Masterclass on Crane Procurement, Modernization, and Maintenance

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Masterclass Topics

Section One: Crane Procurement

Section Two: Crane Modernization

Section Three: Crane Useful Life Assessment and Maintenance

Section One: Crane Procurement

Crane Procurement Overview

Evolution of quay crane industry

Demands and restraints

Crane procurement strategies

Options

- *Case study—tailor made*
- *Mechanical and electrical system choices*
- *AC vs. DC motors and drives*
- *Standard or specialty cranes*

Conclusions

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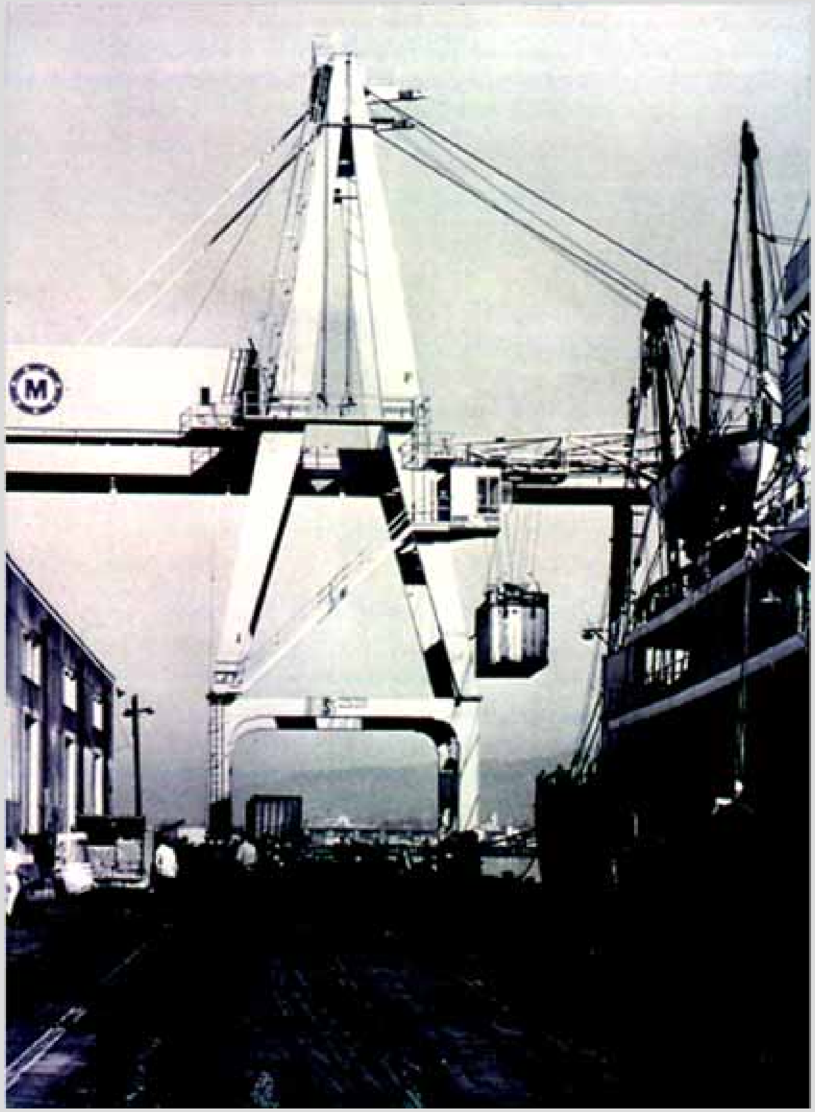
Evolution of Container Crane Industry



Paceco 1960

Pioneer

Good quality

Standard features

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Evolution

Europeans (Early 1960's)

Japanese (Late 1960's)

Repeated with:

- *Koreans (1970's)*
- *Others*
- *Chinese (1990's)*
  - *Significant impact in tailor-made procurement*

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Current Environment

Chinese success

Highly competitive pricing

Cost-cutting measures

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Cost-Cutting Measures

Sub-contract fabrication

Remote fabrication

Standardize components

Reduced profits

APL Los Angeles cranes
Noell, Abu Dhabi

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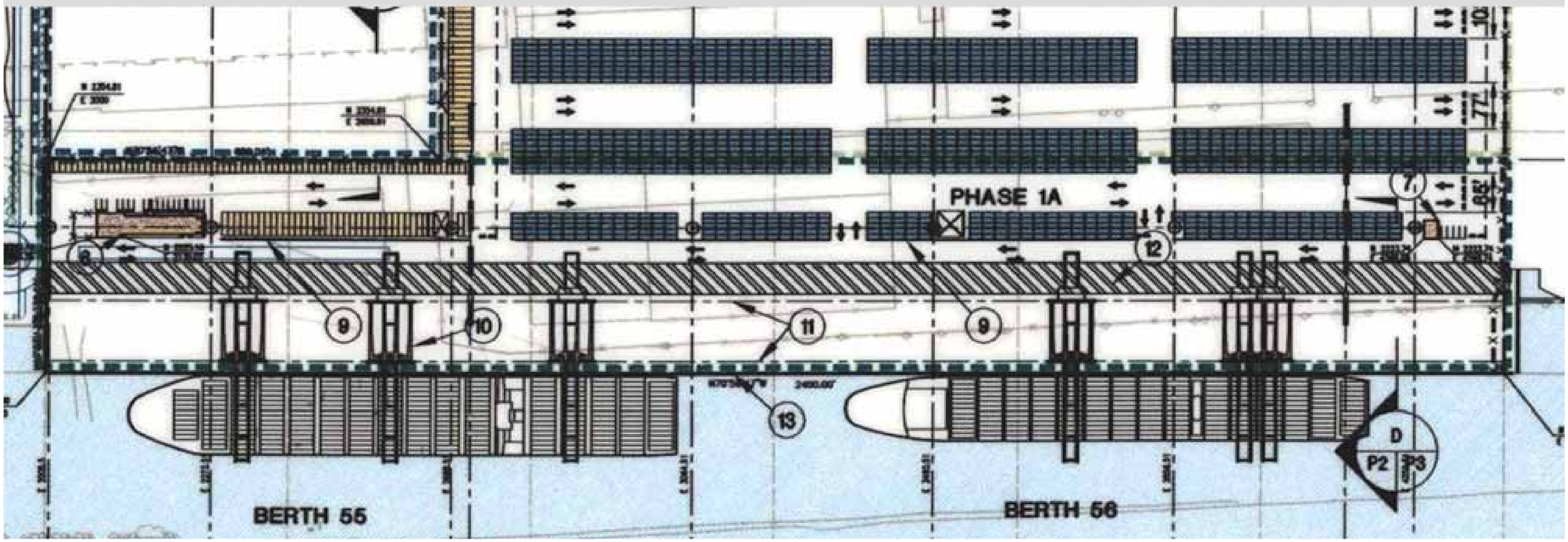
Terminal Demands and Restraints

Terminal demands

Geometry and restraints

Planning for the future

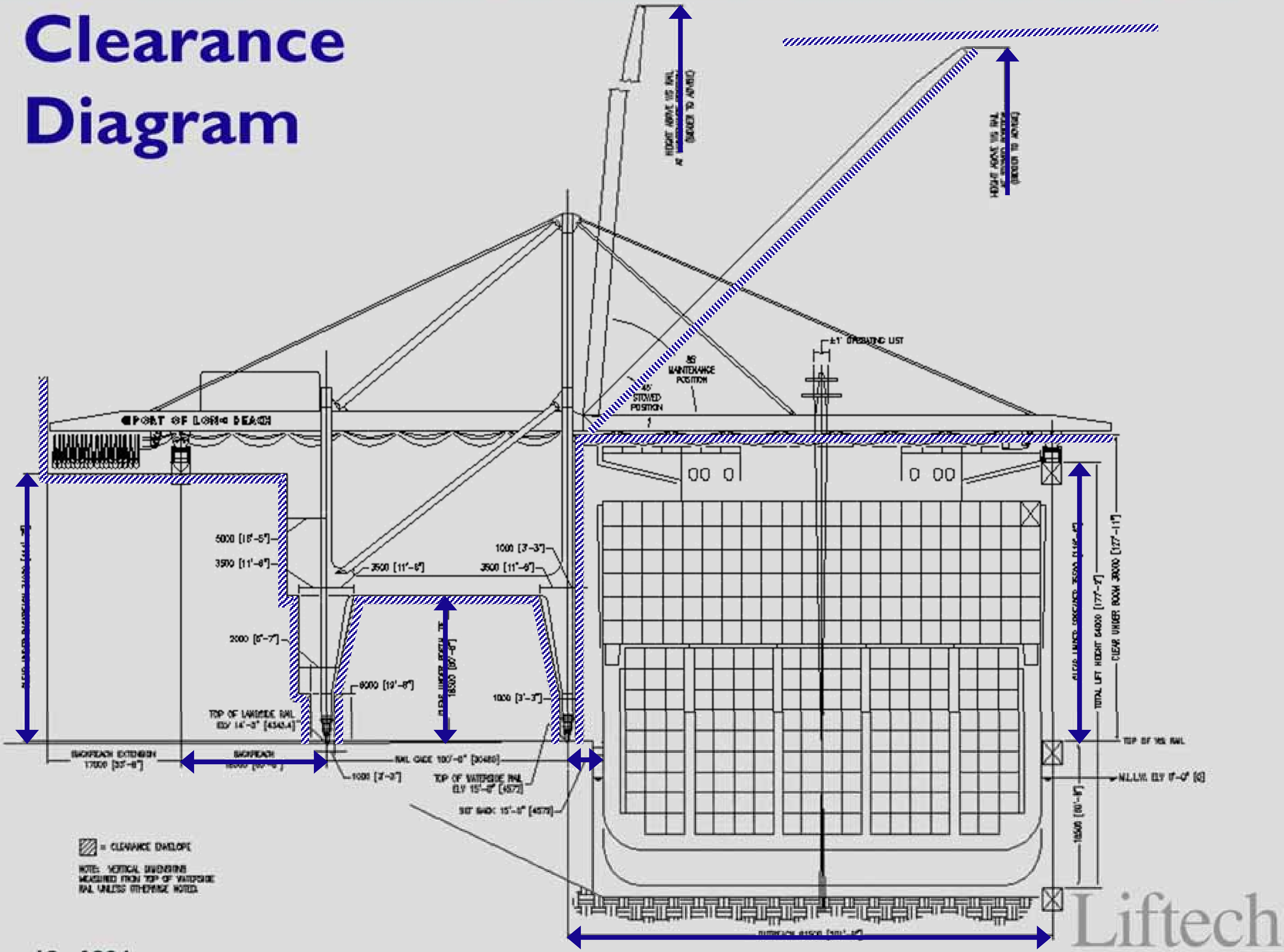
Source: JWD Group



Crane Geometry vs. Ship Size

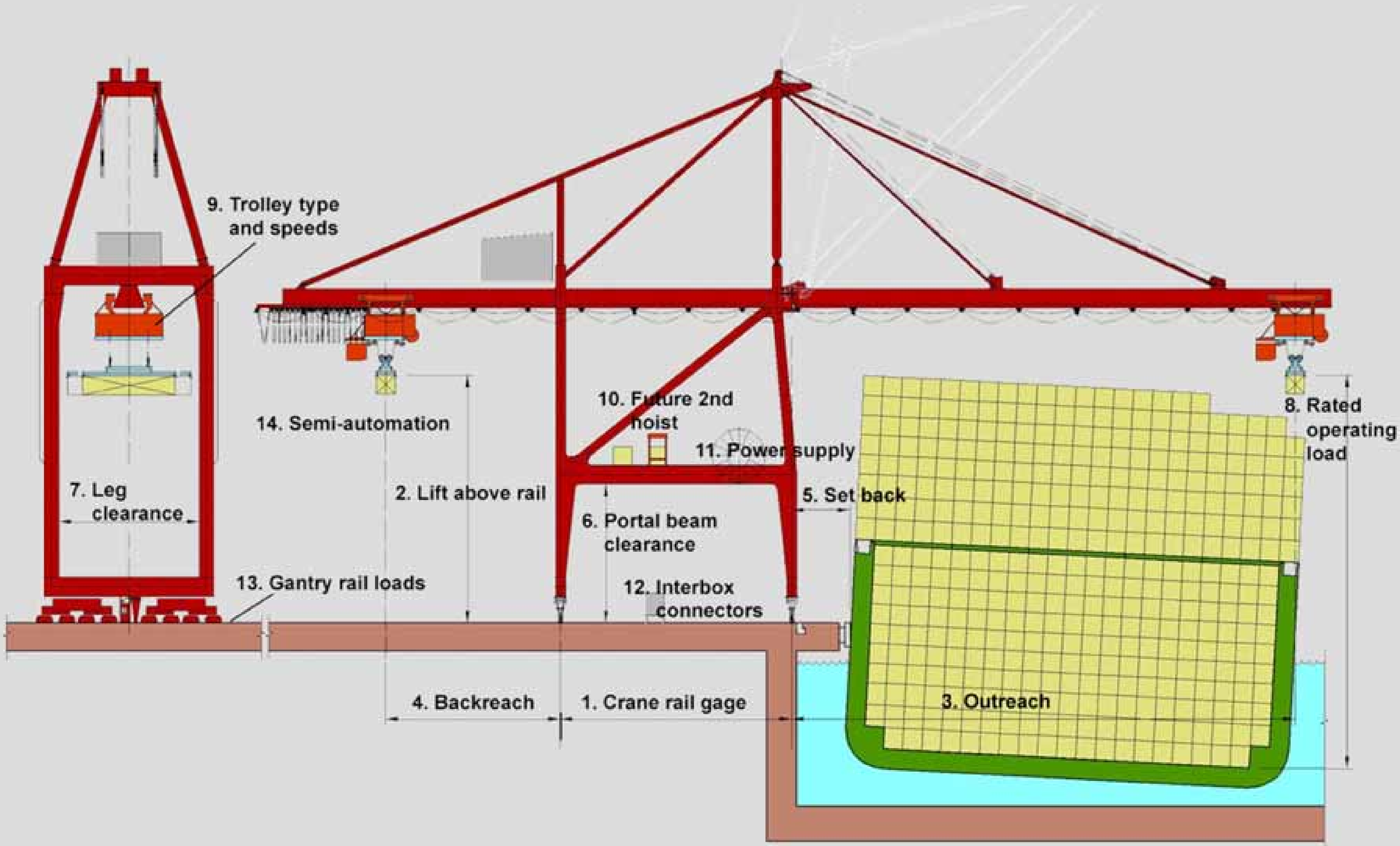
Typical values	Panamax APL C9	Post Panamax C10	Regina Maersk	New Maersk Standard	Suez-max	Malacca - max
Containers across deck	13	16	17	22	23	24
Ship Draft, m	11.6	12.5	13.7	15.2	17.1	21.0
Ship Beam, m	32.0	39.3	41.8	54.3	50.3	54.9
Outreach, m	35.8	45.7	51.6	64.2	66.7	69.2
Setback, m	4.3	4.3	7.6	7.6	7.6	7.6
Gage, m	15.24	30.48	30.48	30.48	30.48	30.48
Backreach, m	9.1	15.2	15.2	15.2	15.2	15.2
Wheels per Corner/ spacing	8 / 1.5					
Out-to-Out distance between bumpers, m	27.0					
Capacity, LT	30	40	50	60	65	65

Clearance Diagram



Leg/Rail Setback

Future Planning



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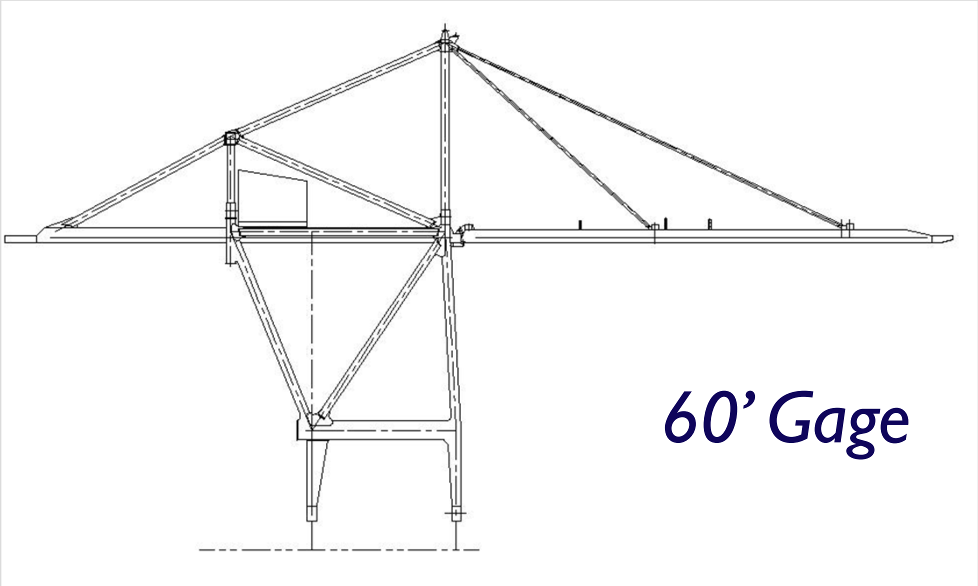
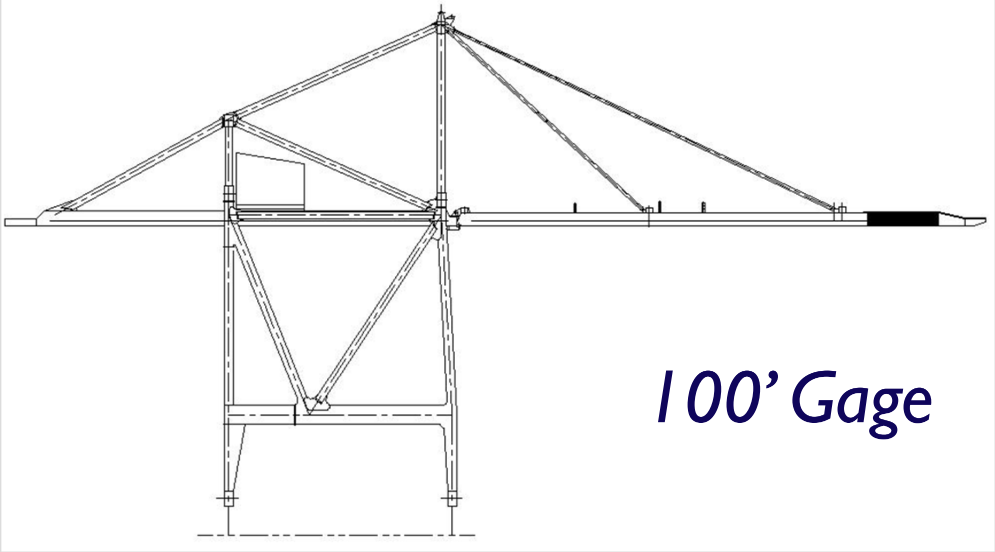
Tacoma Crane Concept



Before Extension



After Extension

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Crane Procurement Strategies

Manufacturer selection:

Off-the-shelf

Tailor-made

Hybrid

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Off-the-Shelf

Visit operating cranes—2 to 3 vendors

- *Get input from Operations and Maintenance personnel*
- *Obtain manufacturer specifications*

Understand procurement process and quality monitoring effort

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Off-the-Shelf Procurement Process

Issue specification outline

Solicit terms

Confirm manufacturer specifications

Negotiate

Implement monitoring effort

Off-the-Shelf Specification Outline

Key Points

Geometry and capacity requirements

Stability against storm winds

Quay capacity

Power supply

Electrical vendors

Specific features and components

Off-the-Shelf Limitations

Suitable for private industry

- *Can use different standards*
- *Not limited to low bidder*
- *Can negotiate*

May not be suitable for public agencies

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Off-the-Shelf Case Study

Red Hook Terminal, NY

Public financing of private industry

Small – medium size

Limited monitoring effort

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Tailor-made

Detailed specifications

Confirm technical proposals

Consider bid alternates

Implement quality monitoring program

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Specifications & Standards

*Standard specifications cover standard cranes, not **container** cranes*

Container cranes are unique for many reasons

- *Eccentric loads*
- *High speeds*
- *Heavy duty cycles*
- *Very high reliability requirements*

Standards and specifications must be interpreted by experienced engineers

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Detailed Performance Specifications

SPECIFICATIONS FOR
CERES HALIFAX TERMINAL CRANES

TECHNICAL PROVISIONS

for
Cerescorp Company
Halifax, Nova Scotia, Canada

FIRST EDITION
AUGUST 7, 2000

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McKay International Engineers

Start with detailed baseline specifications

Identify specific components

Identify specific needs

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Consider Bid Alternates

Require bid for specified crane

Alternate bids for vendor specifications

- *Bidders note exceptions*
- *State reasons for exceptions*
- *Only use proven designs*

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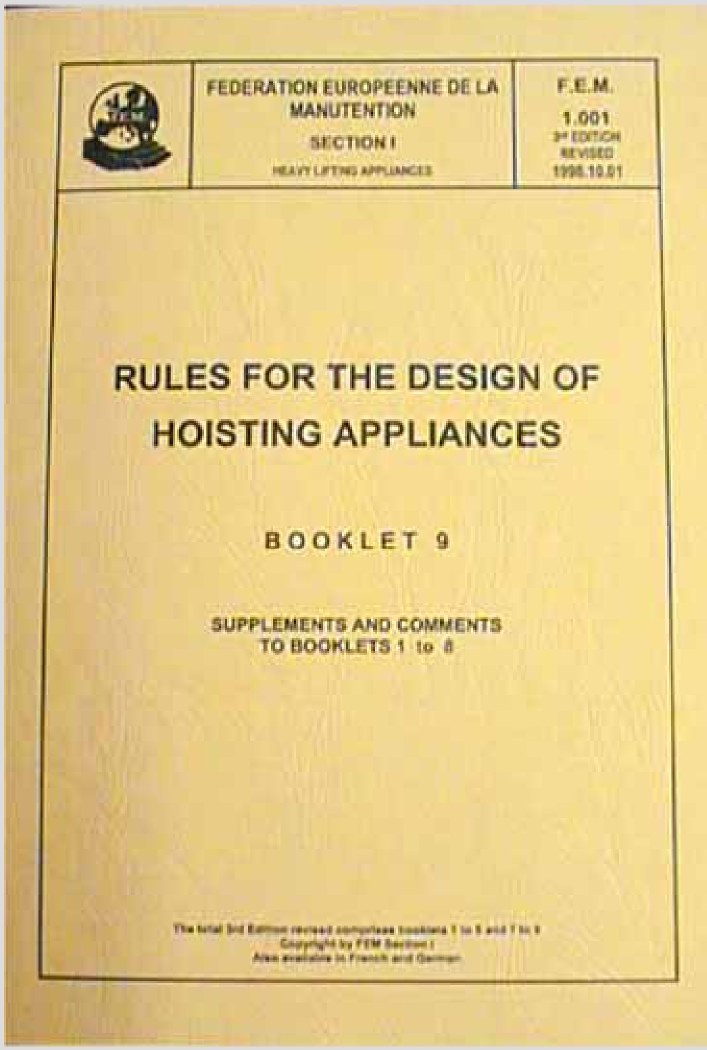
Confirm Technical Proposals



Specifications compliance

Evaluate standards

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Evaluate Commercial Proposals

Capital costs

Lifetime costs

Monitoring costs

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Quality Monitoring

Verify designs

Verify manufacturing quality

On-site inspection

Verify commissioning

Punch list

Monitoring Costs

Depend on:

Manufacturer location

Manufacturer quality control

Extent of sub-contracting

Existing relationships:

Purchaser – Manufacturer

Manufacturer – Fabricator

Fabricator – Erector

Typical monitoring costs:

Off-the-shelf	*0.5 - 1.5%*
Tailor-made	*2.5 – 5.0%*

(as % of price of a two-crane order)

