Automating Yard Operation in Brownfield Container Terminals: Infrastructure

A PEMA Information Paper

The introduction of fully automated container handling operations at new-build terminals has resulted in substantial operational advantages in terms of safety, efficiency and sustainability. Interest is now growing among brownfield container terminal operators to make existing manually operated terminals and equipment partially or fully automated.

This information paper provides an overview of issues to consider when automating a variety of container crane types, explores various challenges that need to be addressed, and offers insights into the extent to which automation of existing container equipment is possible and desirable.

Automating Yard Operation in Brownfield Container Terminals: Infrastructure is the first part of a two-part PEMA Information Paper. The second part of this paper – Automating Yard Operation in Brownfield Container Terminals: Crane Modification will be published in due course.

PORT EQUIPMENT MANUFACTURERS ASSOCIATION

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1. INTRODUCTION

DOCUMENT PURPOSE

The introduction of fully automated container handling operations at new-build terminals has resulted in substantial operational advantages in terms of safety, efficiency and sustainability. Interest is now growing among brownfield container terminal operators to make existing manually operated terminals and equipment partially or fully automated.

This information paper provides an overview of issues to consider when automating a variety of container crane types, explores various challenges that need to be addressed, and offers insights into the extent to which automation of existing container equipment is possible and desirable.

The paper illustrates the benefits of automation, such as continuous operations, personnel safety, operational efficiency and environmental impact. It also describes the systems and components used to automate cranes based on equipment type and infrastructure characteristics. It outlines potential strategies for implementing partially and fully automated yard operations to minimize disruption to day-to-day operations.

Automating Yard Operation in Brownfield Container Terminals: Infrastructure is the first part of a two-part PEMA Information Paper. The second part of this paper – Automating Yard Operation in Brownfield Container Terminals: Crane Modification will be published in due course. This part of the paper focuses on infrastructure needed to introduce automation at brownfield terminals including, for example, remote-control. The second part of the paper will deal with the range of changes necessary to automate a variety of different crane types.

ABOUT THIS DOCUMENT

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2. EXECUTIVE SUMMARY

New-build container terminals have seen the benefits of automation in terms of increased safety, greater productivity, improved predictability, and reduced environmental impact. There is now growing interest in bringing varying degrees of automation to brownfield container terminals.

The key to successful brownfield automation is to limit disruption to operations. Furthermore, operations should be developed in such a way as to ensure personnel become familiar with new routines gradually. This helps ensure greater operational efficiency and reduces the risk of system failure or hazardous situations. Naturally, specific approaches will differ between terminals due to differences in local conditions and the types and composition of equipment currently in use.

3. AUTOMATING EQUIPMENT AT BROWNFIELD SITES

3.1 Benefits of automating equipment

- Considerable operational and maintenance cost savings
- Improved efficiency and availability
- Improved safety
- Reduced environmental impact in terms of reduced emissions and noise pollution
- Increased capacity
- Improvement in working conditions

3.2 Challenges to automating equipment at brownfield terminals

- Disruption to operations
- Existing terminal layouts may complicate implementation of new layouts, routines
- A substantial proportion of existing equipment is mid-service life
- Labour issues: changes in required skill sets; changes to existing contracts etc.
- Risk associated with upgrading existing Terminal Operation System (TOS)
- Risk associated with new IT infrastructures Prior to starting automation conversion projects, terminal operators should consider the following questions:
- Will existing terminal design remain unchanged for at least 10 years or more?
- Are yard blocks in sufficiently good condition for automation?
- Do existing RTGs already use automatic steering in yard blocks?
- How could yard gradient affect CHE position detection?
- How old are existing CHE fleets, where would retrofits be conducted, which CHEs need to be replaced?
- Are existing CHEs suitable for automation? (e.g. anti-sway spreader)
- Which electricity provider supplies power to existing RTGs, what type of programmable logic controller (PLC) is installed?
- Remote control requires fast and stable LAN/ WLAN connection: should this be provided with an electrification, bus bar or cable reel system?
- Does the electricity provider offer sufficient electrical capacity to power E-RTGs?
- Is it possible to balance recovered electrical energy from the terminal or the grid?

A key consideration is whether to allow a maximum amount of time to test new systems or to focus on the swift adoption of new processes and organizational culture associated with automated operations. A slower transition will enable more thorough testing and training of operational personnel, but a quicker transition may be preferable for operational reasons.

4. CRANE TYPES

This paper reviews rubber-tyred gantries (RTG), automated rubber-tyred gantries (ARTG), rail-mounted gantries (RMG), automated rail-mounted gantries (ARMG), straddle carriers (SC), overhead bridge cranes (OHBC), automated lifting vehicles (ALV), and reach stackers (RS). The primary focus of this paper is the automation and electrification of RTGs and SCs.

4.1 RTGs and RMGs

With relatively new RTG and RMG equipment, in many cases it is possible to automate existing fleets. Current yards can be adapted to automated operations, starting with one or more container stacks. Automating RTG and RMG terminals does not necessarily require changes to terminal layouts, but layouts optimized specifically for automation may improve efficiency, especially if there are changes made to horizontal transportation.

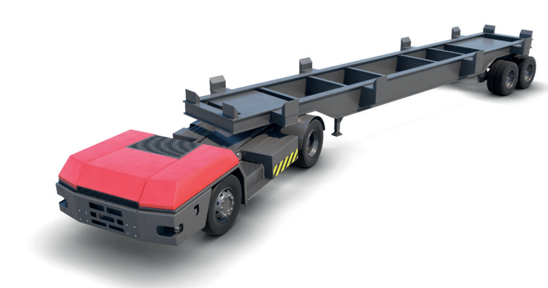
An automated RTG terminal may employ various types of horizontal transportation equipment. These can range from conventional terminal tractors and manual shuttle carriers to automated terminal tractors (ATT), automated guided vehicles (AGV) and fully automated shuttle carriers (ASC).

