide for raising, lowering, and rotating the alignment of the wheels.

Although not required by the specifications, the boom is designed to be stable if one support is removed.

PACECO BOSTON PROPOSAL

This winning proposal takes advantage of the broad boom support concept but places the main hoist and trolley drive machinery on the boom. This crane is, therefore, the Paceco standard, only bigger - about 50 percent bigger. The wheel loads are therefore about 50 percent bigger. The allowable working operating wheel loads are unusually high - 200 kips per wheel for a five foot spacing. There are eight wheels at each corner. See figure 7.

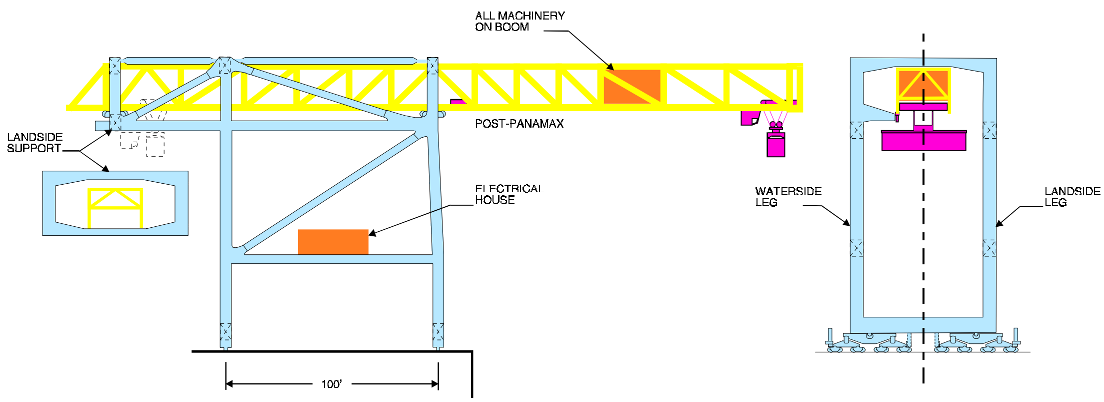

Figure 7: GENERAL ARRANGEMENT
Paceco/Liftech - McKay
Boston Proposal 1993

The spread between the boom supports is 150 feet. This reduces the moving load shear in the boom by 33 percent and the stowed boom moment by 39 percent. Again, these effects compound and the savings in weight is significant. The weight would be even less if all the machinery were on the frame, but the added mechanical cost is more than the reduction in the structural cost.

The extreme landside position of the landside boom support allows use of an O-frame instead of hangers or brackets. This saves weight and eliminates the leg spread problem. It also provides positive stops which prevent the trolley from traveling too far landside.

Brackets cantilevering from the waterside legs provide the waterside boom support. Brackets are used because of the owner's preference. The cost differential between brackets and hangers is small. Both are reliable. Provisions will be made for alignment of the boom support wheels during erection.

The 150 foot spread between the boom supports is nearly as great as the boom travel distance, about 165 feet. The machinery is located so the center of gravity of the boom is a little waterside of the waterside support when the boom is in the operating position, and a little waterside of the landside support when the boom is stowed. Waterside hold-down rollers are therefore not required.

The boom travels on wheels and operates on fixed pads. The wheels are raised and lowered by hydraulic jacks. Elastometric pads allow for relative movements at the fixed supports.

In order to provide adequate work space, the machinery house, which is built into the boom, extends outside the boom structure to the limits of the allowable boom width. The electrical house is on the portal beam to reduce the boom load and the effects of lateral loads.

The frame is somewhat different from Everglades in that the landside leg is not sloped. This is to meet the specified clearance diagram. A change in the clearance has been requested. If accepted, the landside leg will slope from the portal beam, and the upper vertical landside leg above the portal beam will be eliminated.

SAMSUNG HEAVY INDUSTRIES BOSTON PROPOSAL

Although this proposal, figure 8a, was not the winner, it has some interesting features. The machinery is fixed on the frame, but to one side. See figure 8b. This simplifies the machinery and allows ample work space.