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Options

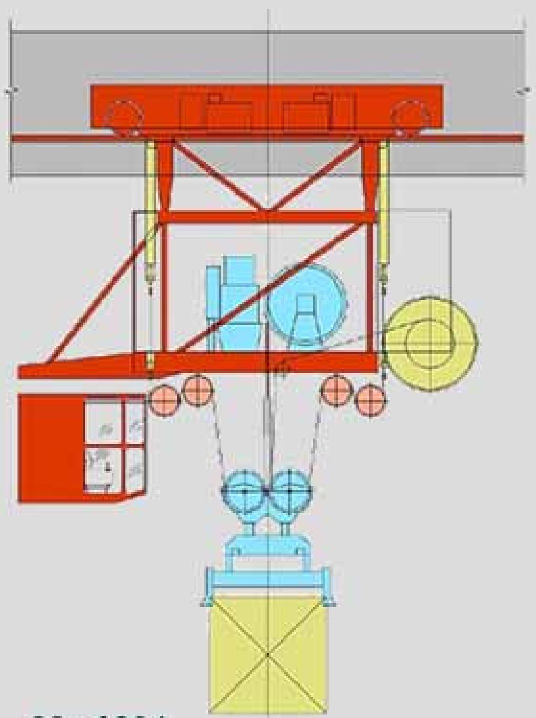
Productivity enhancements

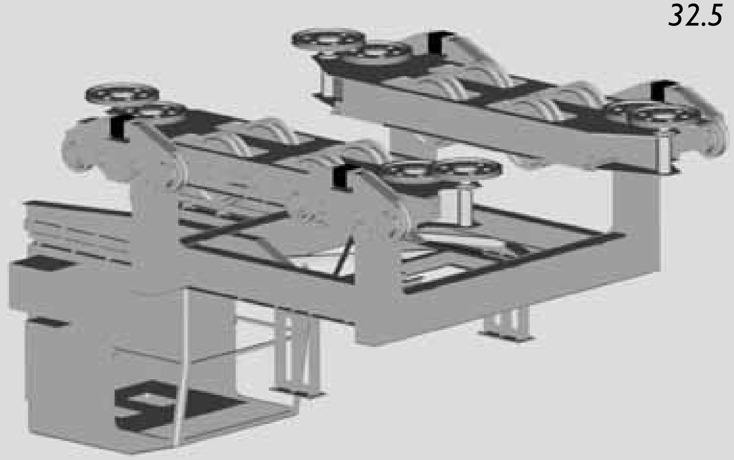
Capacity

Trolley type

32.5 LT

32.5 LT





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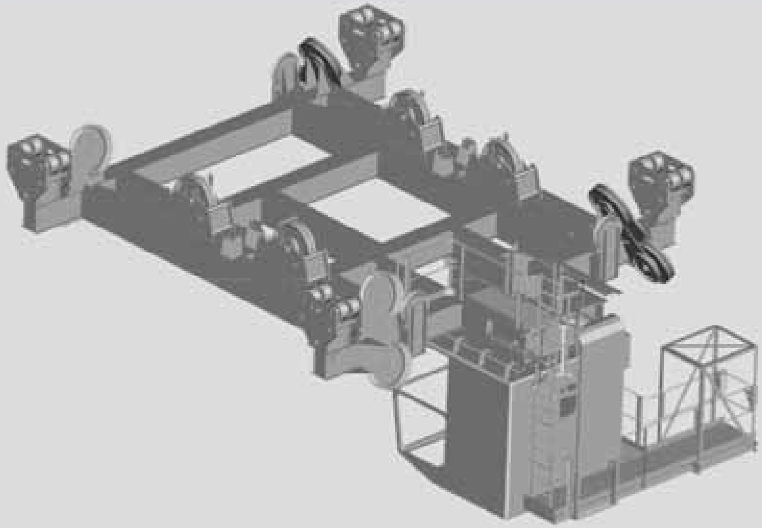
Trolley Types



Rope trolley (RTT)

- *Continuous support*
- *Catenary trolleys*
- *Self-driven option*

Machinery on trolley (MOT)

- *Rope-towed option*

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RTT

Catenary trolleys

Continuous support

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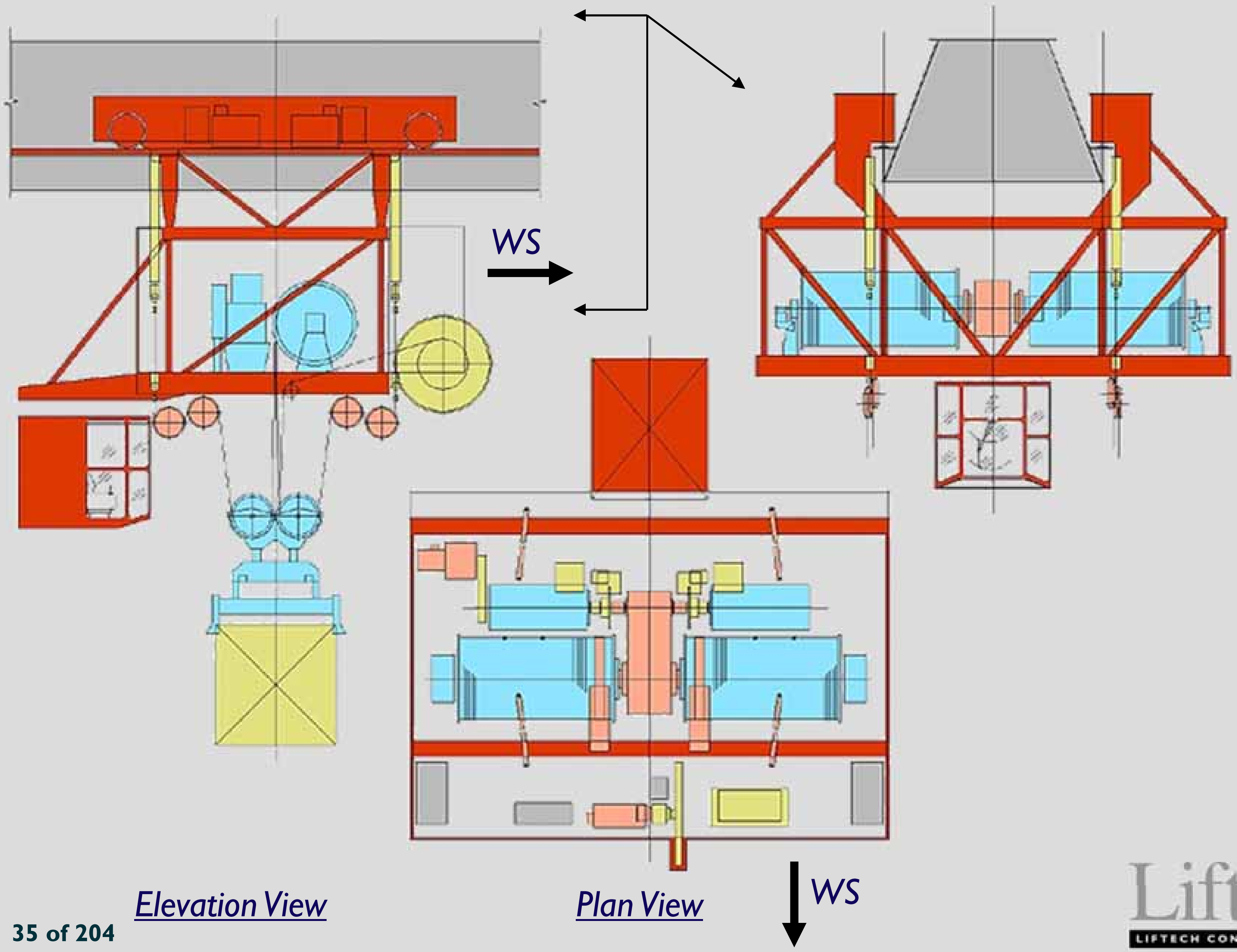
MOT



Elevation View

Plan View

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Trolley Type Comparison Matrix

	Fleet Thru Rope Towed Continuous	Fleet Thru Rope Towed Cat. Trolleys	Fleet Thru Self Powered	Machinery On Trolley	Rope Towed Machinery On Trolley
Trolley Weight	Moderate	Lowest	Moderate	Highest	High
Trolley Motors	1	1	2-4	2-4	1
Trolley Motor Power	Moderate	Moderate	Moderate	Highest	High
Trolley Acceleration	High	High	Lowest (Wheel Slip)	Moderate (Wheel Slip)	High
Trolley Tow Ropes, Tensioner, Sheaves	Yes	Yes	No	No	Yes
Catenary Tow Rope, Tensioner, Sheaves	No	Yes	No	No	No
Hoist Rope Length	Long	Long	Medium	Short	Medium

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MOT vs. RTT

Crane structural fatigue damage & weight comparison

	Rope Trolley	Machinery Trolley
Trolley weight (tons)	25	90
Moving load (tons): Trolley + Spreader + HB + 65 LT	110	175
Moving load (tons): for Fatigue Damage	80	145
Fatigue damage	1.0	6.0
Crane weight (tons)	1,300	1,600

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Trolley Trends

Majority: RTT

Increasingly: MOT

- *APL, Maersk, Modern Terminals*
- *Europe, Hong Kong, Malaysia, PSA*

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Performance or Detailed Specification

Case Study

Ground Rules for Cranes

- 3 crane order
- Beyond post-Panamax capability
  - 21 containers wide on deck
  - 7 high deck load
- High speed
  - Capable of 35+ containers per hour

Procurement Process

- **Competitive negotiation (RFP vice IFB)**
  - **Not locked in to low price**

- ***<u>New ideas</u>***
  - **Use a modified performance spec**
  - **Setting a minimum performance standard in CPH**
  - **Let each bidder determine characteristics to attain CPH through simulation program**

What Type of Crane ?

- Single hoist
- Dual hoist elevating platform
- Elevating girder

Contract Options

Option A

3 Single Hoist Cranes

Option B

2 Single Hoist Cranes

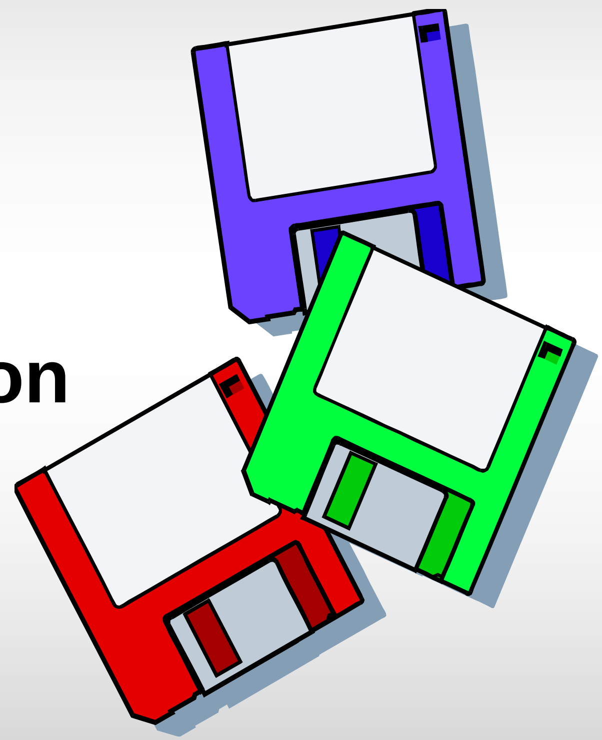
1 Elevating Girder Crane

Technical Specification

- **Section 1**
  - Proposal
  - Schedule
  - Standards
- **Basic characteristics and features**
  - Capacity 50 LT
  - Rail gage 30 M
  - Lift height 37 m
  - Outreach 22 Containers
- **Misc. structural, mechanical, electrical**
- **Disk containing simulation program**

Crane Dynamics

- Simulation program includes
  - physical characteristics
  - dwells
  - ship/container configuration
  - minimum CPH



- speeds
- accelerations

motor sizes

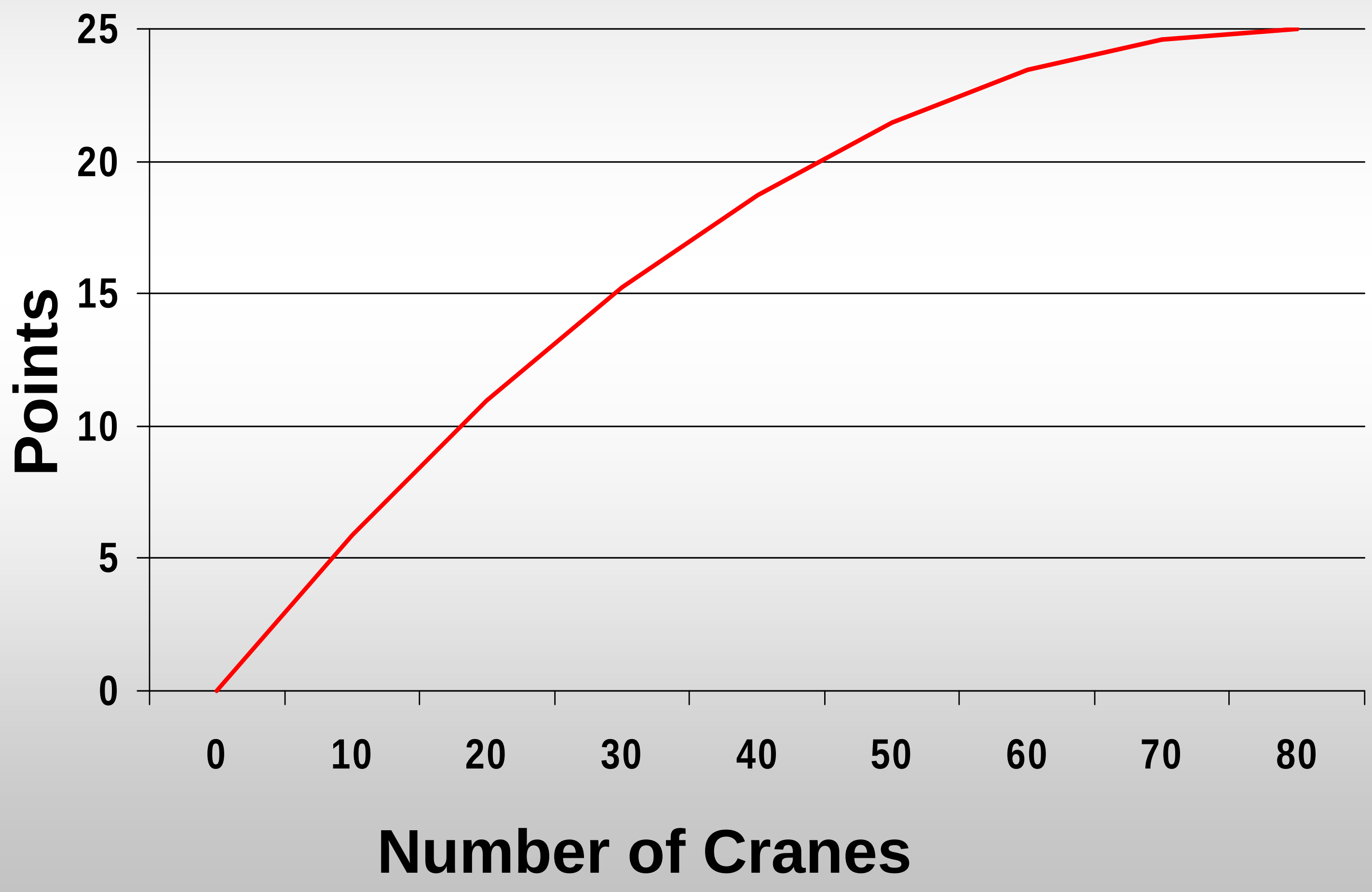
Initial Proposal Results

- **13 bidders Option A**
- **6 bidders Option B**
- **Only 3 of 13 supplied complete info**
- **Option A bids**
  - **Average price for per SHC $6.4M**
- **Option B bids**
  - **Average price for ETGC $7.6M**
  - **Average differential for ETGC about $2.0M**

Evaluation Criteria

Experience	25
Quality & Suitability	25
Delivery	15
Price	30
Training/Support	5
Total	100

Experience Points



Points for Delivery

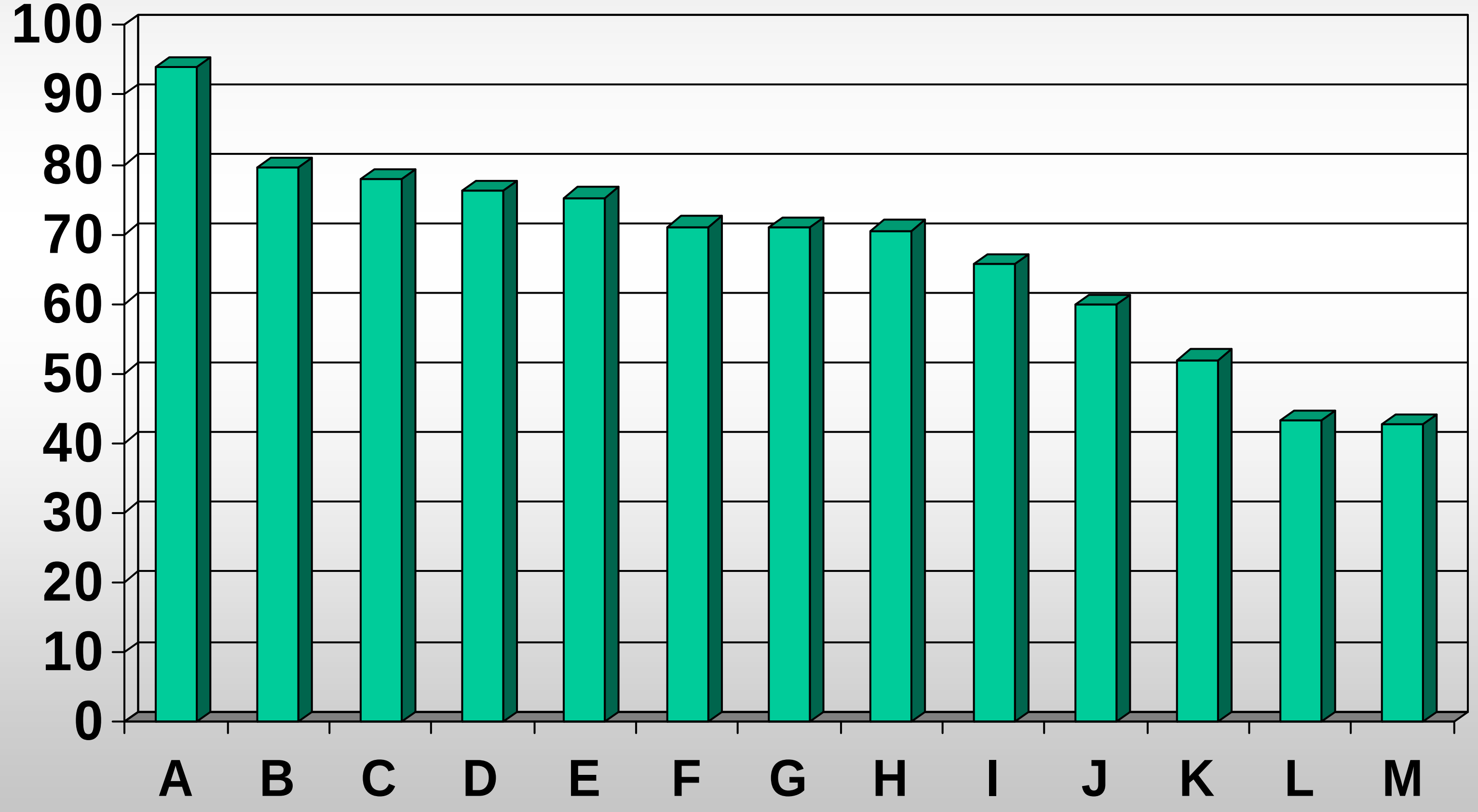
- Based on total # of months for 1st, 2nd, and 3rd cranes
- 15 points for fastest deliverer
- Others in ratio of (fastest : other) x 15.0

Points for Price

- 30 points to lowest bidder

- Others in ratio of (lowest : other) x 15.0

Points Summary

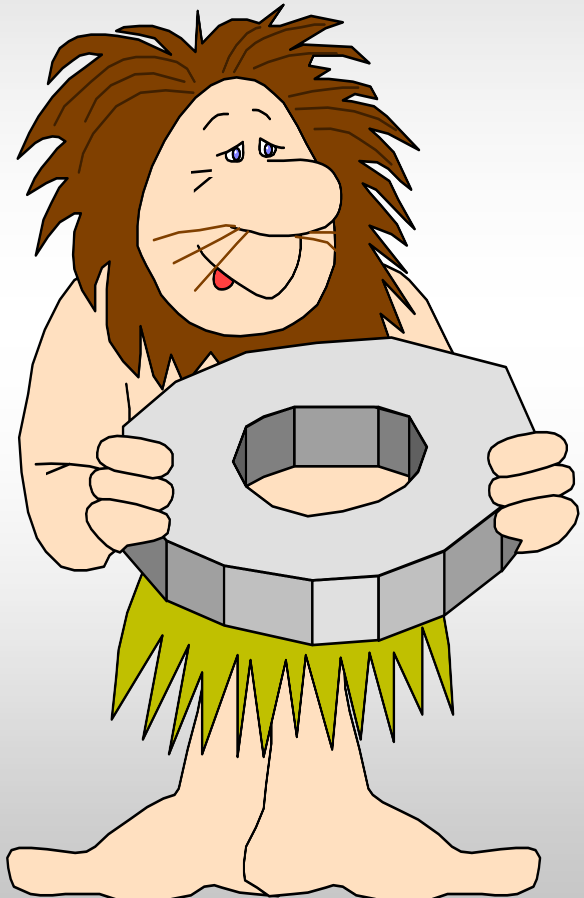


Negotiation Process

- Chose 3 bidders with the highest point totals.
- Bidders were provided a detailed (guideline) specification for negotiation of technical details.
- Negotiation based on ***exceptions*** to detailed spec.

North NIT ZPMC Cranes

Did our new ideas work ?



Modified Performance Spec ?

Yes.

Acted as a screen to let suppliers tell us what they intended to provide.

Guideline spec deviations allowed us to define specifics.

CPH Performance Standard ?

Yes.

Allowed suppliers to see if their recent drive designs would meet our performance standard.

Mechnical and Electrical System Choices

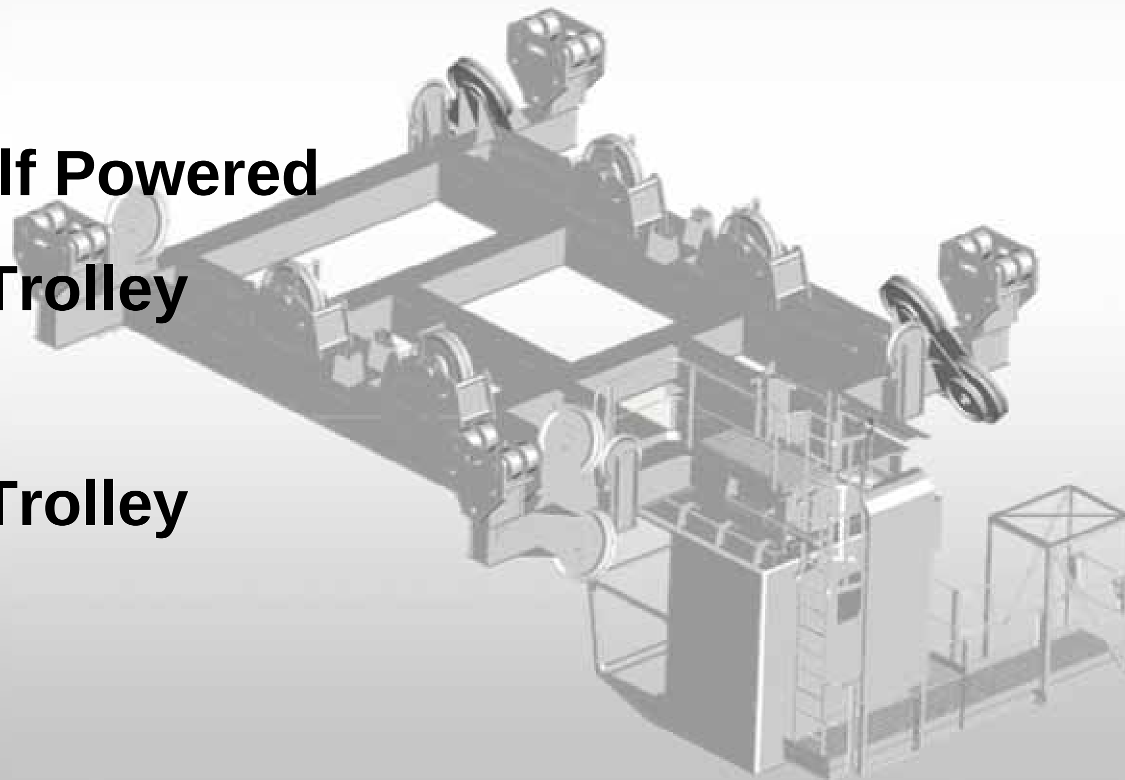
Rope Tow Trolley (RTT)

or

Machinery on Trolley (MOT)

Trolley Types

1. Fleet Thru – Rope Towed – Catenary Support Trolleys
2. Fleet Thru – Rope Towed – Continuous Catenary Support
3. Fleet Thru – Self Powered
4. Machinery On Trolley
5. Rope Towed
   Machinery On Trolley



RTT - Fleet Thru with Catenary Trolleys

- Catenary trolleys necessary for long spans
- Provides intermediate festoon support
- Additional sheaves, reeving, tensioners, and trolley machinery

RTT - Fleet Thru with Continuous Support

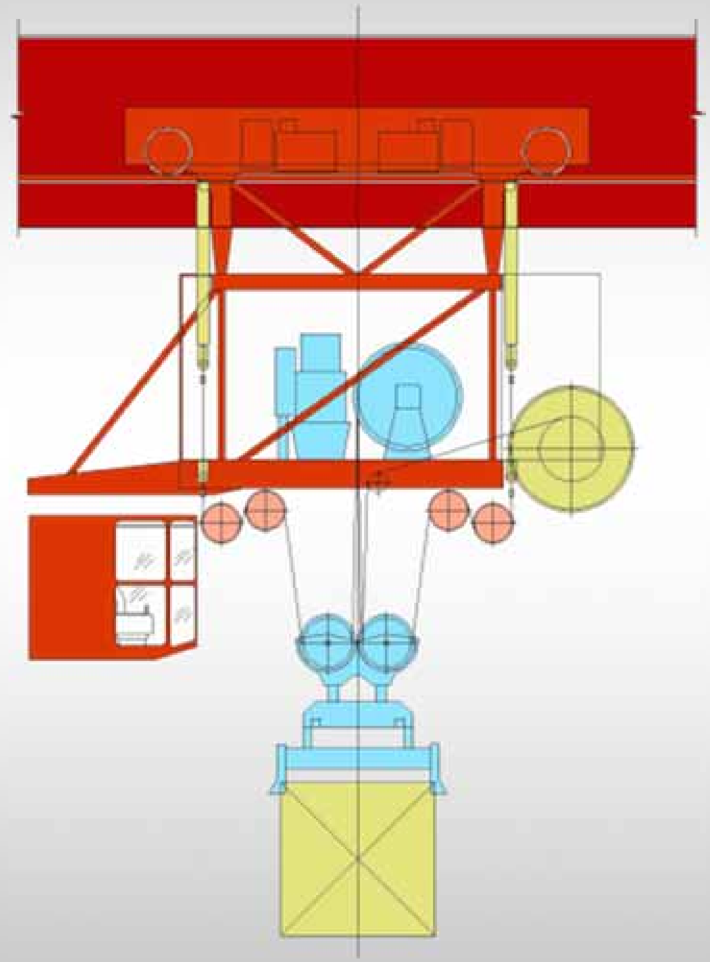
- No catenary trolleys
- Smaller catenaries = more control
- More sheaves = heavier trolley & larger trolley motor

Fleet Thru Self Powered

- Simple reeving
- No trolley tow ropes or tensioner
- Possibility of wheel slip
- Slower acceleration rates

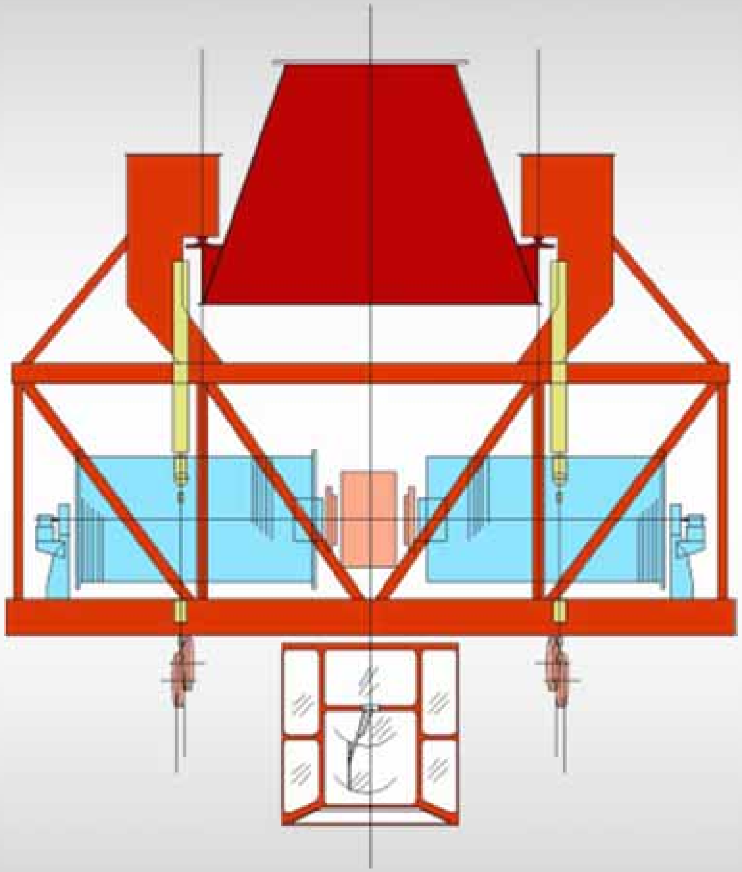
MOT Machinery on Trolley

- Least amount of reeving
- Heaviest trolley
- Possibility of wheel slip
- Slower acceleration rates
- Small machinery room
- Design for maintenance access is important



Rope Towed MOT

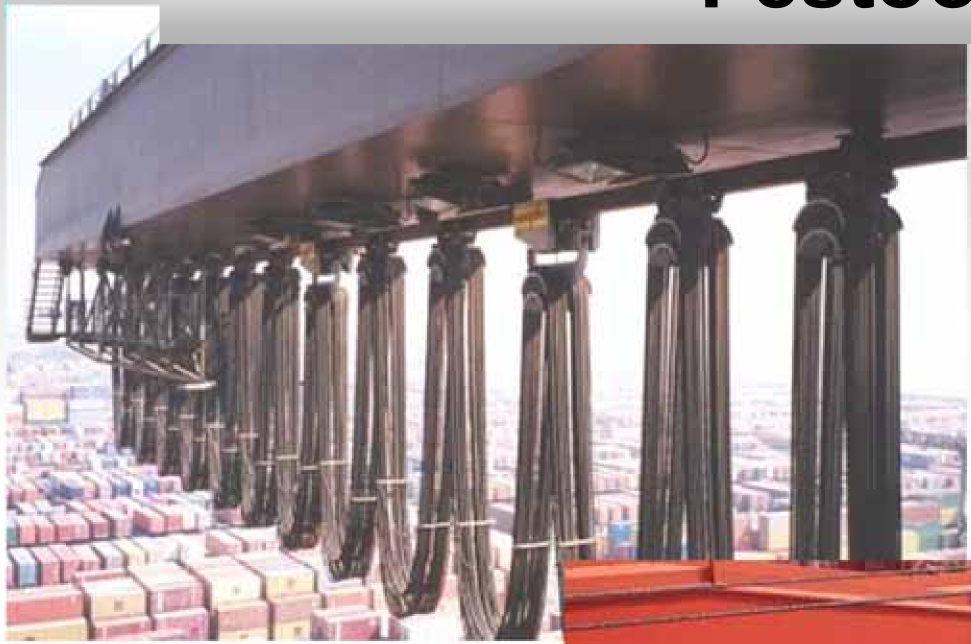
- Simple reeving
- No concern of wheel slip
- Full acceleration rates
- Requires trolley tow ropes and tensioner
- Reduced hoist rope length



Why Consider MOT Crane?

- Potential for maintenance expense reduction.
- Potential for increased reliability.
- Industry trends.
- Consider another design prior to wharf design.

Festoon



MOT

RTT

Boom Design

MOT
Monogirder
Boom

RTT
Twin-girder
Boom

Trolley Weight

RTT	MOT
18 tons	82 tons

Crane Weight

RTT	MOT
1270 tons	1600 tons

Wheel Loads

(operating)

	RTT	MOT
Waterside	176 kips/wheel	200 kips/wheel
Landside	96 kips/wheel	133 kips/wheel

Mechanical Systems

	RTT	MOT
Total rope length	11,900 ft	1600 ft
# of sheaves	50	4

Maintenance Comparison

	RTT	MOT
Maintenance time per crane per year	156.5hrs	87.2 hrs
Main hoist rope life	1500 hrs	3000+ hrs
Hoist rope replacement cost	$21,000	$5,700

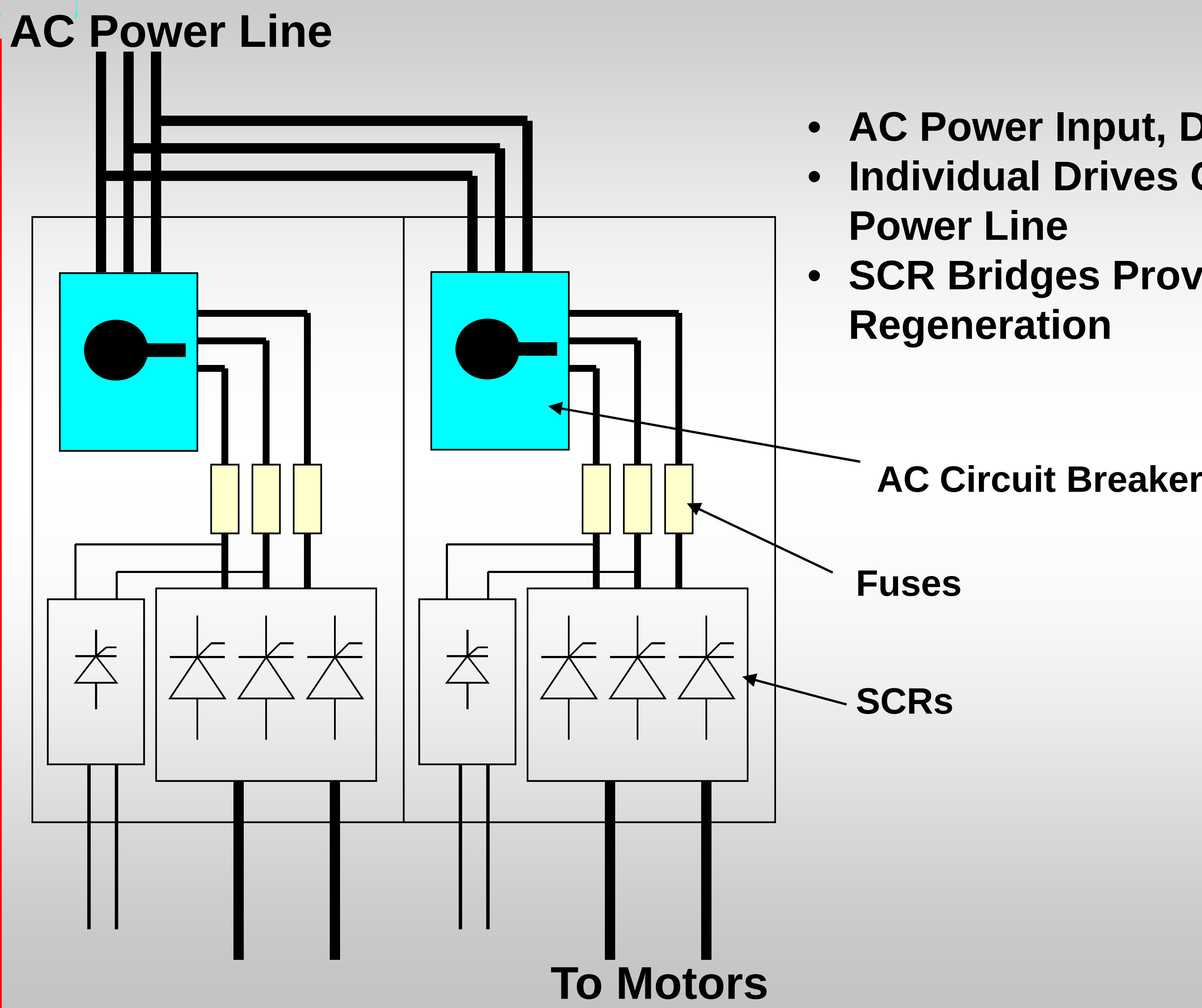
Operator Feedback of MOT

- Trolley speed about the same but acceleration slower than RTT.
- Not as responsive.
- Spreader skew stability about the same.
- Tendency for trolley to drift when coming off stick.
- **<u>Prefers RTT.</u>**

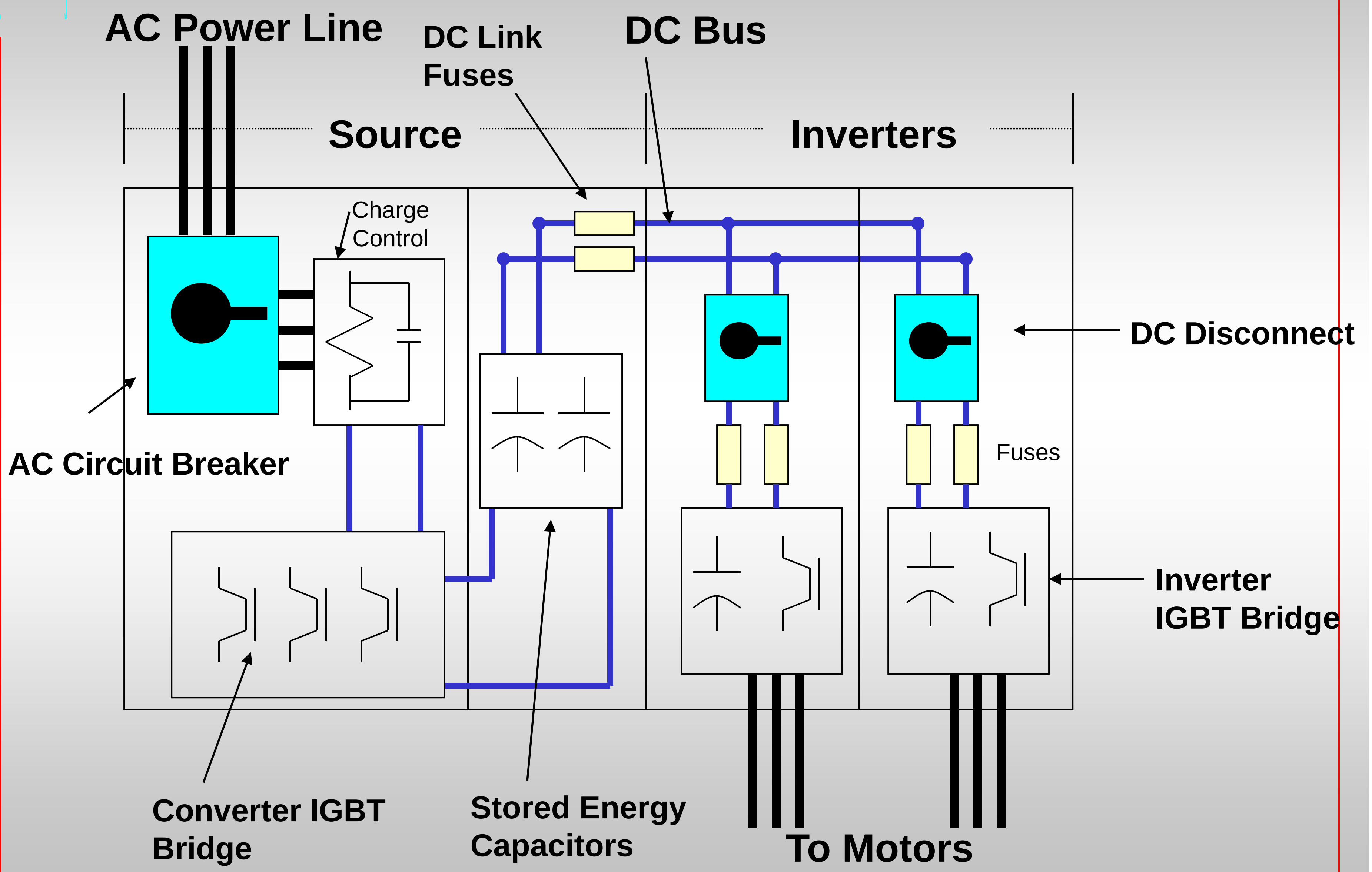
AC VS. DC Motors and Drives

DC Drive Topology

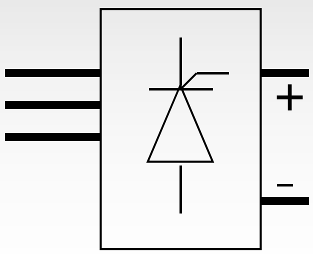
- AC Power Input, DC Power Output
- Individual Drives Connected to AC Power Line
- SCR Bridges Provide Power and Regeneration



AC QC Drive Topology

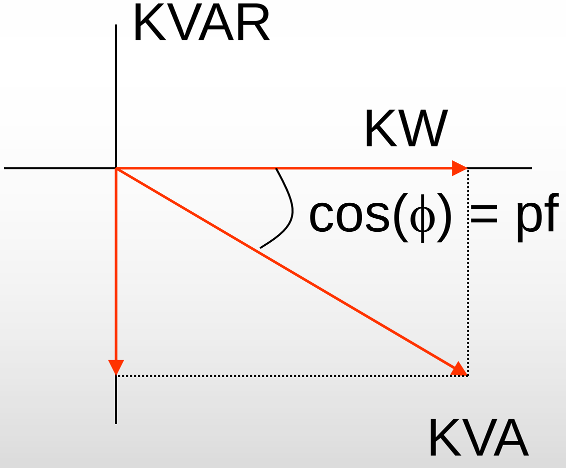


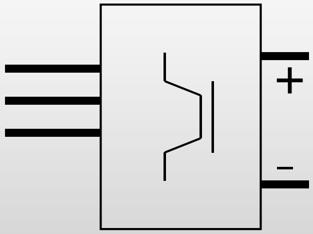
Power Factor



DC Drives

- **Speed Dependent**
- **Average 0.55 Lag**



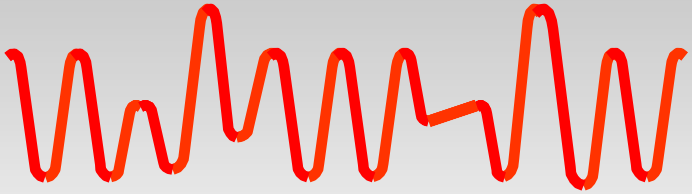


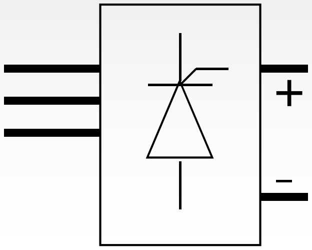
IGBT Source

- **Always Near Unity**
- **Average ~ 0.99 Lag**

Advantage : AC

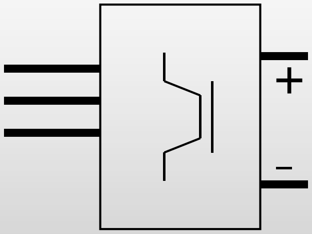
Power System Transients





DC Drives

- Poor Power Factor Causes Line Dips
- Line Dips can Prevent Regeneration and Cause Malfunction



IGBT Source

- DC Bus Capacitance Stores Energy
- Robust to Line Dips, Swells, and Momentary Power Loss

Advantage : AC

Size and Weight

- DC requires only a single stage power conversion
  - Smaller cabinet size
- AC motor sized to have sufficient stall torque at lower speeds
  - Larger motor for similar characteristics
- DC motor has lower rotor inertia
  - More compact
- AC more overall weight

Advantage : DC

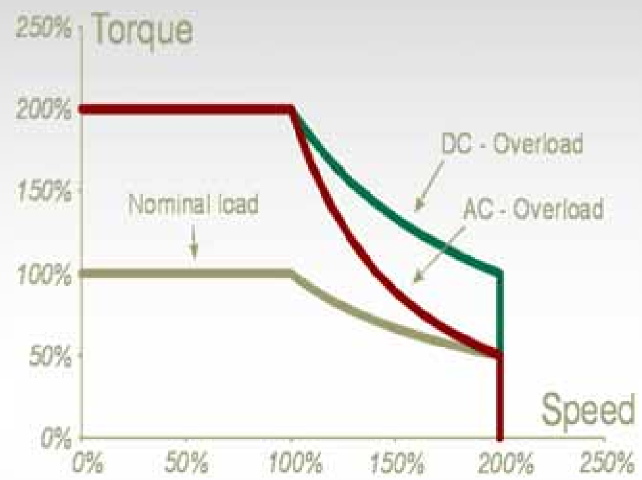
Maintenance

- **DC Brush life depends on:**
  - **Commutator temperature**
  - **Brush material**
  - **Vibration**
  - **Humidity**
  - **Corrosives in air**
  - **Can see up to 8000 hours service**
- **AC Motors**
  - **No brush /commutator maintenance**
  - **Better sealed for marine environment for AC motors**
  - **No carbon dust to contaminate bearings**

Advantage : AC

Performance

- **Performance**
  - **Torque & Speed Control very similar with DC digital encoder feedback and AC vector control.**
  - **DC has wider constant torque range Motion.**
  - **Switching times may increase for or increased cost.**
  - **Operating AC motor at rated torque at under half speed could overheat motor.**



- **Accuracy**
  - **Similar level of speed regulation- approx 0.01%.**

- **Zero speed load holding without brake**
  - **DC - No Drive Limitations**
  - **AC - Drive can have Low Frequency limitations**

Advantage : Slightly DC

Cost

- **IGBTs and control electronics cost higher for AC.**
- **DC motor cost higher.**
- **Regeneration cost higher for AC.**
- **Separate armature and field control preferable for shared drives.**
- **2<HP<100 AC more economical.**
  - **Premium for AC vector control In high HP applications.**

Advantage : DC

Other Factors

- **Experience of maintenance staff**
- **Commonality of existing equipment**

Bottom Line:

- ***Neither type of drive is inferior***
- ***Technology is moving AC along faster than DC***
- ***VIT experience - continue DC procurements***

Standard or Specialty Crane

Choices of Specialty Cranes:

- Dual Hoist Stationary Platform
- Dual Elevating Platform
- Elevating Trolley Girder
- Others not yet designed or built