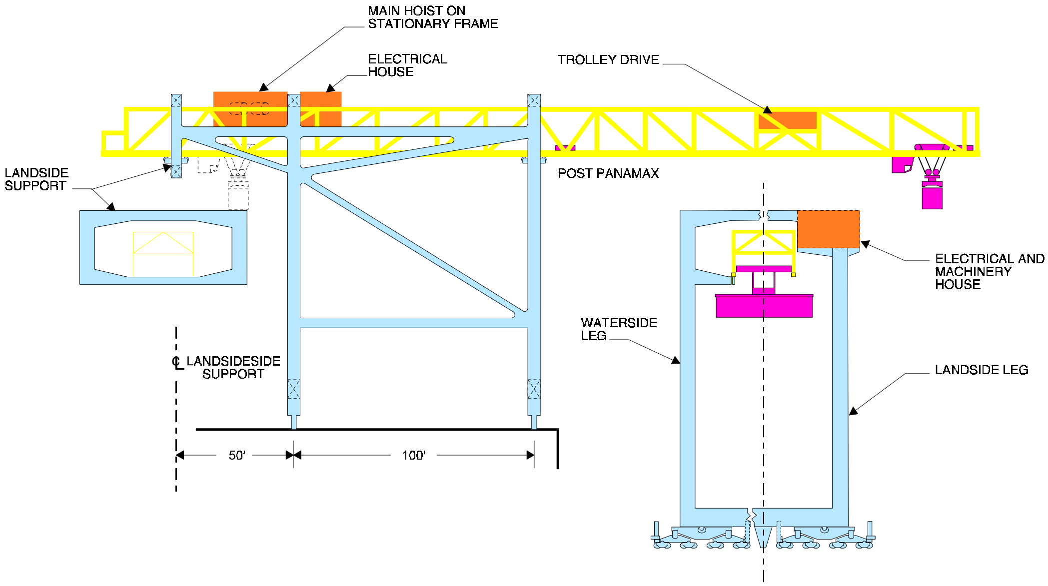

Figure 8a: GENERAL ARRANGEMENT
Samsung Heavy Industries/Liftech
Boston Proposal 1993

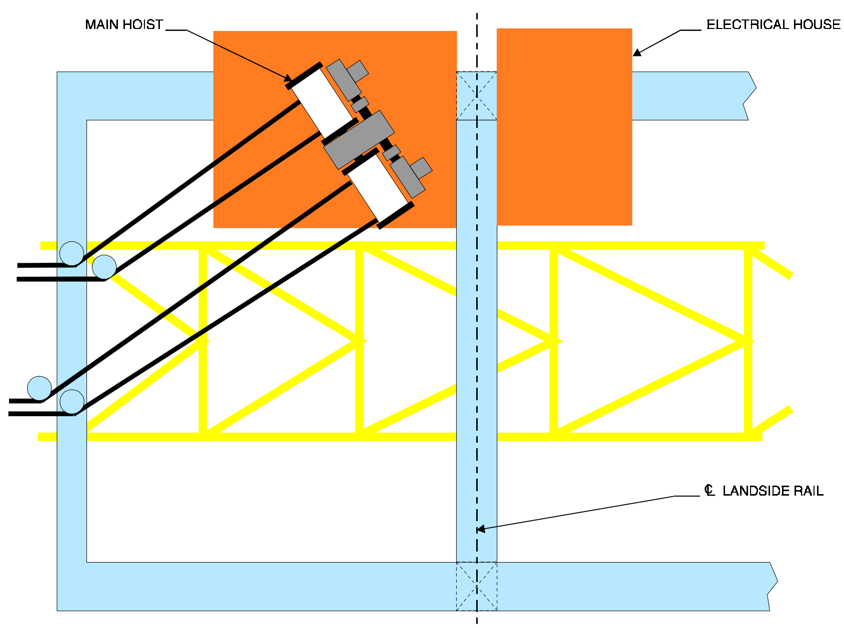

Figure 8b: GENERAL ARRANGEMENT
Samsung Heavy Industries/Liftech
Boston Proposal 1993

Samsung estimated three designs: the one shown, one with the machinery on the boom, and one with a plate girder boom.

The plate girder boom had two vertical girders with horizontal bracing at mid-depth leaving a space above the bracing within the boom. The machinery was fixed to the frame but hung below the upper flange into this space.

CONCLUSION

The original Matson crane was designed, drawn, and analyzed by hand with pencil, paper and a slide rule. Only a few ideas could be explored. Computers have changed this: ideas which were impractical because of analysis difficulties are now practical. This is not just an advancement in technology. Computer analysis allows the objective examination of many ideas and the qualitative evaluation of each idea.