Dual Hoist Cranes

Singapore

ECT

Dual Hoist Cranes

Baltimore

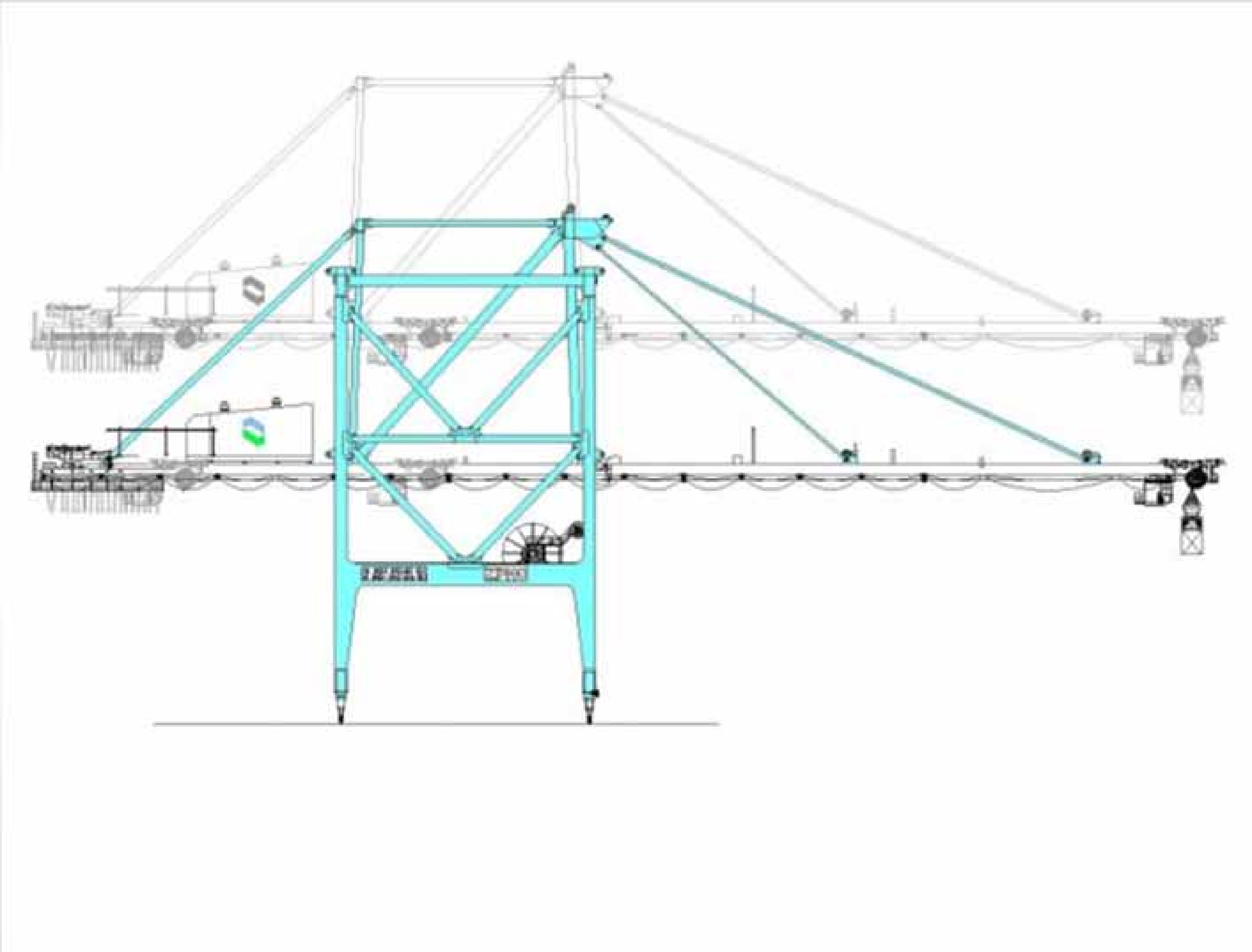
Tokyo

Dual Hoist cranes

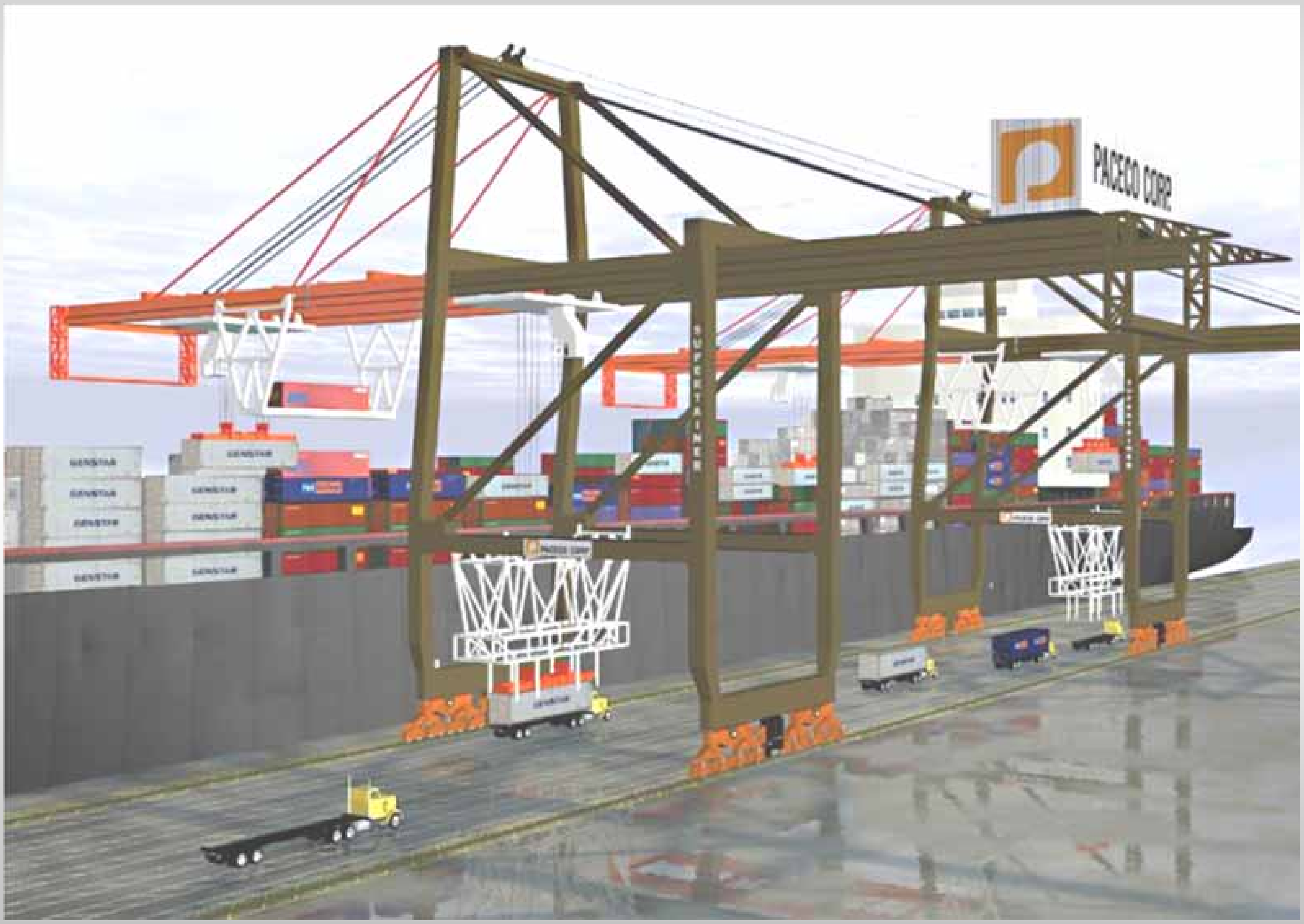
Dual Hoist Cranes

VIT

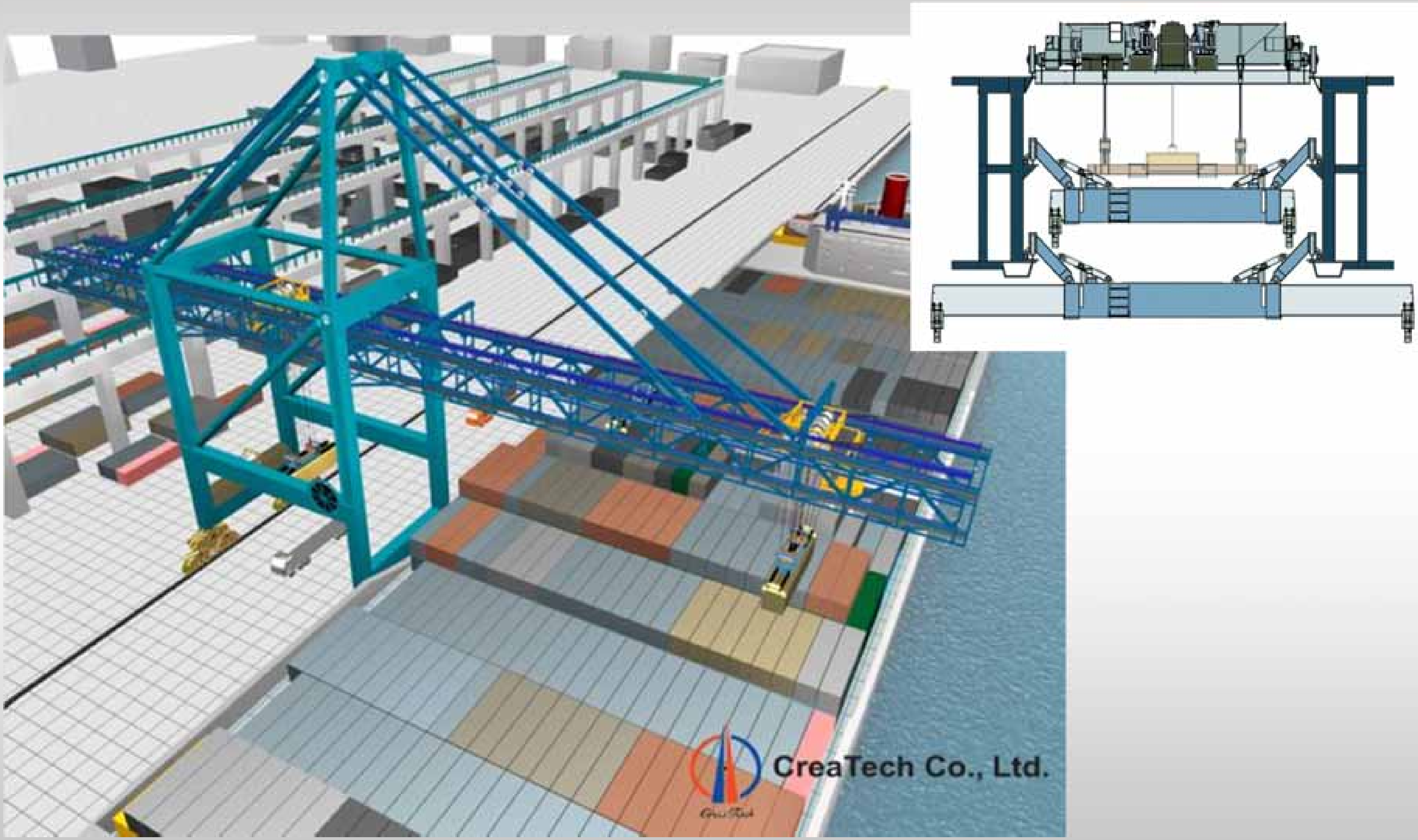
Elevating Trolley Girder Crane



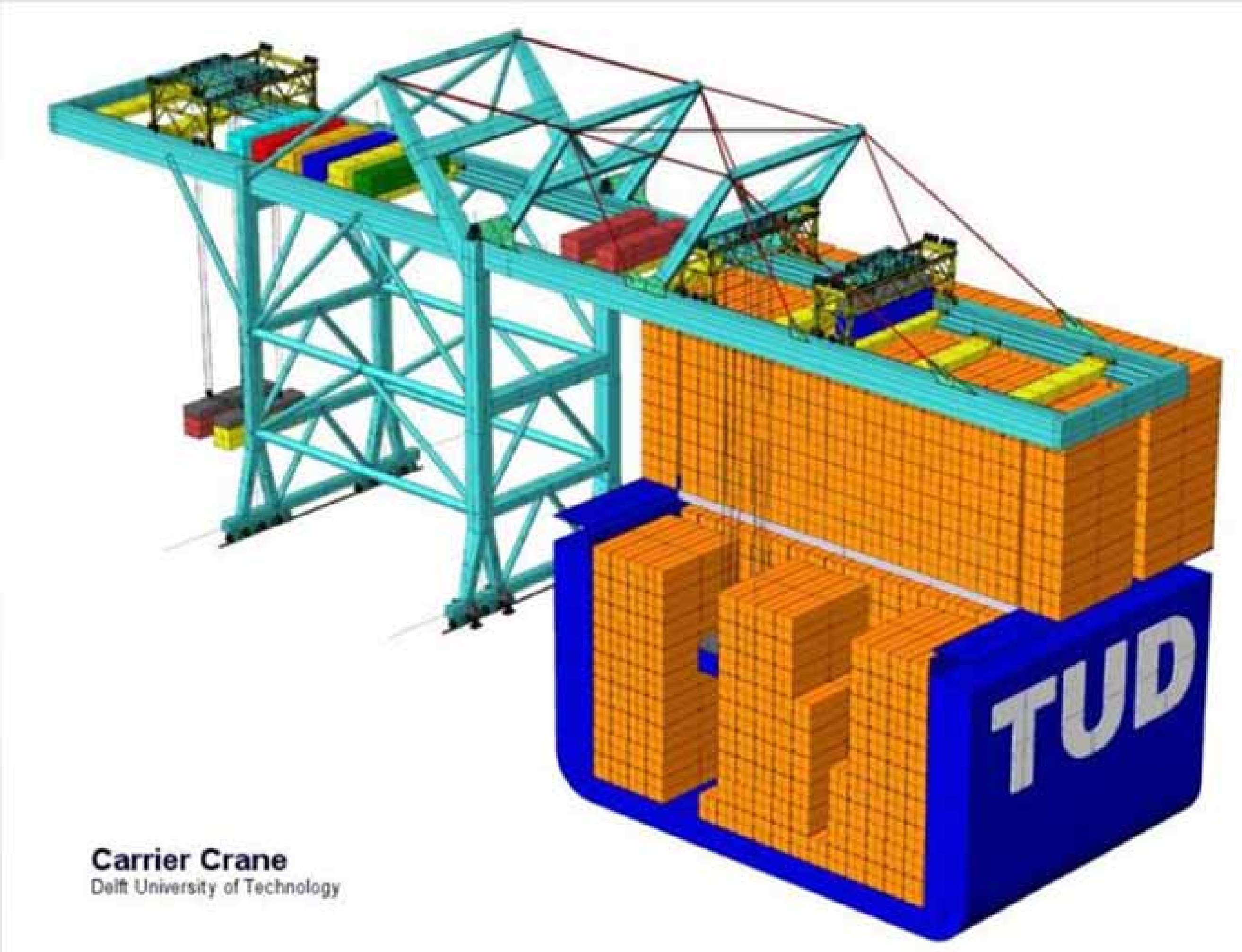
Paceco Supertainer©



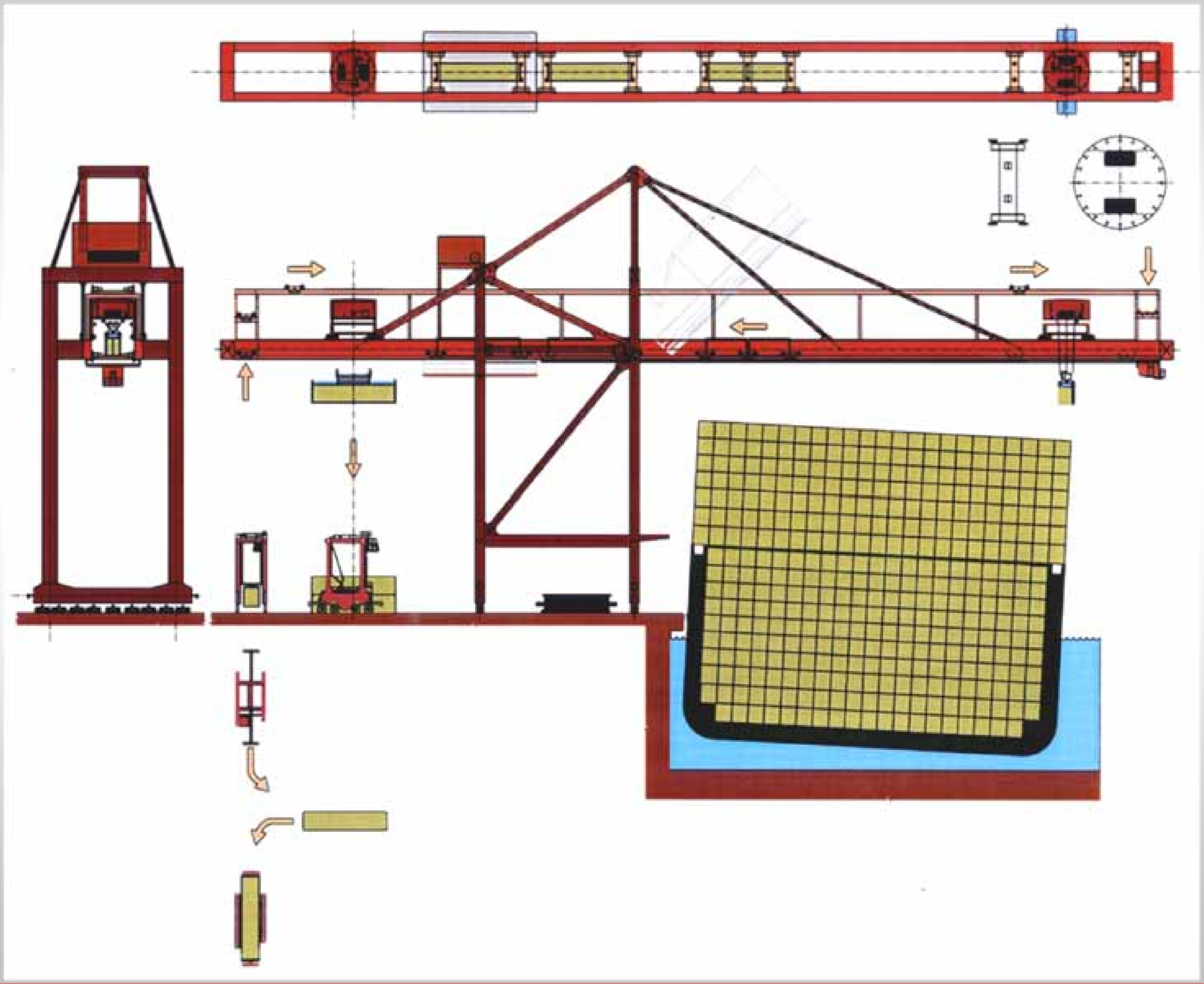
CreaTech Technotainer©



Delft University Carrier Crane



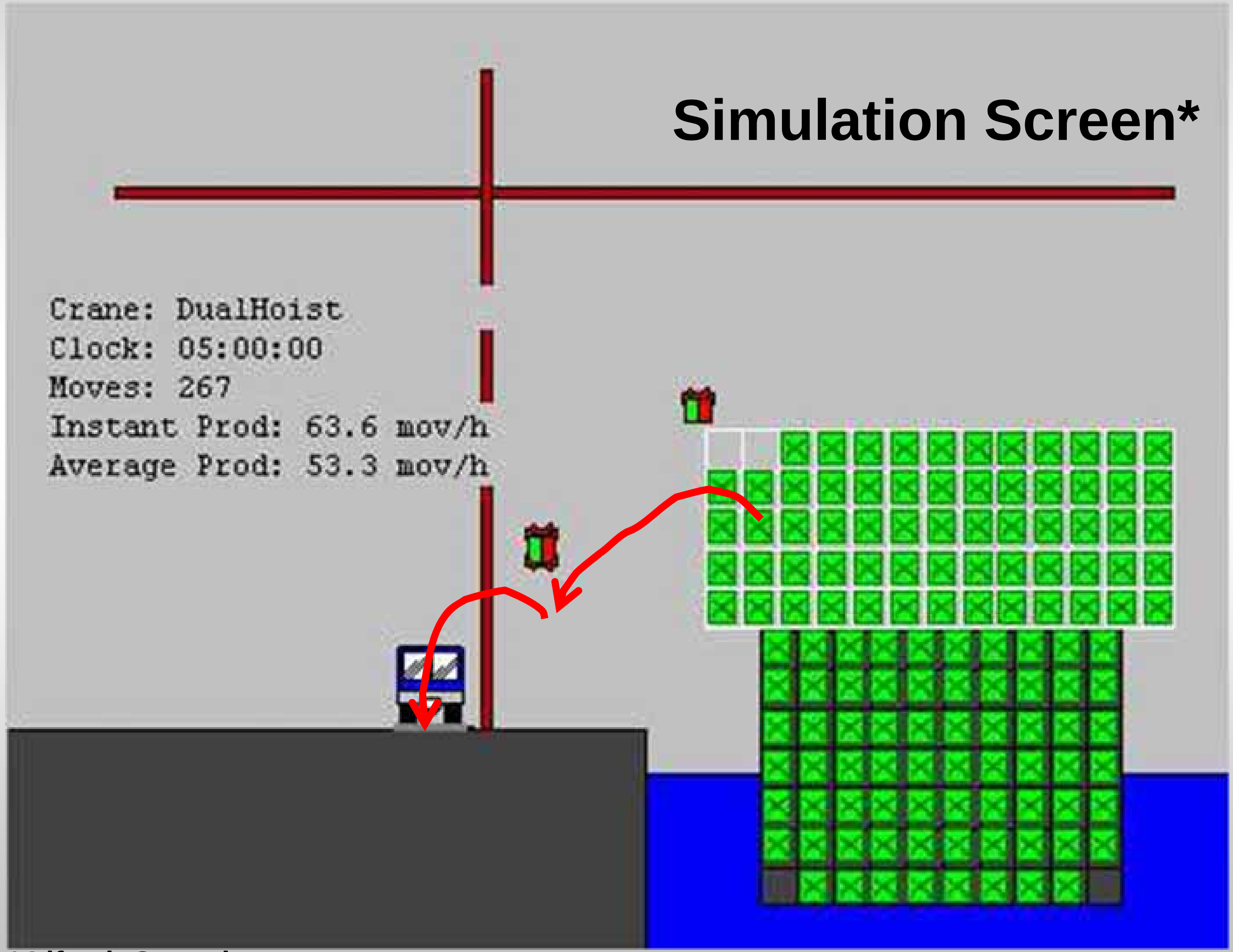
Liftech SuperCrane©



Productivity

- A major factor in making the "bottom line."
- Definition is illusive depending on where measured, how measured, and criteria used.
- "Apples to Apples" comparison of port productivity is rare.

Predicting Crane Productivity



* Liftech Consultants

Monitoring an Operation

Data Accumulation

- **Dual hoist and single hoist**
- **15,000 records - 16 fields per record**
  - **Event start and end**
  - **Event type - load/discharge/delay**
  - **Crane #**
  - **Operator**
  - **Stevedore**
  - **Ship type**
  - **Delay type**

    .
    .
    .

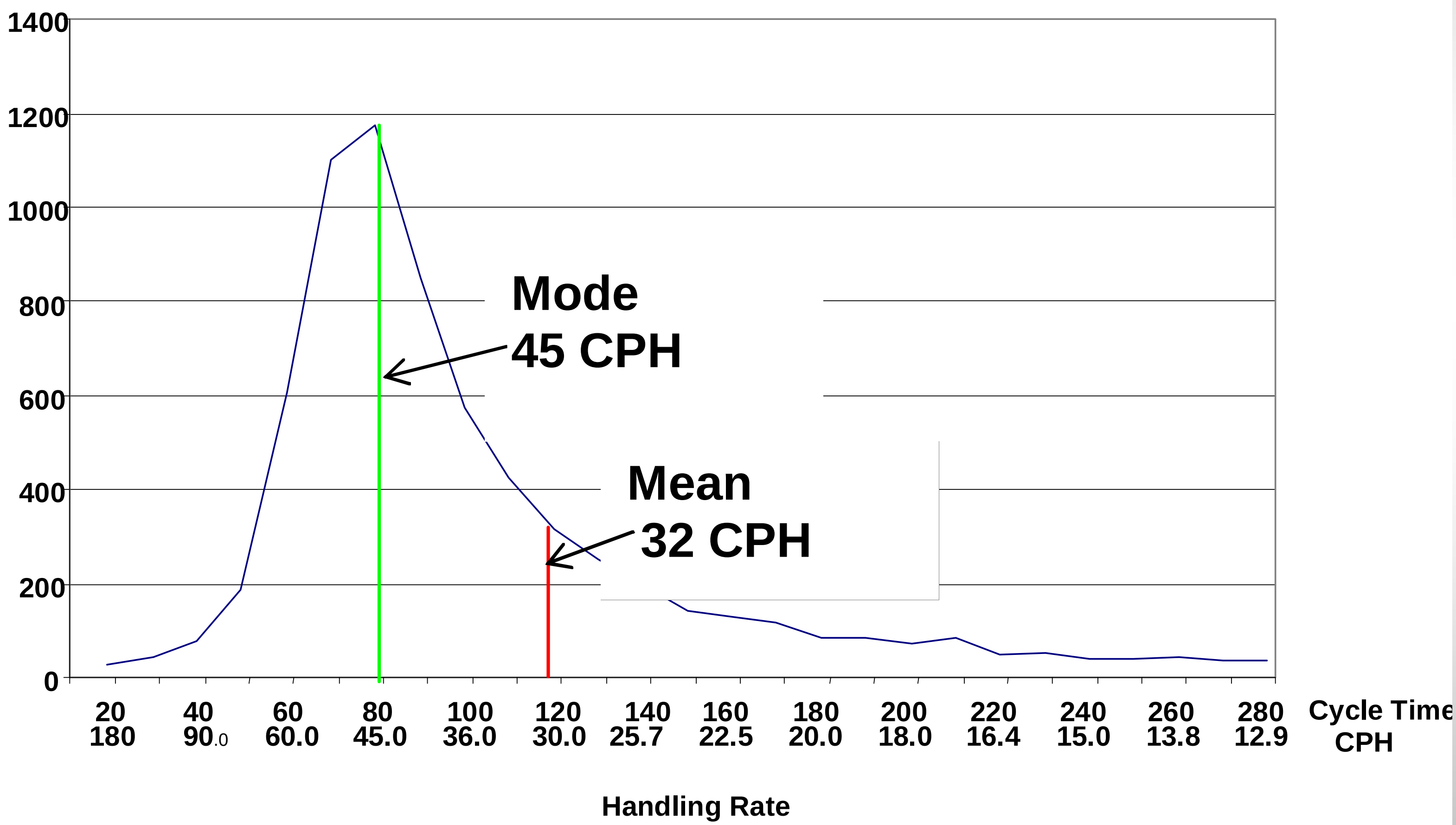
DHC vs. SHC Productivity Comparison

- **3rd Generation**
  - Single hoist crane
  - Straddle carrier operation
  - 50 ft rail gage

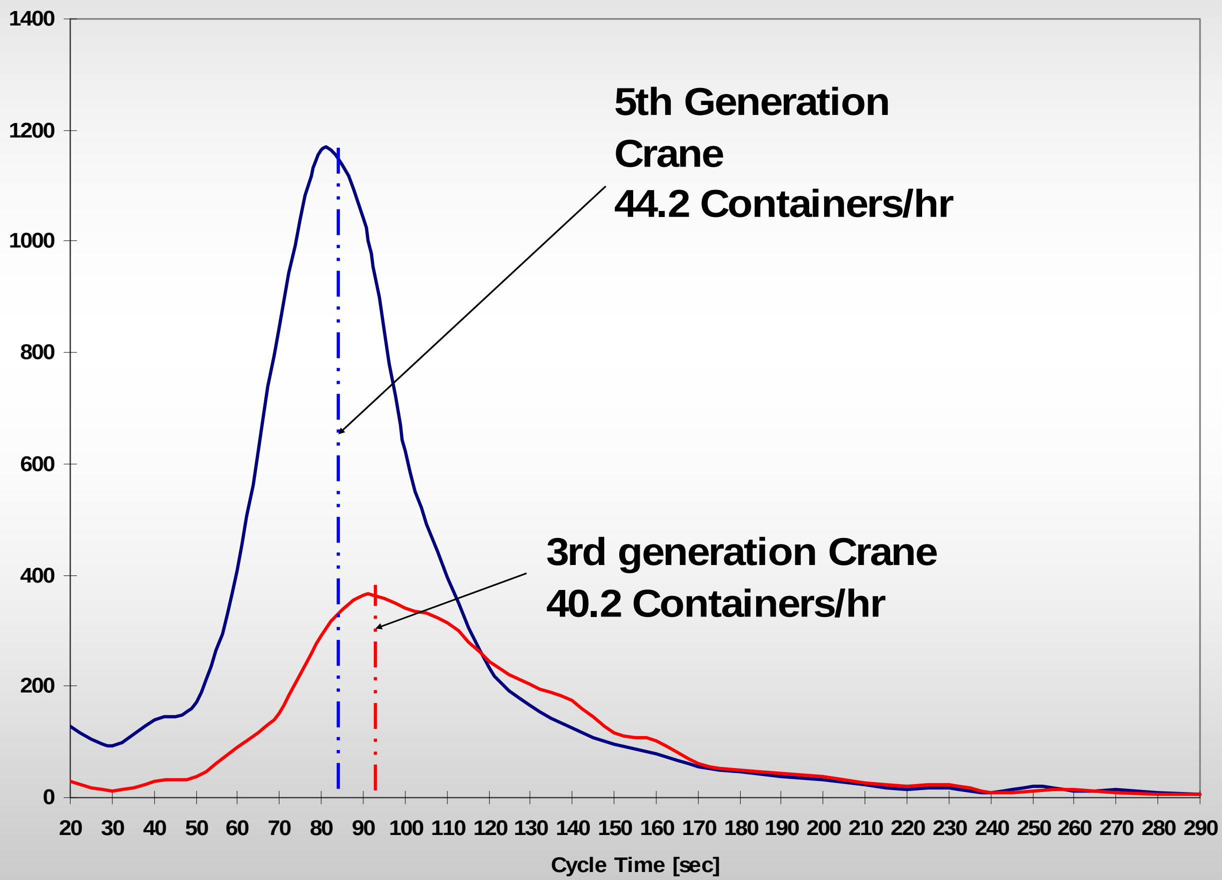
- **4th Generation**
  - Dual hoist crane
  - Chassis / bomb-cart operation
  - 50 ft rail gage

- **5th Generation**
  - Single hoist crane
  - Straddle carrier operation
  - 100 ft rail gage

DHC Cycle Time Frequency Distribution



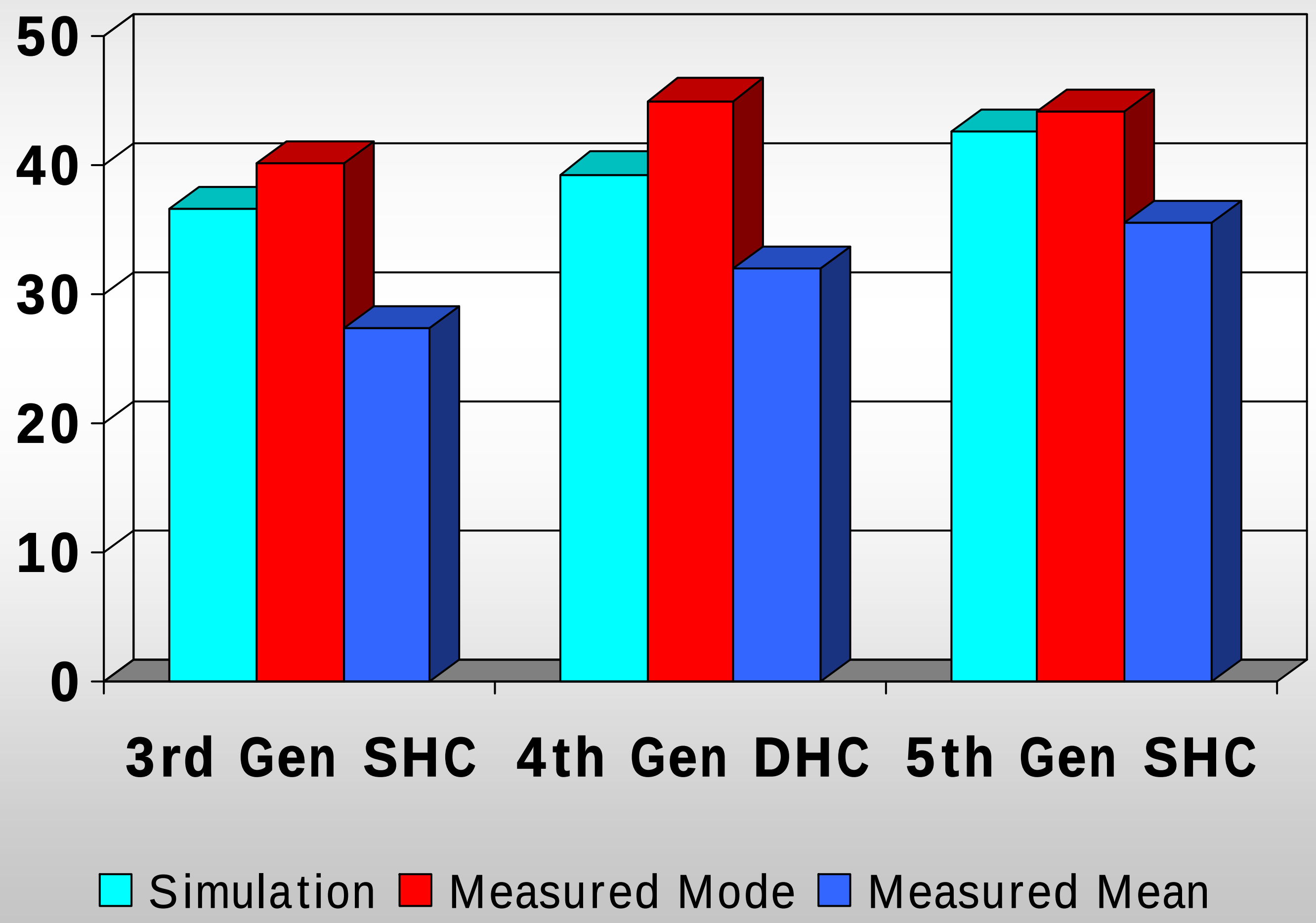
SHC Cycle Time Frequency Distribution



DHC Theoretical vs. Actual

Productivity Mode	45.0 CPH
Actual Productivity	32.0 CPH
+ Delays	6.4 CPH
+ Operator Proficiency	3.0 CPH
+ Ship Stowage	3.6 CPH

Productivity Measurement Comparison



Elevating Trolley Girder Crane

Dual Hoist Cranes Experience

- **High capital outlay**
- **Expensive to maintain**
- **Most require an extra operator**
- **Productivity gains marginal**

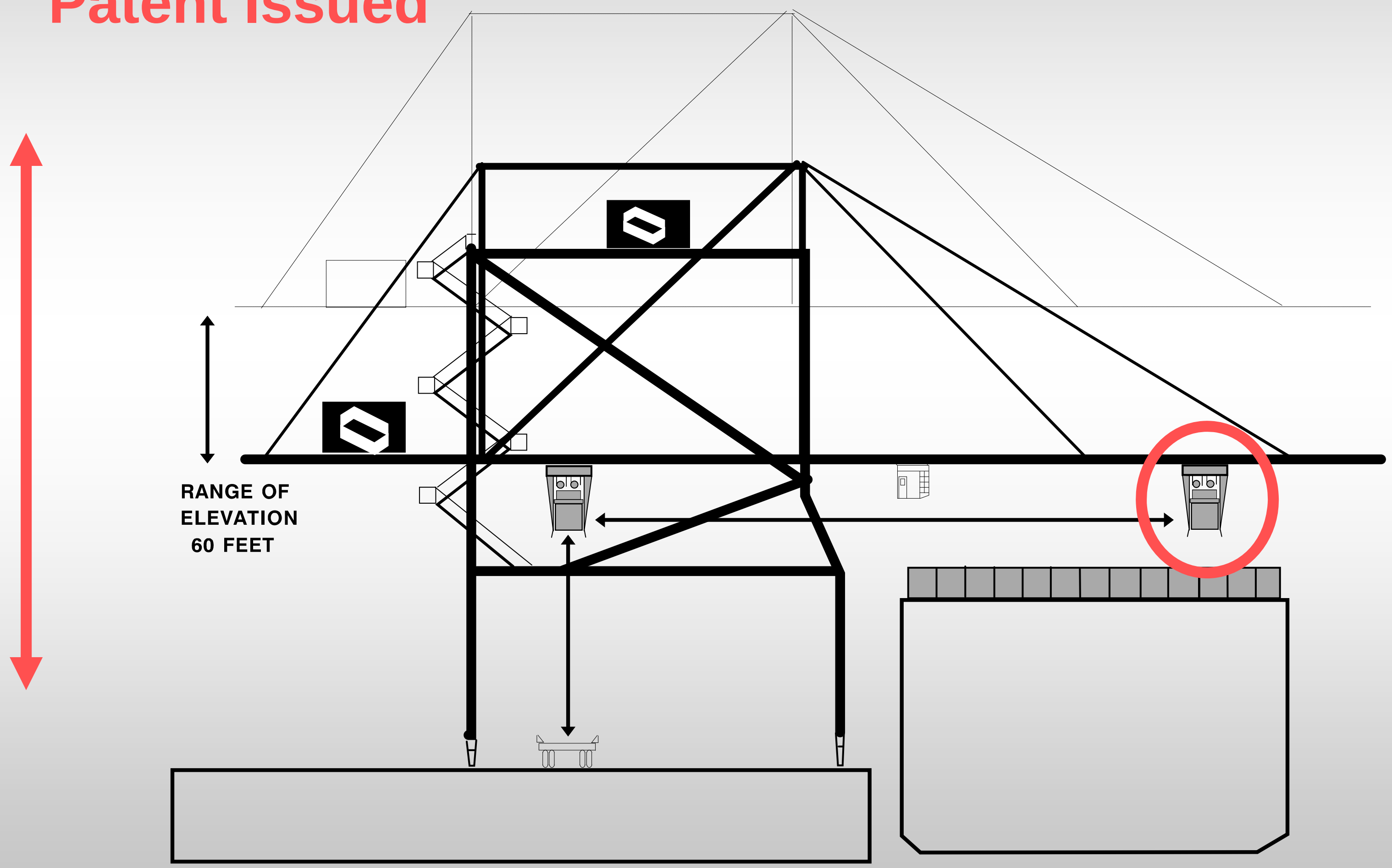
? Is it possible to have:

- One operator
- Higher productivity
- Operator closer to work
  - Less than 40 m for smaller ships
- Small premium for specialty crane
- Simpler maintenance than a DHC

Initial Ideas

VIT's ETGC Concept

Patent Issued

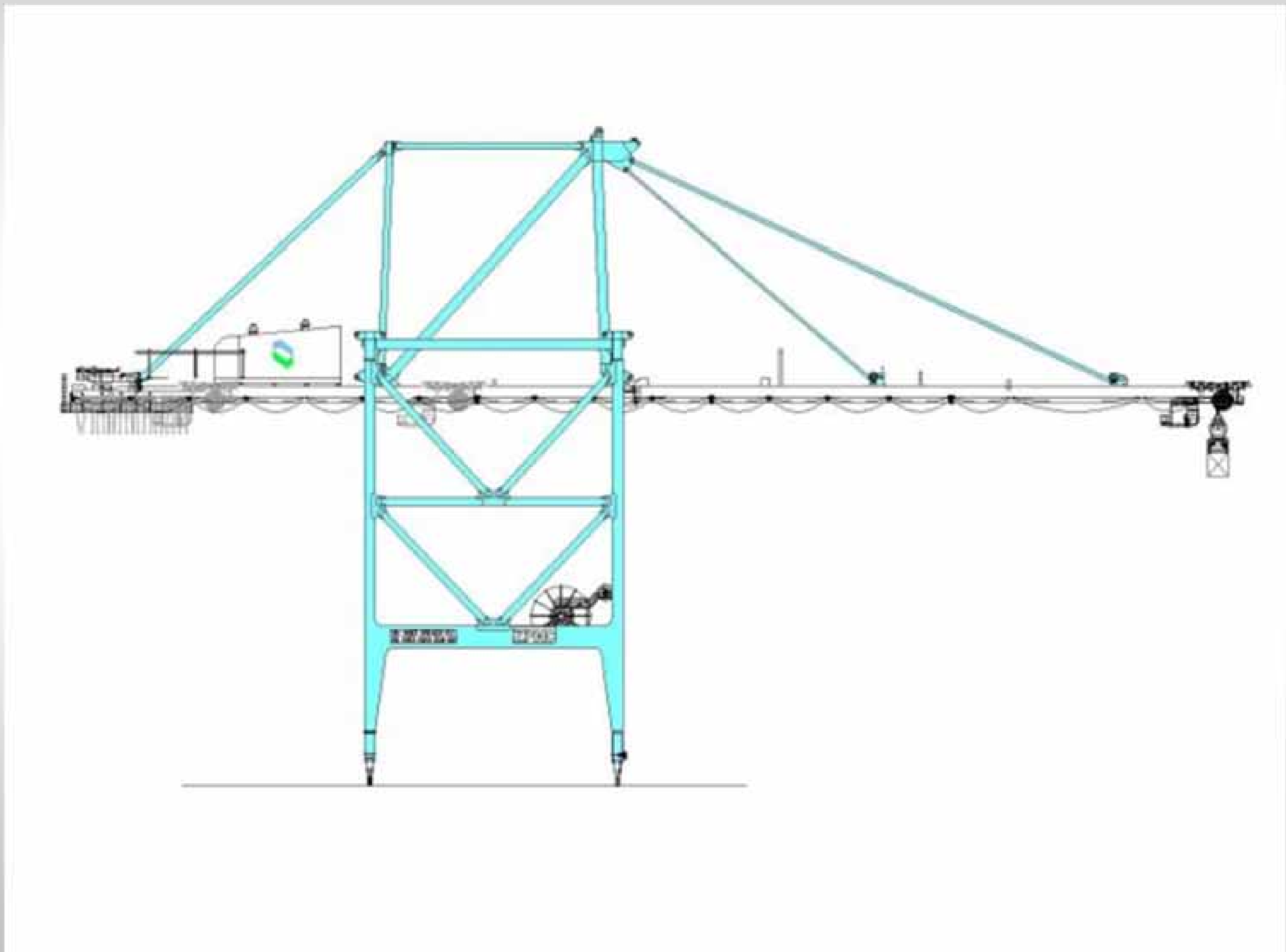


NIT North Cranes by ZPMC

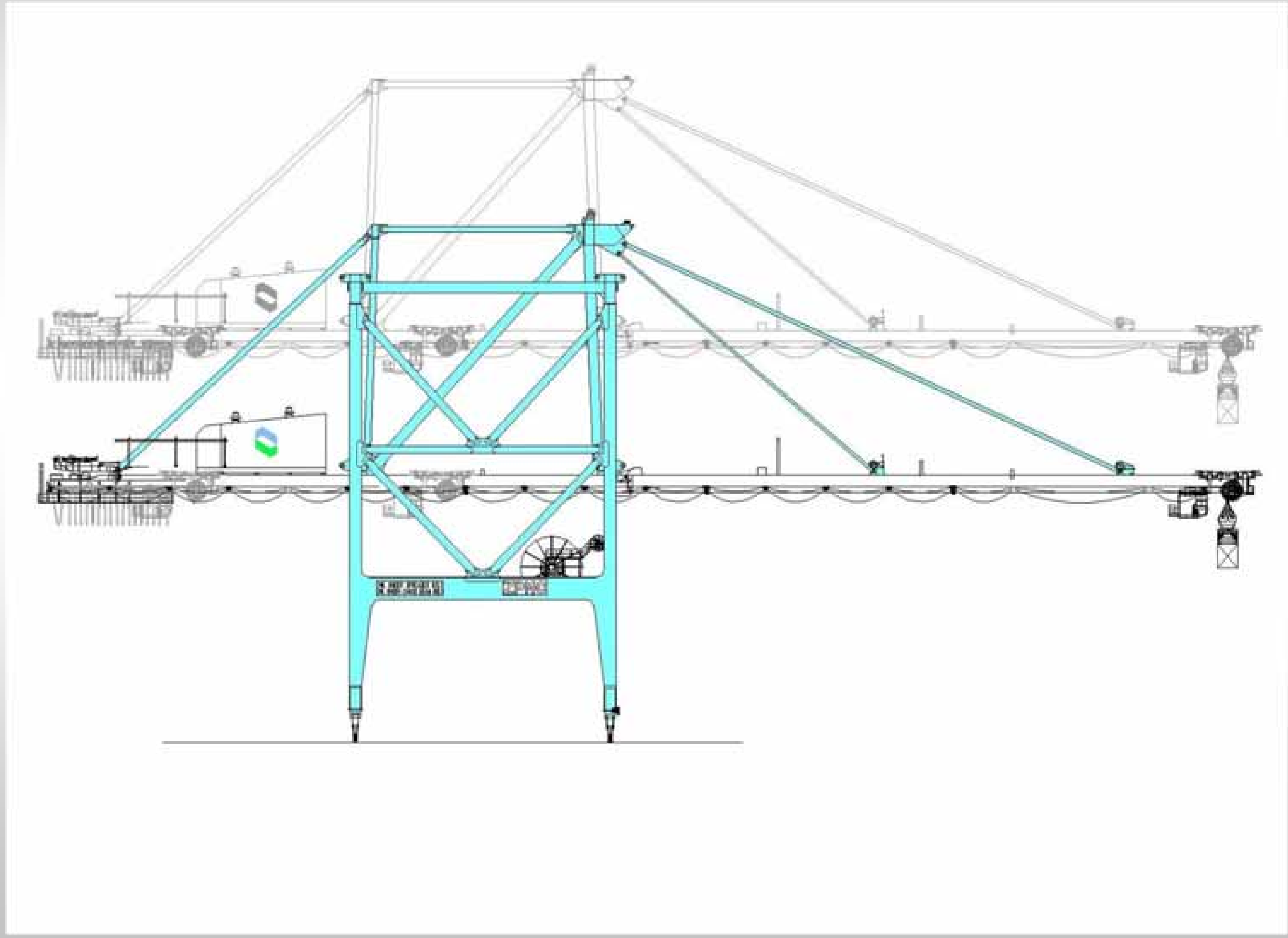
New Suez Class

- 140 meters clear under spreader
- 63.5 m outreach - 26 wide
- 90 m/min loaded hoist speed
- 244 m/min trolley speed

ZPMC/Liftech Design



ZPMC/Liftech Design



Girder Positioning

- Infinite locations within lifting range *not* feasible
- VIT's experience pointed to:
- 5 discrete positions - preset prior to vessel arrival
- Elevating speed of ½ m/min
- Simulation shows increases over standard of

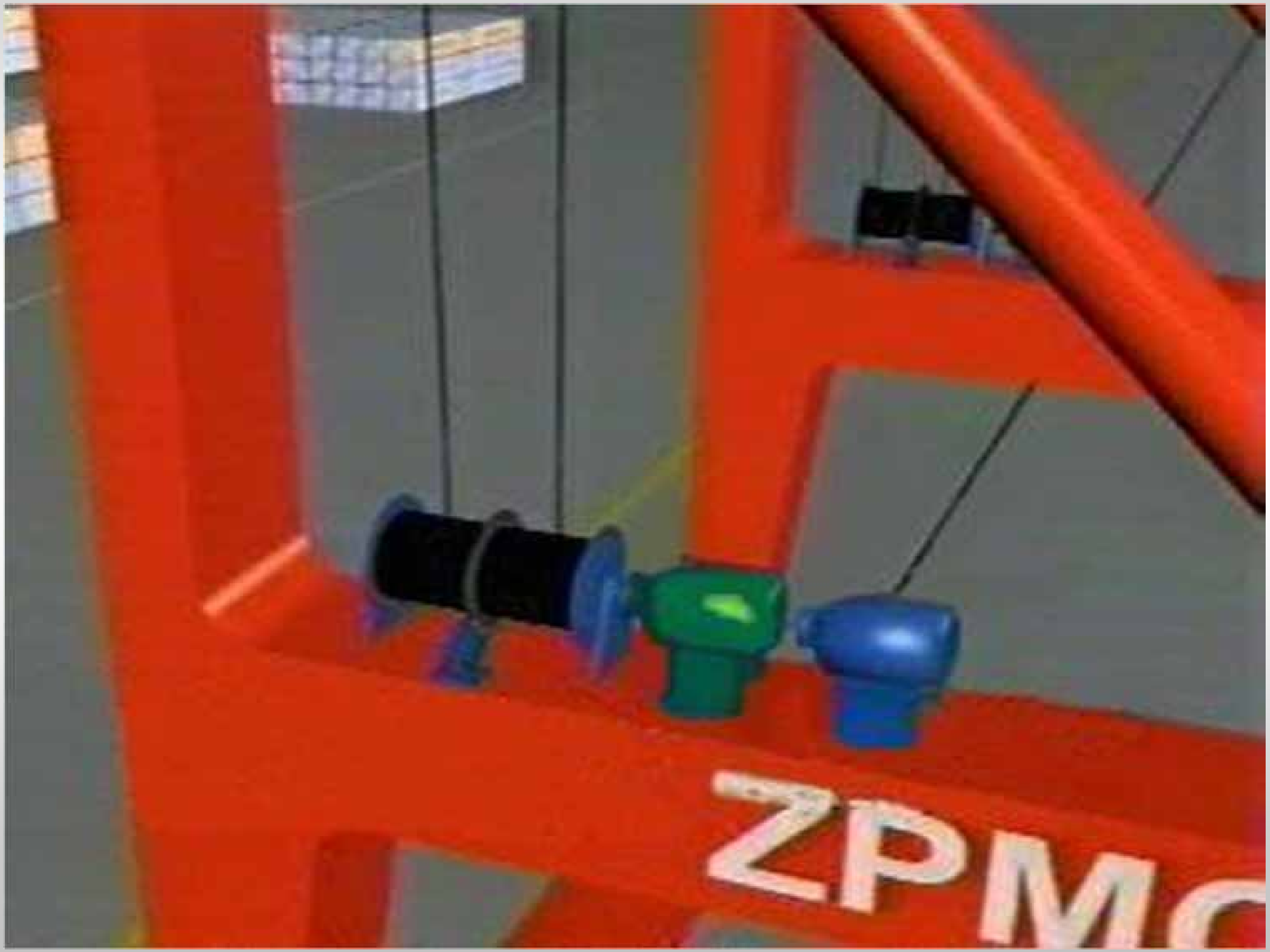
  2 – 8 CPH depending on ship and level

Lifting Mechanism

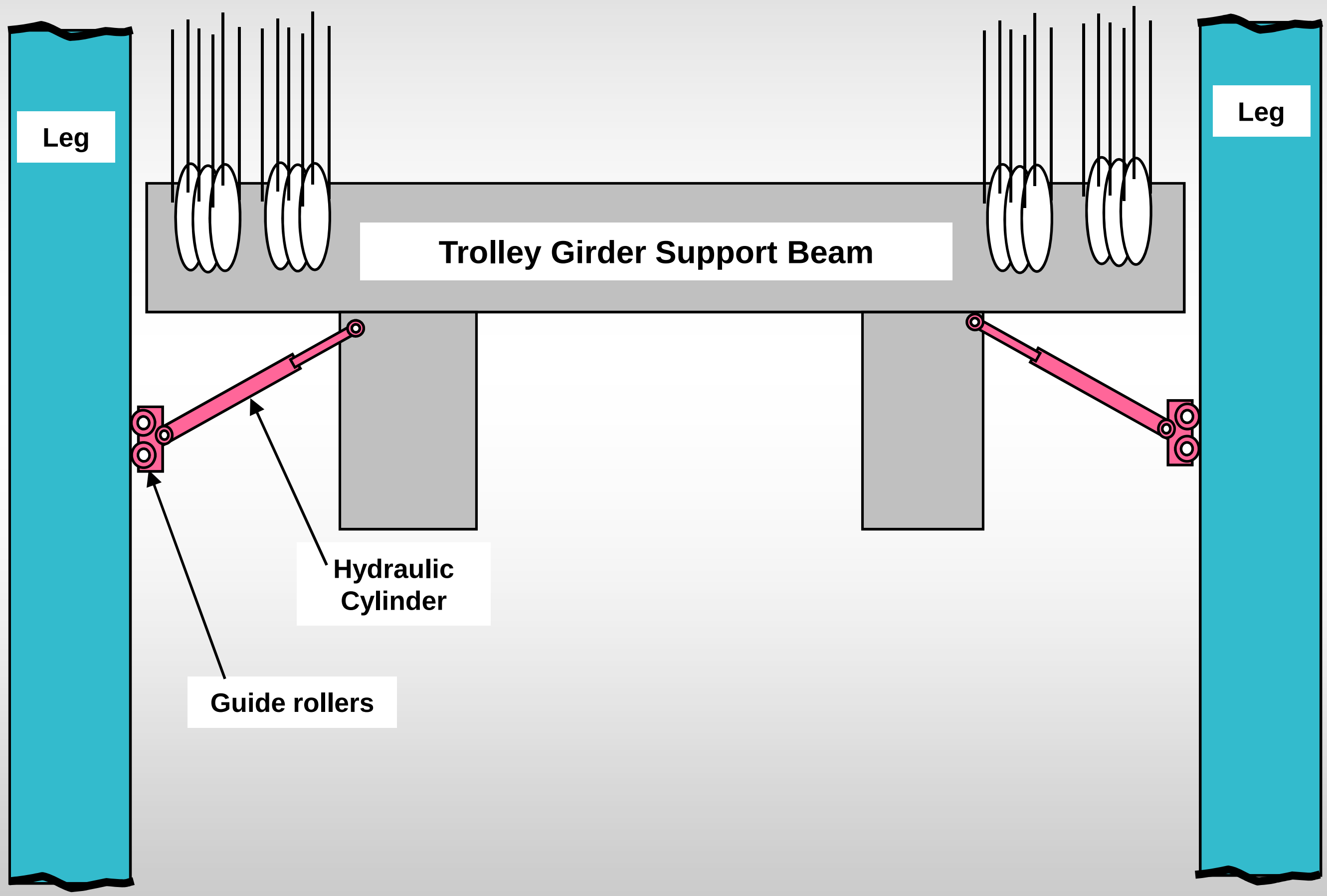
Possibilities

- Geared mechanical
- Hydraulic
- <u>Electro-mechanical winch</u>

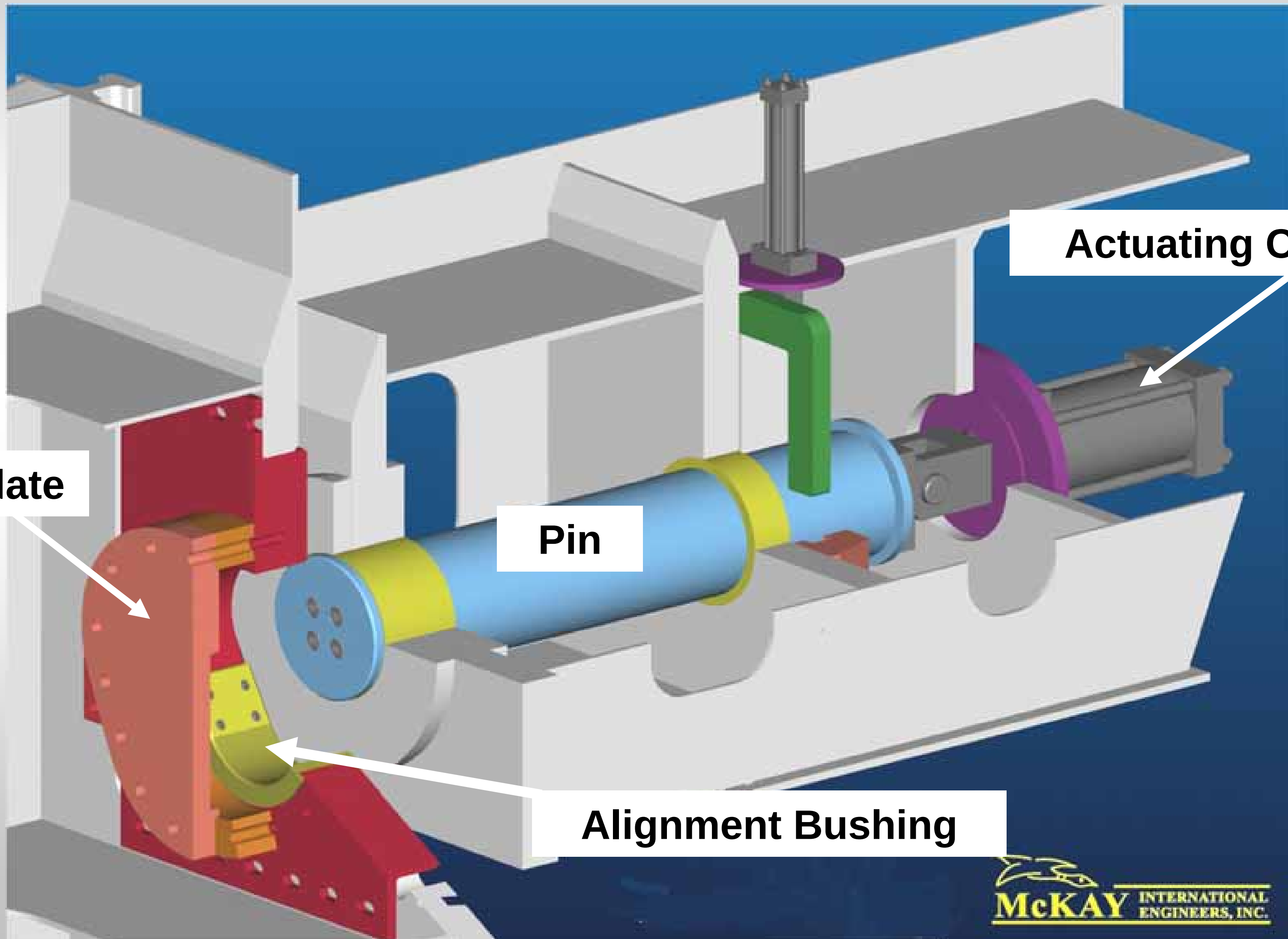
Elevating Machinery



Guide Rollers



Lock and Holding Pin Mechanism



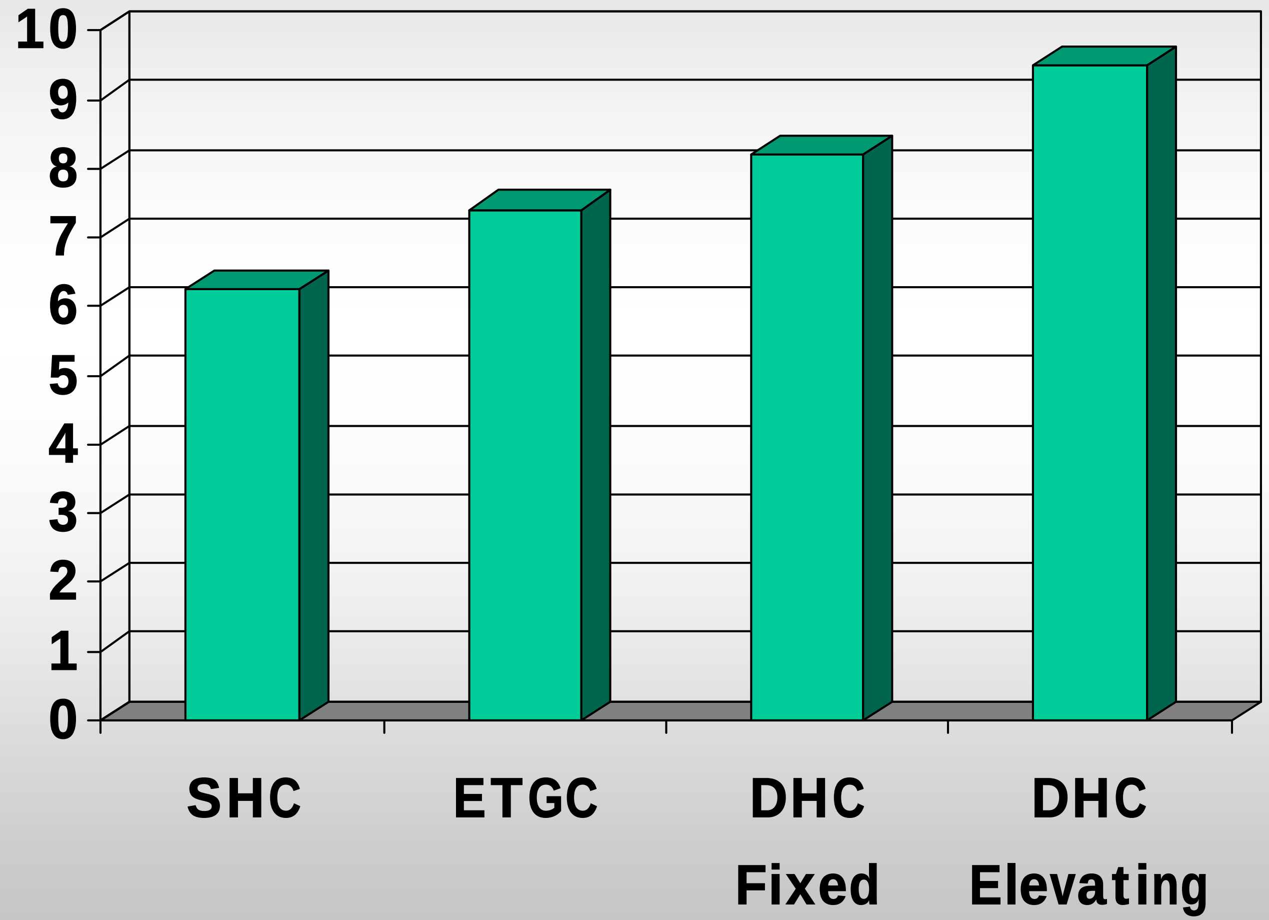
Construction Schedule

➢ **Start fabrication**	**March 2003**
➢ **Testing in plant**	**Oct 2003-Jun 2004**
➢ **Off-loading in VA**	**Oct 2004**
➢ **Commissioning**	**Nov 2004**

Productivity Influence Summary

➢ Specialty Crane	≈ 3-5 CPH
➢ Delays	≈ 3-5 CPH
➢ Operator Proficiency	≈ 3-5 CPH
➢ Type of Operation	≈ 3-5 CPH
➢ Ship Stowage	≈ 3-7 CPH

Estimated Initial Cost



Estimated Cost Summary

	Annualized Initial Cost 20 years at 8%	Operating Labor Cost @ $45 per hour	Maintenance Cost Labor and Parts	Energy Cost @ $0.10/KWHR	Total Annual Cost 3000 hrs per year	Cost per Container based on 3000 HRS at 70% of Mode
SHC 5th Gen	$ 636	$ 270	$ 92	$ 30	$ 1,028	$ 11.13
ETDC	$ 754	$ 270	$ 120	$ 40	$ 1,184	$ 11.51
DHC Fixed	$ 835	$ 337	$ 180	$ 61	$ 1,413	$ 14.32
DHC Elevating	$ 967	$ 390	$ 194	$ 67	$ 1,618	$ 16.05

Note: Numbers in 000's except last column

Bottom Line

Just the procurement of a specialty crane does not necessarily guarantee large leaps in productivity. Several factors having weights of the same order of magnitude influence ship operation productivity.

Crane Procurement Overview

Evolution of quay crane industry

Demands and restraints

Crane procurement strategies

Options

- *Case study—tailor made*
- *Mechanical and electrical system choices*
- *AC vs. DC motors and drives*
- *Standard or specialty cranes*

Conclusions

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Conclusions

Section One: Crane Procurement

Highly competitive market

Better and cheaper cranes

Can use off-the-shelf or tailor-made

Requires quality monitoring

More diligence by purchaser

Trend: Tailor-made

Section One: Crane Procurement

End, Section One … Scheduled Coffee Break

Section Two: Crane Modernization

Crane Modernization Overview

Used vs. new cranes

Modification options

Relocation

Costs

Awarding the job

Conclusions

Crane Modernization

Why modernize?

- *Major changes in the shipping industry*
- *Competition for new tenants*
- *Response to economic climate*
- *Relocation within countries and across continents*

Modernization vs. new

- *Lower cost and shorter delivery duration*
- *Obsolescence—more myth than reality*

Used vs. New Cranes

Background data

Manufacturers: *Hitachi, IHI, Kocks, Kone, Krupp, Liebherr, Mitsubishi, MES, Morris, Noell, Paceco, Star, ZPMC*

Vintage	**1965 to 1985**	**1996 to present**
Capacity	*30 to 40 LT*	*50 to 65 LT (twin lift)*
Rail gage, m	*10-30.5*	*15.2-36.5*
Outreach, m	*29-38*	*53-69*
Backreach, m	*8-24*	*9-16*
Clearance between legs, m	*12-14*	*16-19*
Lift height	*18-27*	*32-37*
Hoist speed, m/min	*22-53*	*60-90*
Trolley speed m/min	*120-150*	*240*

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Crane Modernization Overview

Used vs. new cranes

Modification options

Relocation

Costs

Awarding the job

Conclusions

Modification Options

Geometry changes

Performance changes

Operational changes

Retrofits

Geometry Changes

Increase lift height

Increase outreach

Rail gage change

Miscellaneous changes

Modification Options
Geometry Changes

Increasing lift height

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Modification Options

Geometry Changes

Increasing lift height

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Modification Options

Geometry Changes

Increased lift height and gage change

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Modification Options

Geometry Changes

Increased outreach

Boom insert/addition

Modification Options
Geometry Changes

Increasing outreach

Modification Options

Geometry Changes

Rail gage changes

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Modification Options

Misc. Geometry Changes

Increase backreach

Increase portal beam height

Increase clearance between legs

Decrease overall gantry out-to-out

Other Modification Options

Performance Changes

Operational Changes

Electric Drive Retrofit

Typical Retrofit

Crane Modernization Overview

Used vs. new cranes

Modification options

Relocation

Costs

Awarding the job

Conclusions

Relocation

Seattle to Panama

Intra-harbor, Buenos Aires

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Crane Modernization Overview

Used vs. new cranes

Modification options

Relocation

Costs

Awarding the job

Conclusions

2001 Cost Guidelines
Geometry Changes

Modification	Dimensions	USA/Europe Cost ($1,000s)	Asia Cost ($1,000s)
Increase lift height	*6 m*	*750*	*500*
Increase outreach	*2 m*	*100*	*75*
	4 m	*200*	*150*
	6 m	*650*	*500*
	9 m	*750*	*600*
Increase backreach	*4-5 m*	*150*	*100*
Increase portal height	*1-2 m*	*100*	*75*
Widening leg clearance	*0.3 m*	*35*	*35*
	1 m	*300*	*250*
Decrease gantry out-to-out		*250*	*200*

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2001 Cost Guidelines

Performance Changes

Modification	USA/Europe Cost ($1,000s)	Asia Cost ($1,000s)
Increase rated capacity (25% increase)	*250*	*175*
Increase main hoist speed, replace drives with digital, replace controls	*1,200*	*700 to 900*
Upgrade gantry braking	*120*	*60*
Install snag protection	*120*	*120 to 250*

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2001 Cost Guidelines

Operational Changes

Modification	**USA/Europe Cost ($1,000s)**	**Asia Cost ($1,000s)**
Convert shore power to diesel power	*350*	*280*
Convert diesel power to shore power	*180*	*90*
Install man-lift	*180*	*100*
Replace operator's cab	*60*	*40 to 50*

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2001 Cost Guidelines

Relocation

Modification		**USA/Europe Cost ($1,000s)**	**Asia Cost ($1,000s)**
Change rail span		*350*	*250 to 350*
Relocate two cranes	*5 km*	*200*	*150*
	1000 km	*500*	*350 to 400*
	5000 km	*1000*	*700 to 800*

Crane Modernization Overview

Used vs. new cranes

Modification options

Relocation

Costs

Awarding the job

Conclusions

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Awarding the Job

1. Original crane manufacturer

Advantages

- *Detailed performance specs not required*
- *May save time, since no bidding required*
- *Manufacturer has all drawings and design expertise*

Disadvantages

- *Crane manufacturer may not be interested*
- *Not equipped for major on-site work*
- *May not own jacking equipment*
- *Cost may be high*

Awarding the Job

2. Turnkey project with contractor

Design/build contract through negotiation or bidding

Pre-qualification and selection based on experience

Contractor assumes product liability

Substantial engineering by contractor

Requires knowledgeable crane designers

May cause contractor to leave large contingency in price

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Awarding the Job

3. Retain crane design professionals

All contractors bid on same package

Owner helped through bidding and construction review by engineer

Costs typically lower

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Conclusions

Section Two: Crane Modernization

Used vs. new cranes

Modification options

Relocation

Costs

Awarding the job

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Section Two: Crane Modernization

End, Section Two … Scheduled Break

Section Three: Crane Useful Life Assessment and Maintenance

Useful Structural Life Assessment

Overview

Owner's Options

Predicting Life

Extending Life

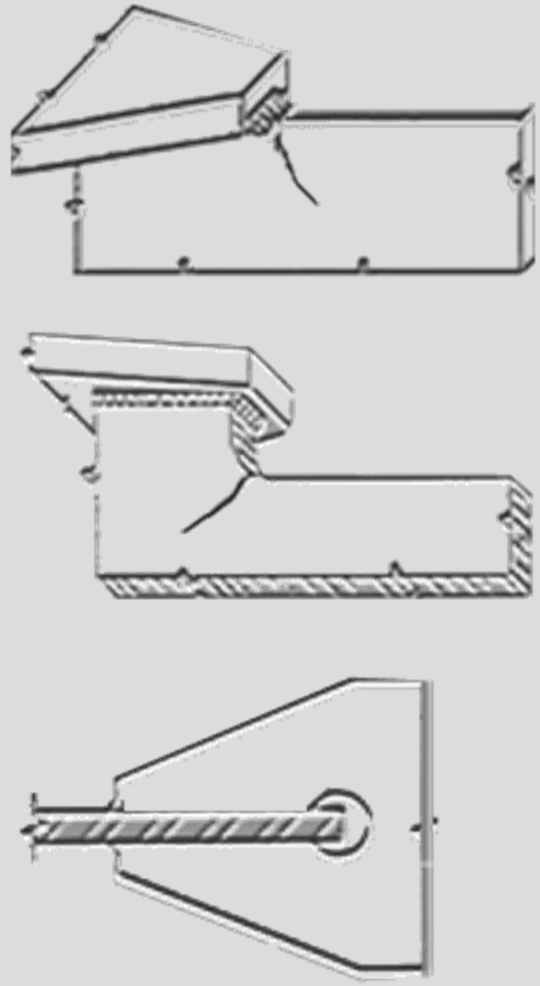
Case Study

Useful Structural Life

Definition—Duration for operating the crane with a tolerable risk of fatigue failure

Unrelated to corrosion and mechanical/ electrical failure or obsolescence

Structural maintenance programs extend useful life



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Useful Structural Life Depends On

Initial structural design

- *Load and cycle spectra*
- *Structural details*

Manufacturing quality

Operations history

Structural maintenance

You Have an Older Crane–What are Your Options?

Do nothing—ignore risks

Useful structural life assessment

- *Prolong life with inspection and repair*
- *Reduce use and/or relocate*
- *Dispose*

Structural Deterioration

Corrosion

Fatigue crack growth

Overload / damage / abuse

Predicting Useful Structural Life

Fatigue phenomenon

Fatigue evaluation

Useful life analysis

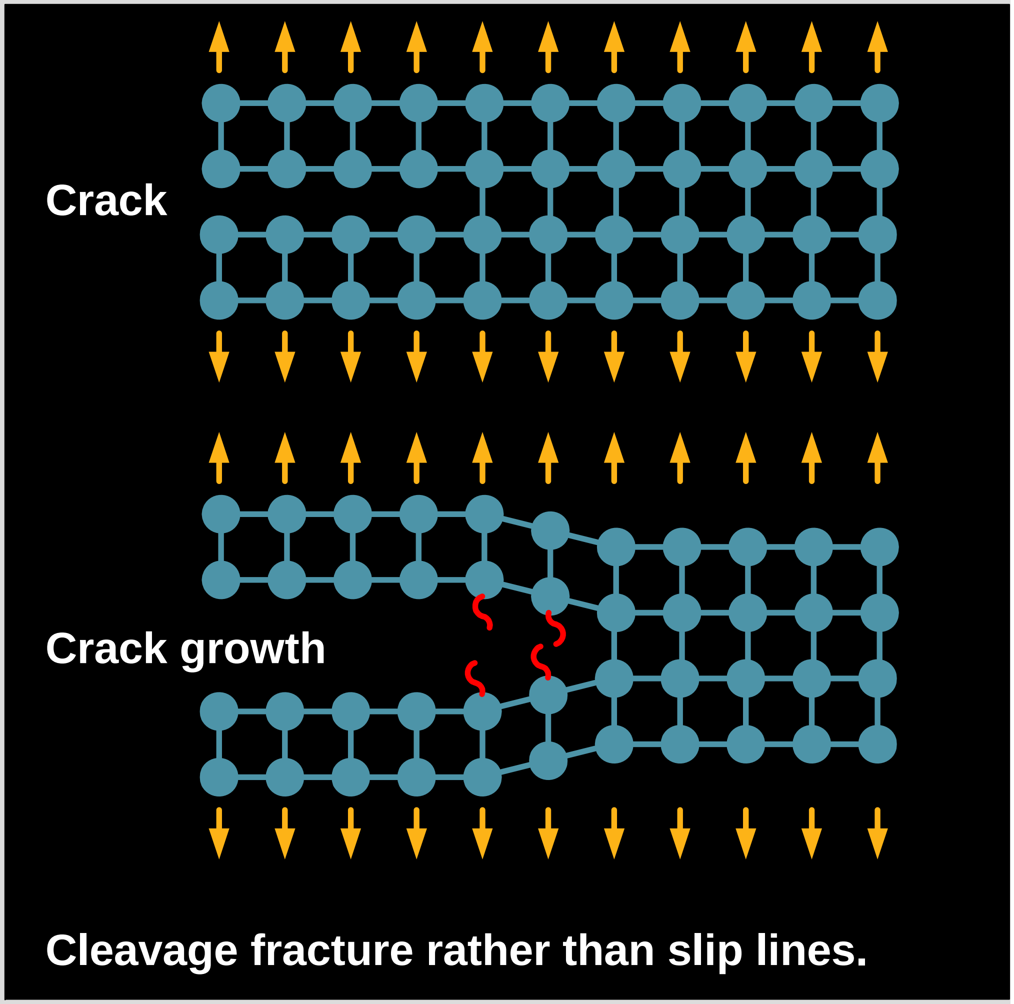
Fatigue Crack Growth

Stress range

Number of cycles

Detailing

Workmanship and quality control



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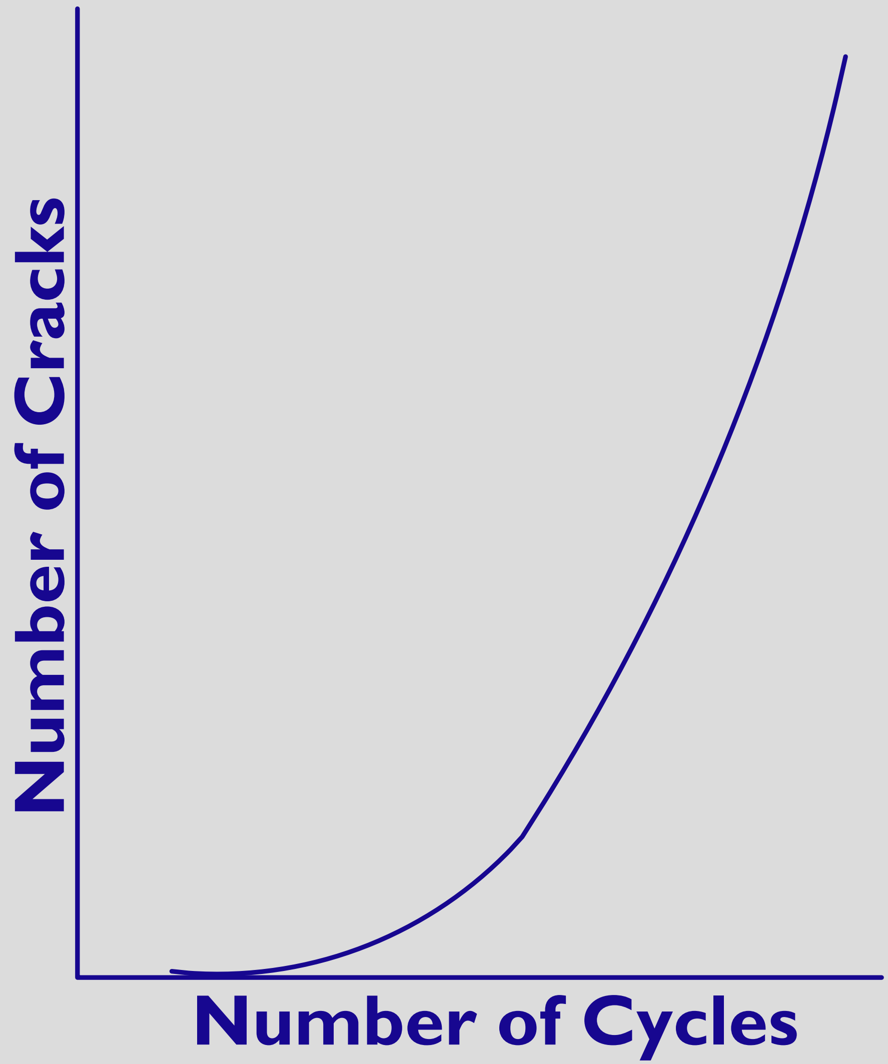
Number of Cracks Accelerates with Use



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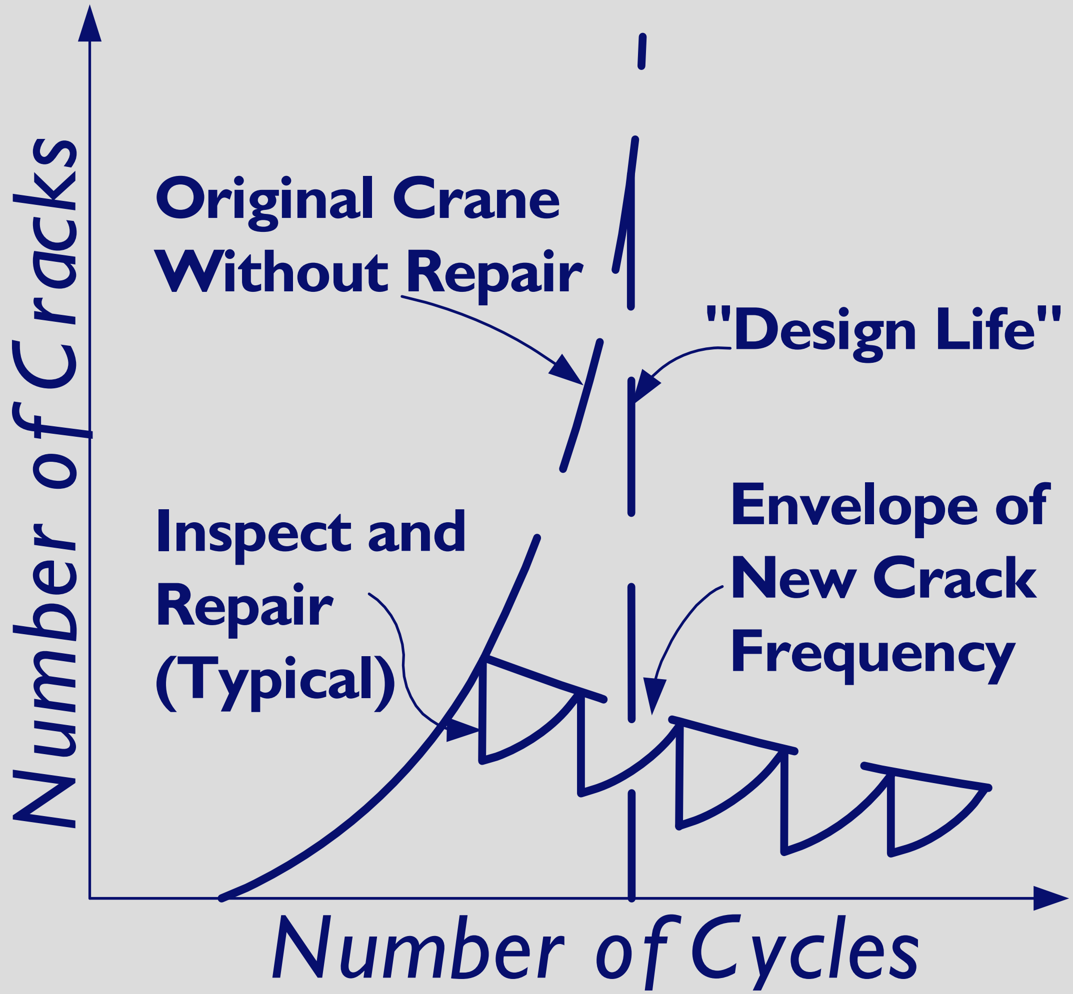
Crack Occurrences and Maintenance



- Poor initial details repaired
- More attention during repair
- Threshold stress range

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Steps of a Useful Life Analysis

Structural condition survey

Useful life estimate before inspection

Inspection program and structural inspection

Useful life estimate after inspection

Risk of Failure

Current design criteria

1 in 50

Adding structural maintenance program

1 in 1,000

Extending Life

Determine if economic to continue to operate crane

Repair and refurbish crane

Plan for future inspections and repairs

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Crane Maintenance

General

Structural

Mechanical & Electrical Considerations

Crane Availability Estimates*

Breakdown repair time

Aggressive target: 0.5%

Minimum target: 2%

Preventive maintenance and periodic inspection time

Typically 16 to 30 hrs per wk

Depends on crane age and usage

Routine servicing time

Typically 4 to 8 hrs per wk

Availability

*Based on typical 2,000-3,000 hrs operation per year

Preventive Maintenance Includes

Weekly pre-operational checks to verify

- *Operations of all motions*
- *Limit switch settings*
- *Wire rope and spreader adjustments*

Periodic Frequent Maintenance

Wire rope

Brake adjustment and testing

Limit switches

Spreaders

Availability*

$$Total\ Availability = 1 - \left(\frac{Hrs_{Breakdown} + Hrs_{prev.\ maint.} + Hrs_{routine\ service}}{7200} \right)$$

$$Operational\ Avail. = 1 - \left(\frac{Hrs_{Breakdown} + Hrs_{prev.maint.}}{7200} \right)$$

$$Breakdown\ Avail. = 1 - \left(\frac{Hrs_{Breakdown}}{7200 - Hrs_{prev.maint.}} \right)$$

**Based on a typical 300-day work year = 7200 hrs/yr*

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Replacement and Spare Parts

Inventory

Availability in case of emergency

Interchangeability

Components available in country

Crane Maintenance

General

Structural

Mechanical & Electrical Considerations

Structural Maintenance & Inspection Program

Inspection manuals

- *Details to be inspected*
- *Classification: FCM or NFCM*
- *Detail location identification*
- *Inspection method: VT, MT, UT, RT*
- *Inspector's qualifications*
- *Reporting procedures*
- *Repair procedures*
- *Improving details*

Inspection frequencies

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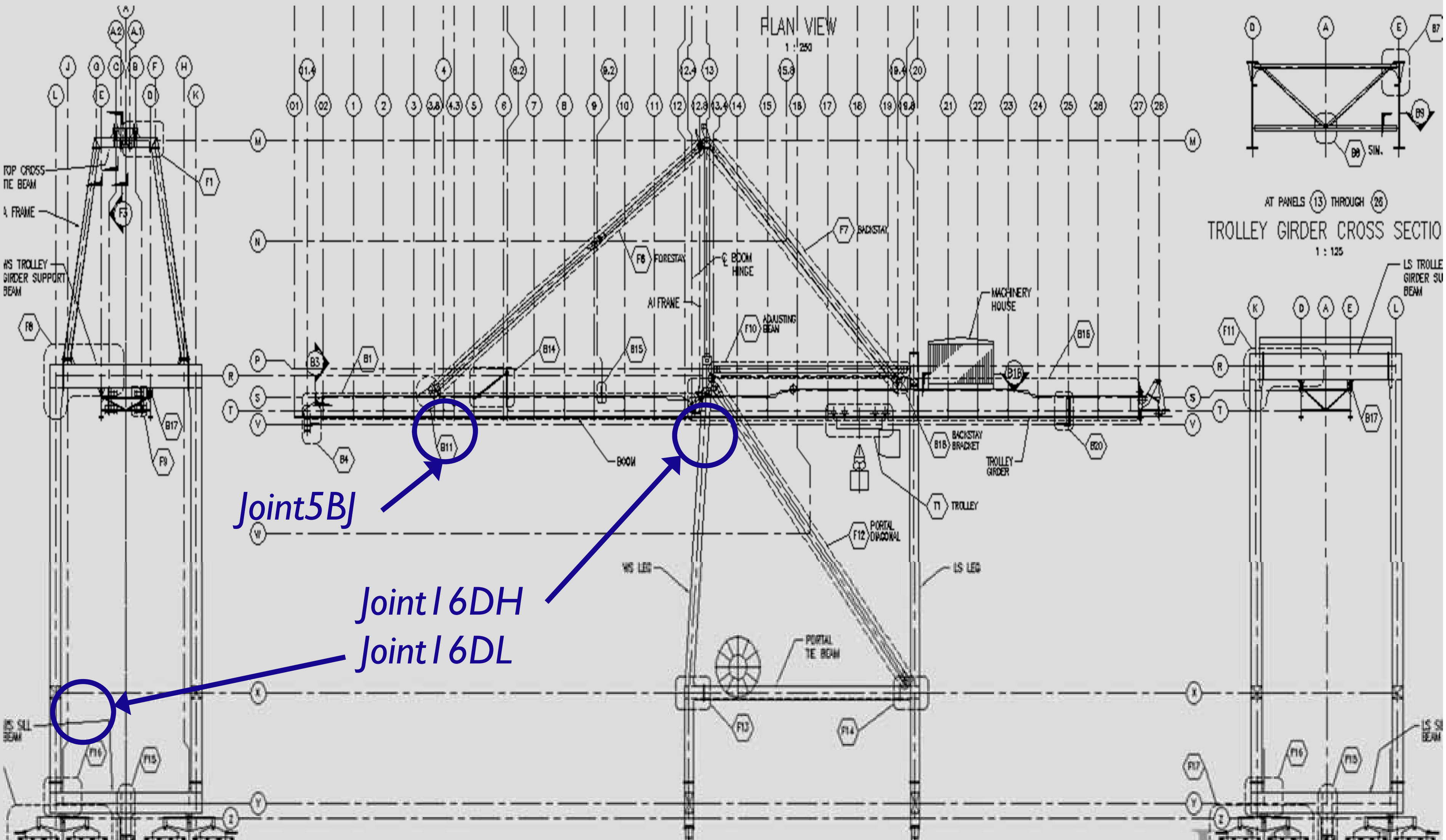
Inspection Program:
Typical General Arrangement



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Inspection Program:
Typical NDT Manual Pages

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by JRD approved FV

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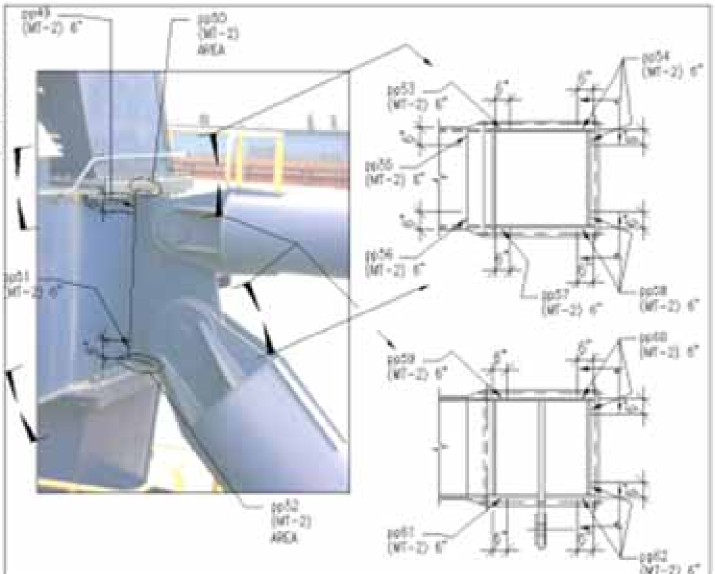

NOTE: VISUALLY VERIFY THAT BOLTS ARE TIGHT AND PLATES HAVE NOT BUCKLED. IN ADDITION, INSPECT MINIMUM OF 10% OF ALL BOLTS PER AISC (AT LEAST TWO BOLTS PER CONNECTION).

F6 1 OF 6

Weld I.D.	Type of Test			Accept	Reject	Remarks	By	Date
	VT	MT	UT					

Equipment used:

If defect detected, indicate if: RS,LTS,WS,LS,IB,OB,U,L.

Joint: 16DH

PACECO QC65 AUDIT

of

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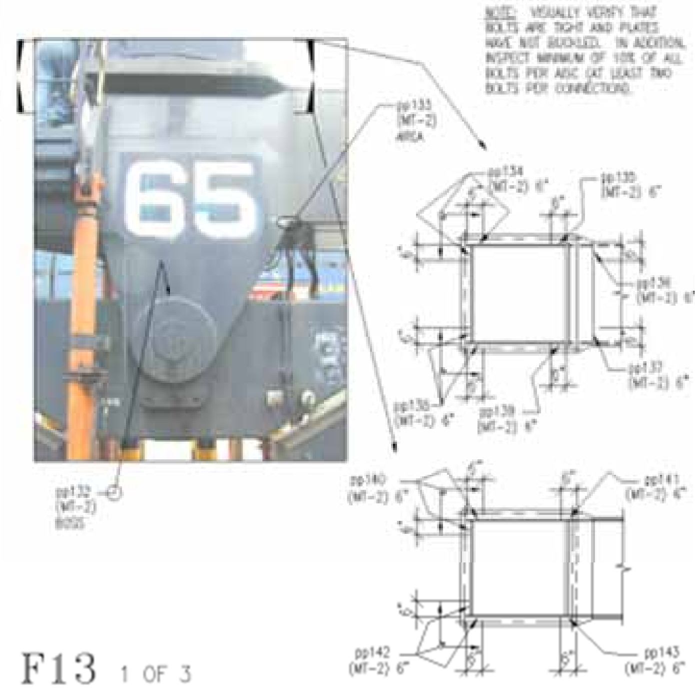
NOTE: VISUALLY VERIFY THAT BOLTS ARE TIGHT AND PLATES HAVE NOT BUCKLED. IN ADDITION, INSPECT MINIMUM OF 10% OF ALL BOLTS PER AISC (AT LEAST TWO BOLTS PER CONNECTION).



F13 1 OF 3

Weld I.D.	Type of Test			Accept	Reject	Remarks	By	Date
	VT	MT	UT					

Equipment used:

If defect detected, indicate if: RS,LTS,WS,LS,IB,OB,U,L.

Joint: 16DL

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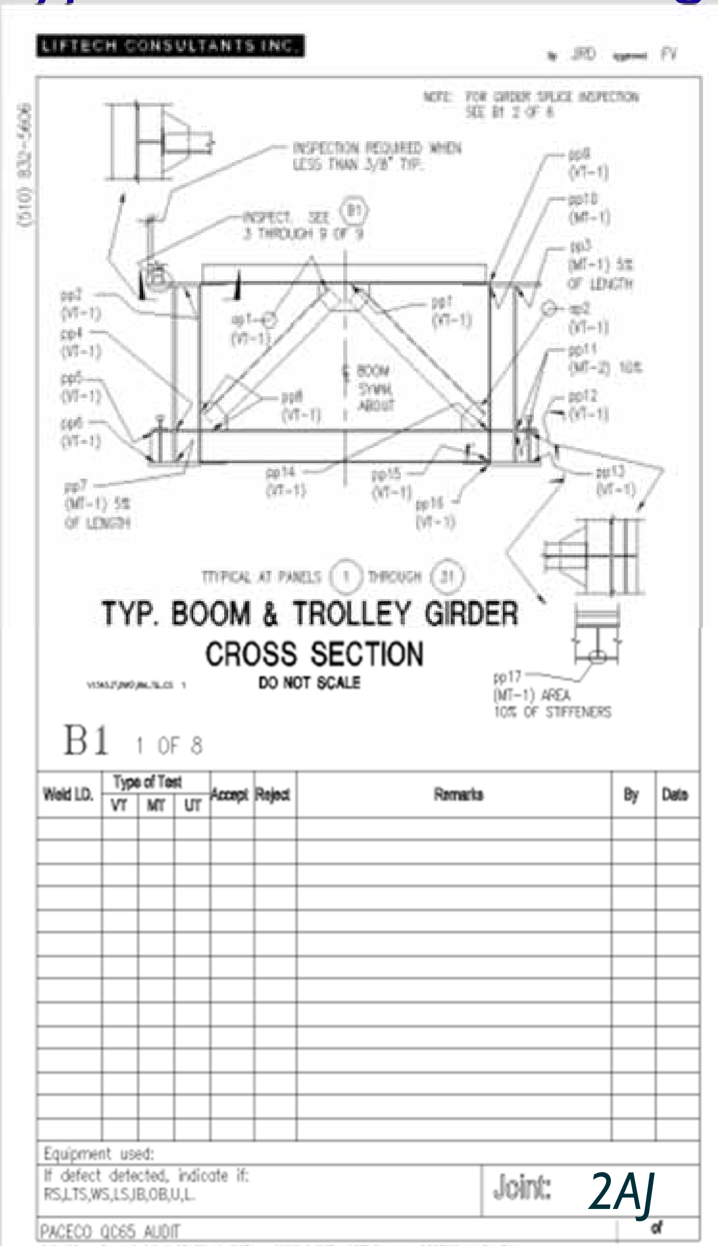
Inspection Program:
Typical NDT Manual Pages



Weld I.D.	Type of Test			Accept	Reject	Remarks	By	Date
	VT	MT	UT					

Equipment used:
If defect detected, indicate if:
RS,LTS,WS,LS,IB,OB,U,L.
Joint: 2AJ
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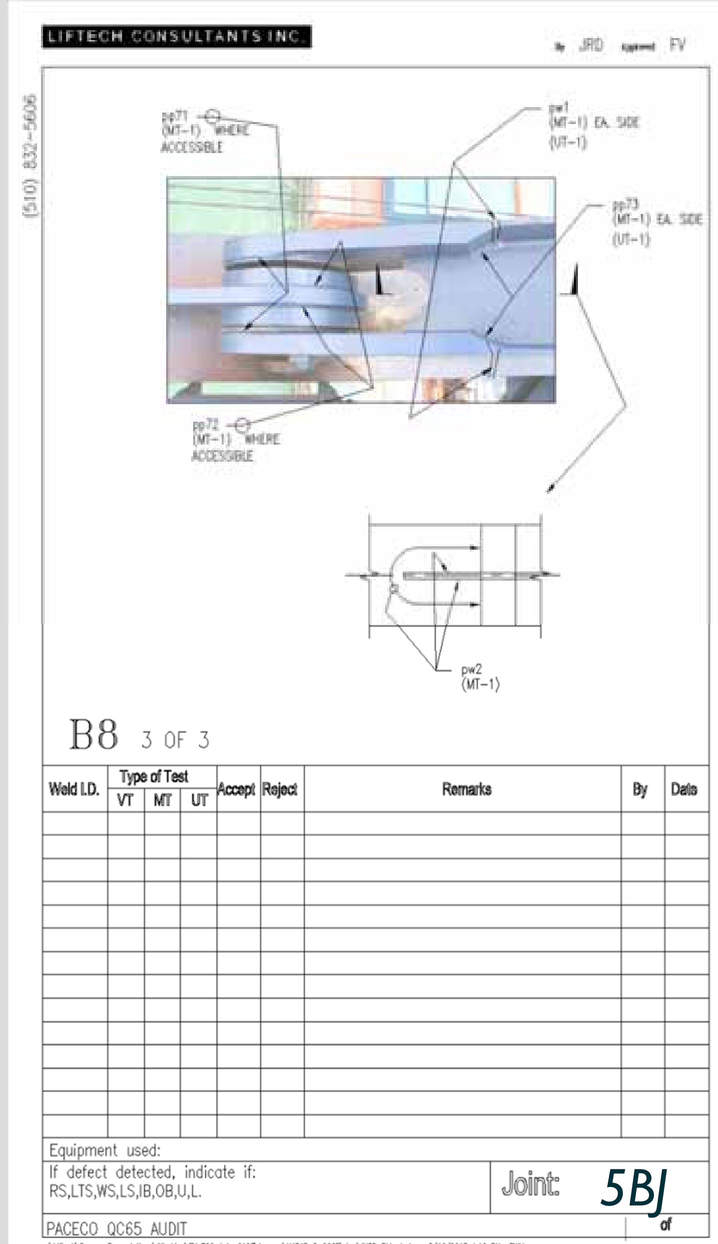
of



Weld I.D.	Type of Test			Accept	Reject	Remarks	By	Date
	VT	MT	UT					

Equipment used:
If defect detected, indicate if:
RS,LTS,WS,LS,IB,OB,U,L.
Joint: 5BJ
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All Cracks Need to be Repaired

Cracks occur at:

- *Poorly designed details*
- *Poorly fabricated details*
- *Corrosion-related damage*

Important to not only repair crack, but also to improve the detail

Engineering judgment is required

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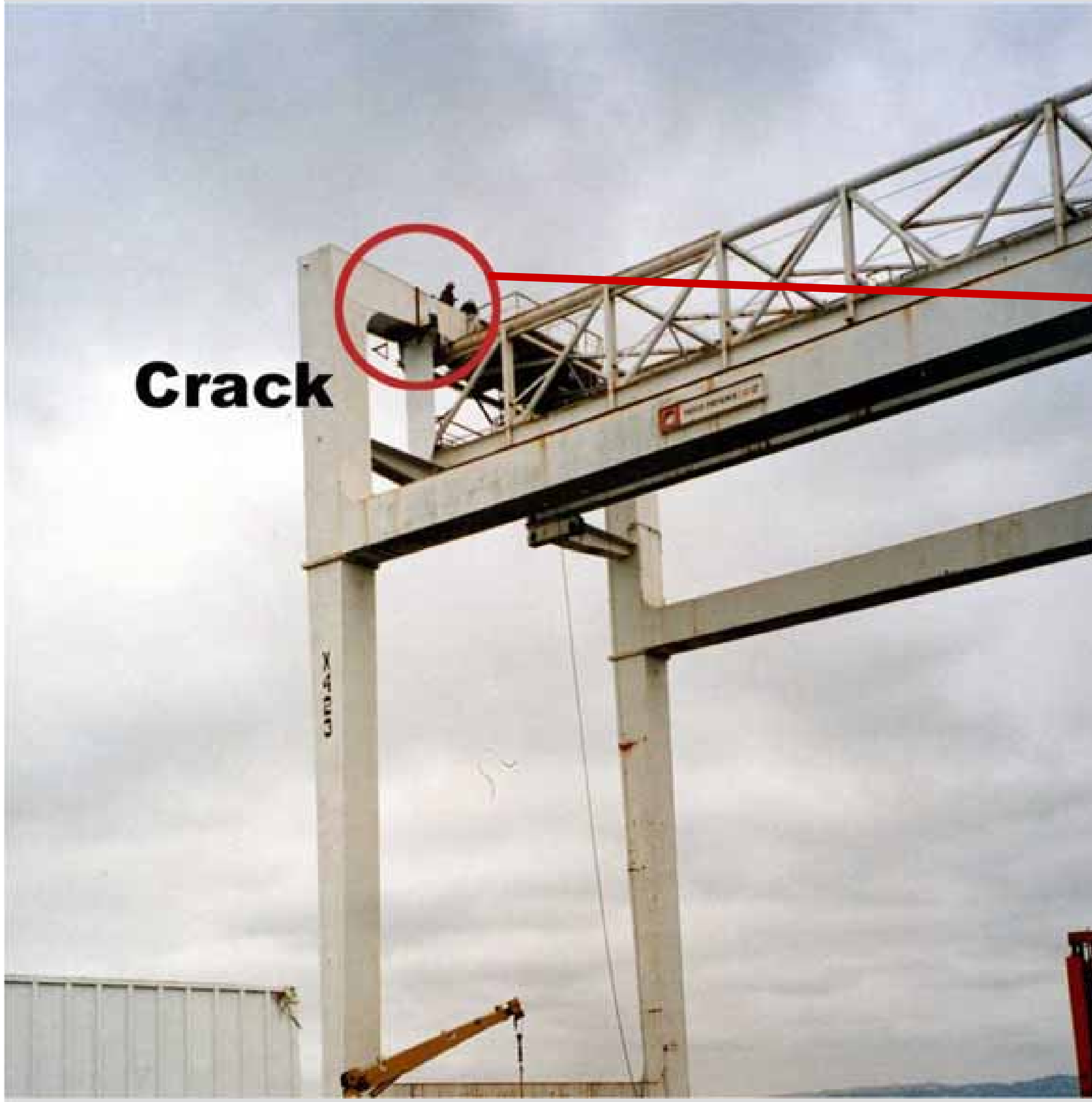
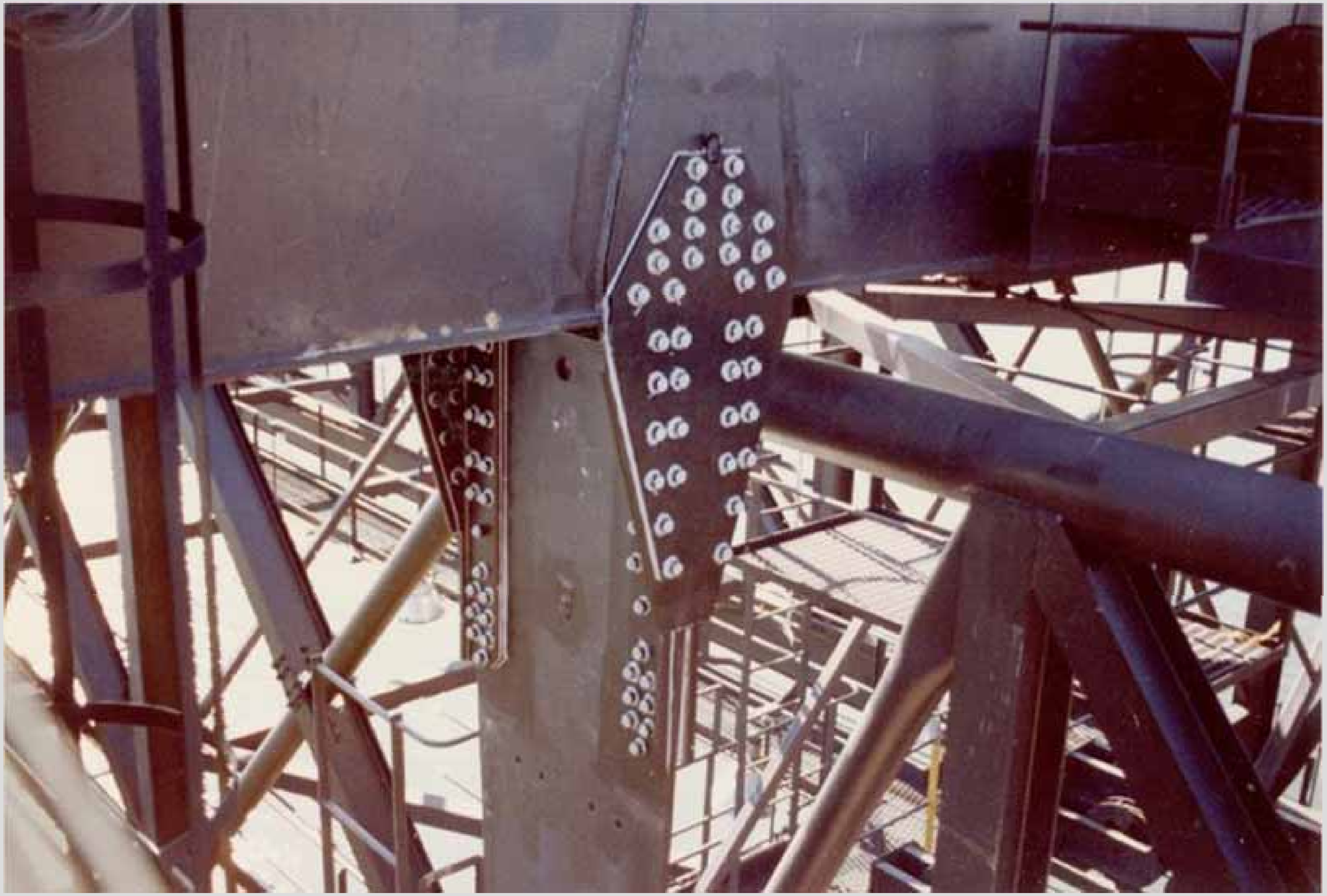
Unstable Fatigue Crack



Reinforcing Plates



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Rejuvenation

If cracks are repaired:

Detail at repaired crack becomes rejuvenated

Repaired joint is at least as good as new

Inspection Frequency

More bang for your buck

Not all joints need inspection at the same interval:

- *More frequent inspection:*
  - *Fracture critical members (FCMs)*
  - *Joints with higher stress ranges*
- *Less frequent inspection:*
  - *Non-fracture critical members (NFCMs)*
  - *Joints with lower stress ranges*
  - *Joints in secondary members*

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Example Inspection Intervals

Component	Fracture Critical?	No. of Moves	Interval (Years)
Trolley Girder Hanger	*Yes*	*300,000*	*3*
Forestay	*Yes*	*600,000*	*6*
Lower Legs	*No*	*1,200,000*	*12*
Portal Beam	*No*	*2,400,000*	*24*

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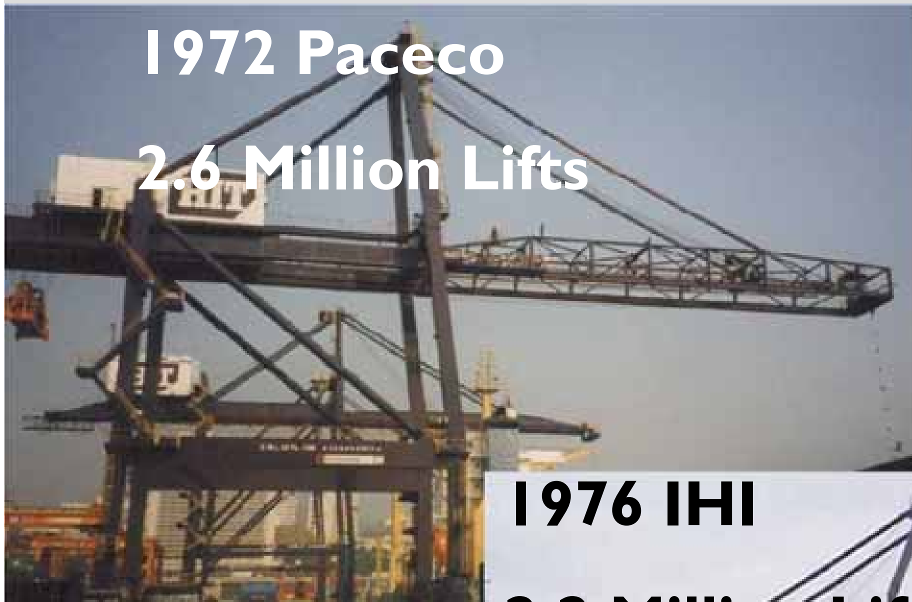
Case Study: Eight Quayside Cranes

Three Manufacturers



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Purpose of Study

Establish a structural maintenance program

- *Inspection manual*
- *Repair procedures*
- *Structural inspection intervals*

Estimate remaining useful life

Recommendations to improve remaining useful life

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Results

	Number of Cracks	
Crane	**Estimate Before NDT Inspection**	**Detected by NDT Inspection**
Paceco	*33 to 38*	*7 to 13*
IHI	*3 to 8*	*2 to 11*
Hitachi	*0 to 1*	*2 to 3*

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Results

Useful Life Estimate (Number of Years)			
Crane	**Before NDT Inspection**	**After NDT Inspection**	**After Cracks Repaired**
Paceco	*0 to 1*	*6 to 11*	*11 to 16*
IHI	*8 to 13*	*6 to 18*	*10 to 17*
Hitachi	*15 to 17*	*8 to 11*	*13 to 16*

Conclusions to Case Study

Findings compared well with the initial estimates

Useful life extended with inspection and repair

Helped client decide what to do

Maintenance Overview

General

Structural

Mechanical & Electrical Considerations

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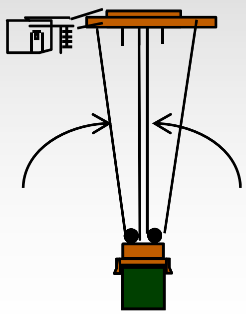
Mechanical and Electrical Maintenance Considerations

Sway Control

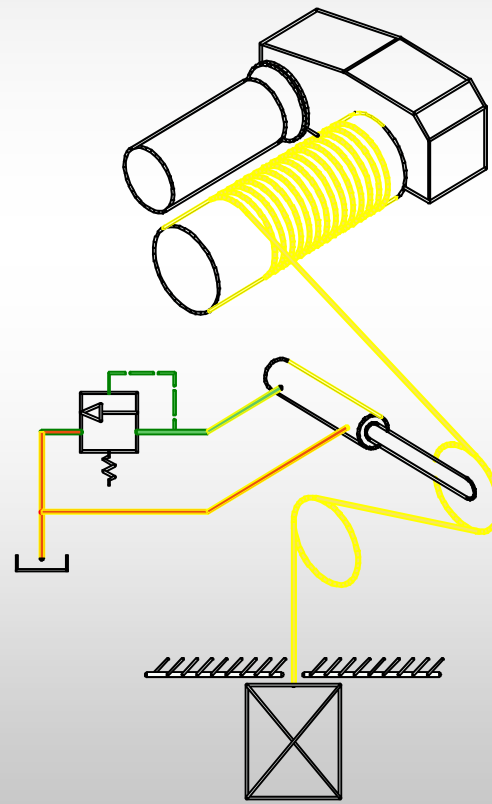


- **Hydraulic**
  - Requires spreader to trolley fleet angle
  - Adds to hydraulics maintenance load
  - Reasonably effective
- **Electronic**
  - Most manufacturers include it in drive
  - Operators perceive that they can do better
  - Requires little or no maintenance
- **Operator**
  - Most effective for controlled periods
  - Affected by fatigue
  - No maintenance

Snag Device

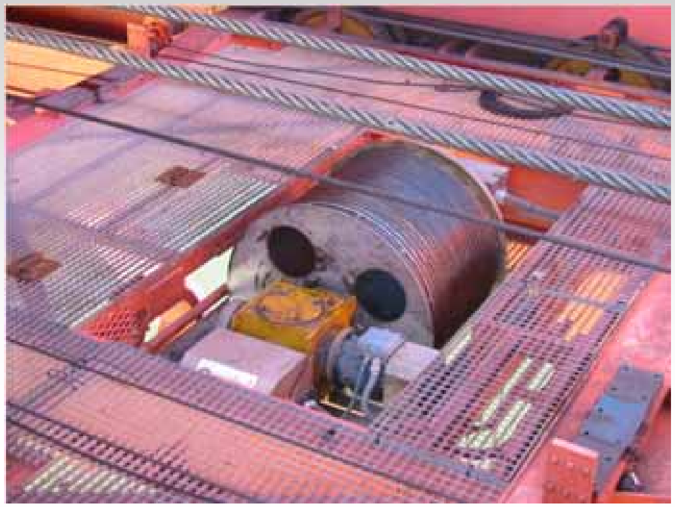
- **Hydraulic**
  - **Most effective**
  - **Usually combined with spreader micro-motions**
  - **Complex but requires minimal maintenance**
- **Crushable Element**
  - **Simple concept**
  - **Easy to maintain**
  - **Expensive and marginally effective due to preliminary crushing**

Hydraulic Snag Device



Spreader Trim, List, and Skew

Spreader Cable Reel or Cable Tub?



- Speeds of recent cranes too high for tub
- Gravity cable installed as back-up with reduced speed
- Problems have been with shock absorber more than drive

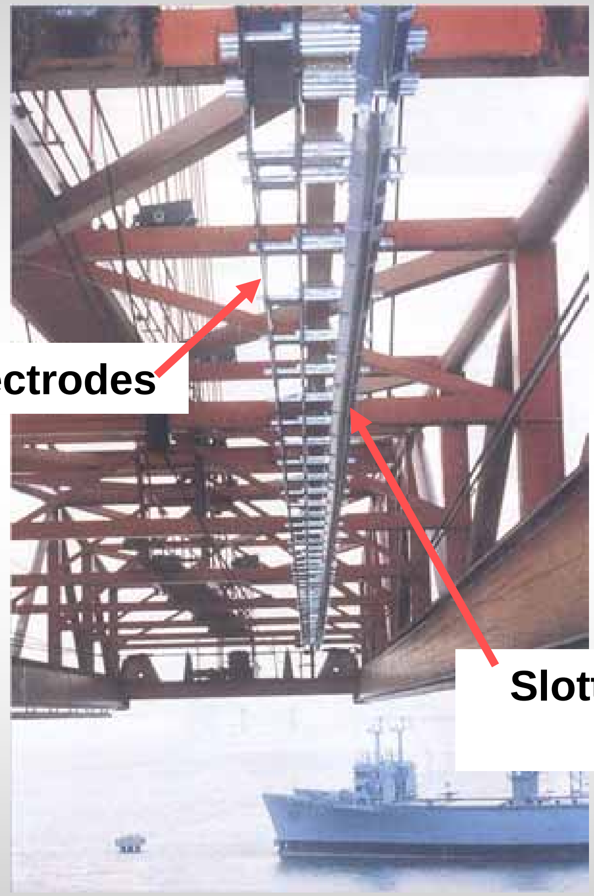
Festoon

Problems with standard festoon:

- **Controlling shock from bumping saddles**
- **Whipping of cables in wind**
- **Maintenance of wheels**
- **Increasing size with machinery on trolley cranes**

CPS / SMG

Contactless Power Supply/ Slotted Microwave Guide



Energy Chain System

- Simple, easy to maintain
- Impervious to wind
- Works in ice and snow

Electronics Troubleshooting

Maintenance Operating Station

- Start Crane
- E-Stop
- Boom up/down
- Spreader extend retract
- Motions in slowdown
    - Gantry
    - Hoist
    - Trolley

Conclusions

Section Three: Crane Useful Life Assessment and Maintenance

Useful Structural Life Assessment

Maintenance

Masterclass Conclusions

Section One: Crane Procurement

Section Two: Crane Modernization

Section Three: Crane Useful Life Assessment and Maintenance

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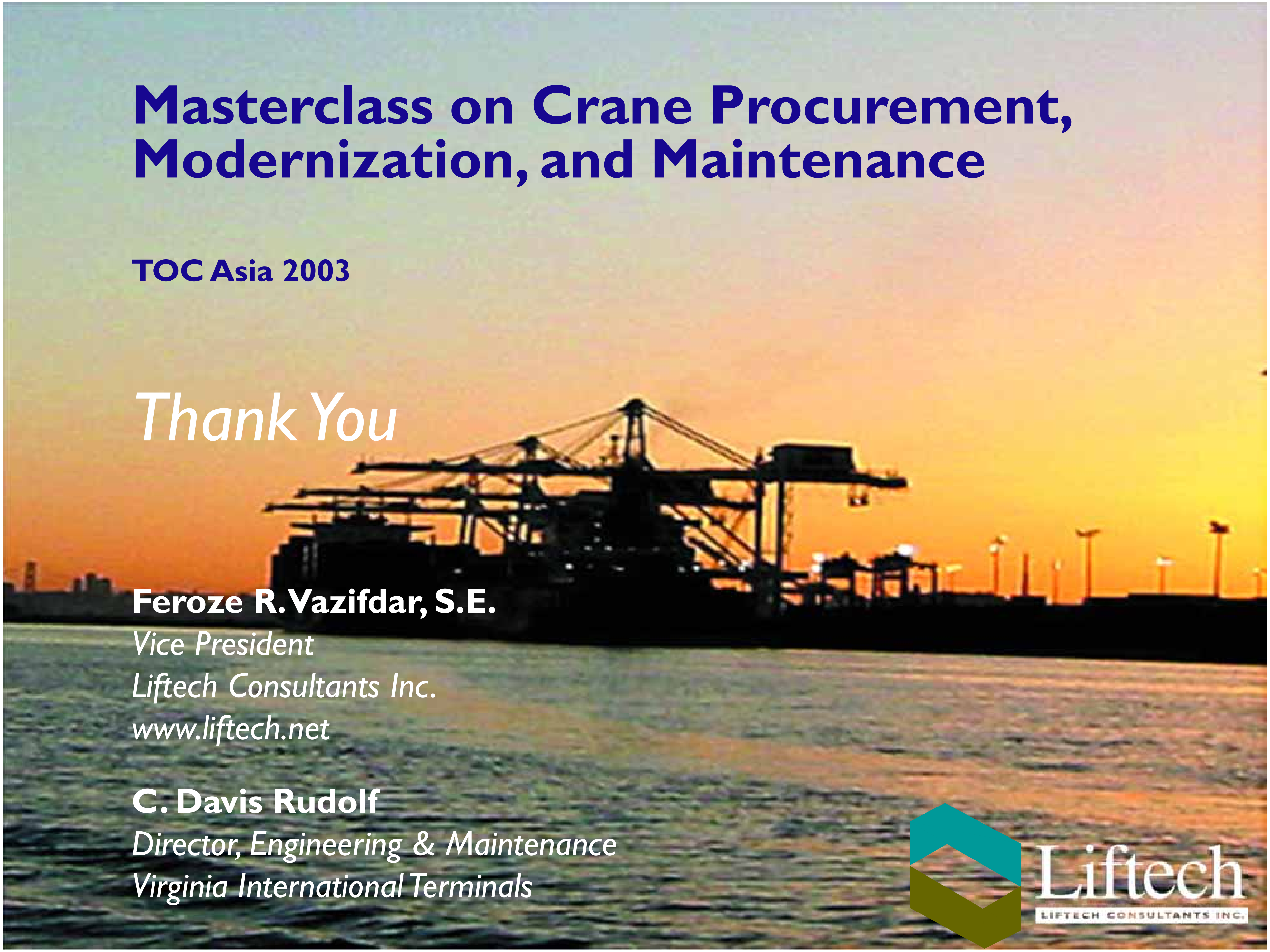

Masterclass on Crane Procurement, Modernization, and Maintenance

TOC Asia 2003

Thank You

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