PLANNING

Automating existing RTG terminals requires careful planning, systems integration, staff training (including external truck drivers), and overall change management as the operation of automated terminals require different skill sets to those needed for operating conventional terminals. A typical timeframe for an automation conversion project may range from 12 to 30 months, depending on a variety of factors including integration and changes made to the TOS.

RTG automation projects could be planned in the following stages:

1. Electrification
2. Remote operation (1:1 ratio of operators to vehicles)
3. Pooled remote operation (e.g. 1:4 ratio of operators to vehicles)
4. Partial automation of RTG functions
5. Fully automated operation



An ATT suitable for use at automated applications. An ARTG at a truck gate. Image credit: Konecranes.

In general, existing RTG travel paths can be reused so that only power and network connections have to be added. Thus, yard modification is kept to a minimum and a conversion can be carried out relatively quickly.

Please see page 14 for details of the main types of RTG electrification.

1. DEGREE OF AUTOMATION

Various degrees of RTG automation can be implemented. Automation can also be implemented step-by-step and block-by-block. Here are some examples of degrees of automation:

Remote-controlled operations: an operator remotely controls one to four ARTG machines simultaneously from a control centre.

Automatic pick and place in stacks: hoist, trolley and gantry moves are made automatically in stacks. Operators remotely control truck lane operations. One remote operator can typically operate up to six ARTGs. Horizontal transport is conducted with manually driven vehicles or automated vehicles.

Fully automated operations: fully automated solutions with automated truck handling and automated horizontal transport, (for example ATTs or AGVs). An operator is now only needed for exceptional handling moves and possibly for handling external road trucks for safety reasons.

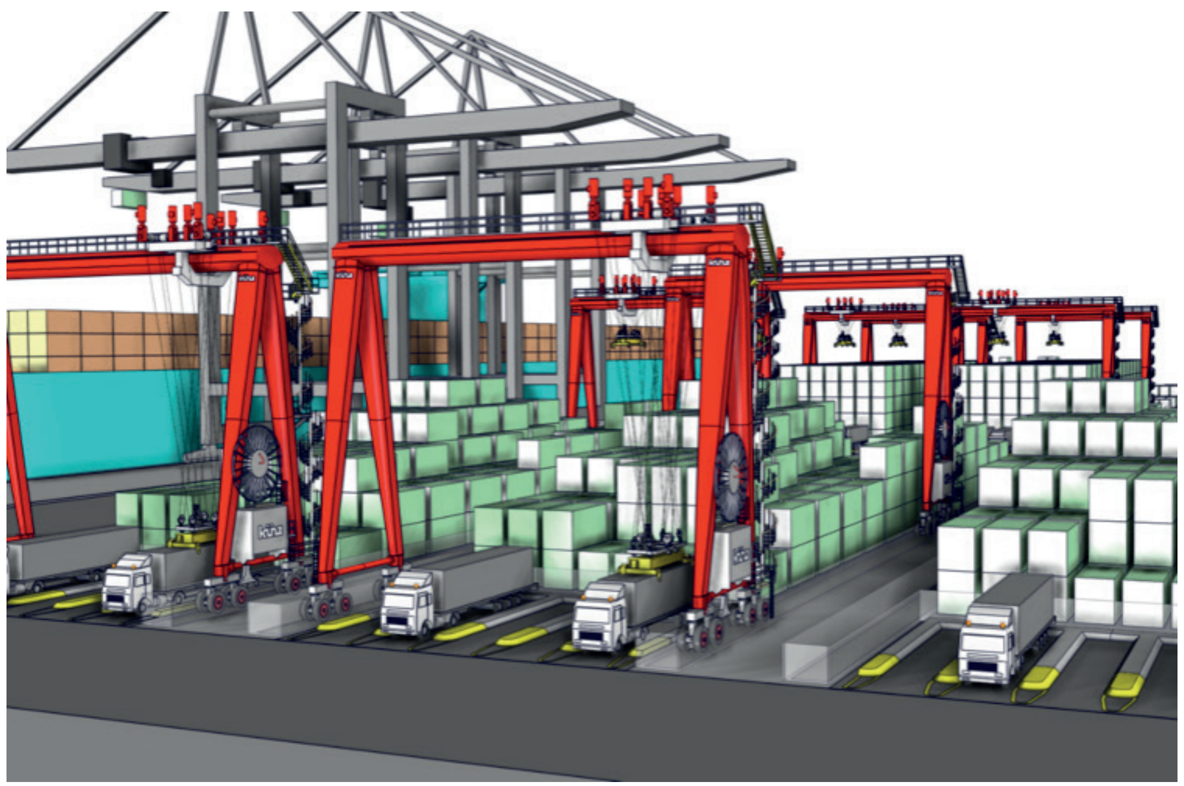


Image credit: Künz.

RMGs and crane runways

Converting conventional RMG terminals to ASC operation could be considered more straightforward than RTG automation, thanks to the existing rails. However, moving from RTG operation to ARTG or ASC operation tends to involve considerable initial costs if yards need to be equipped with new crane runways or rails. Conversion processes may also take significant periods of time to fully implement. Dividing conversions into separate steps limits operational disruption. This approach is used only if a yard needs to be densified to achieve significantly increased stacking capacity.

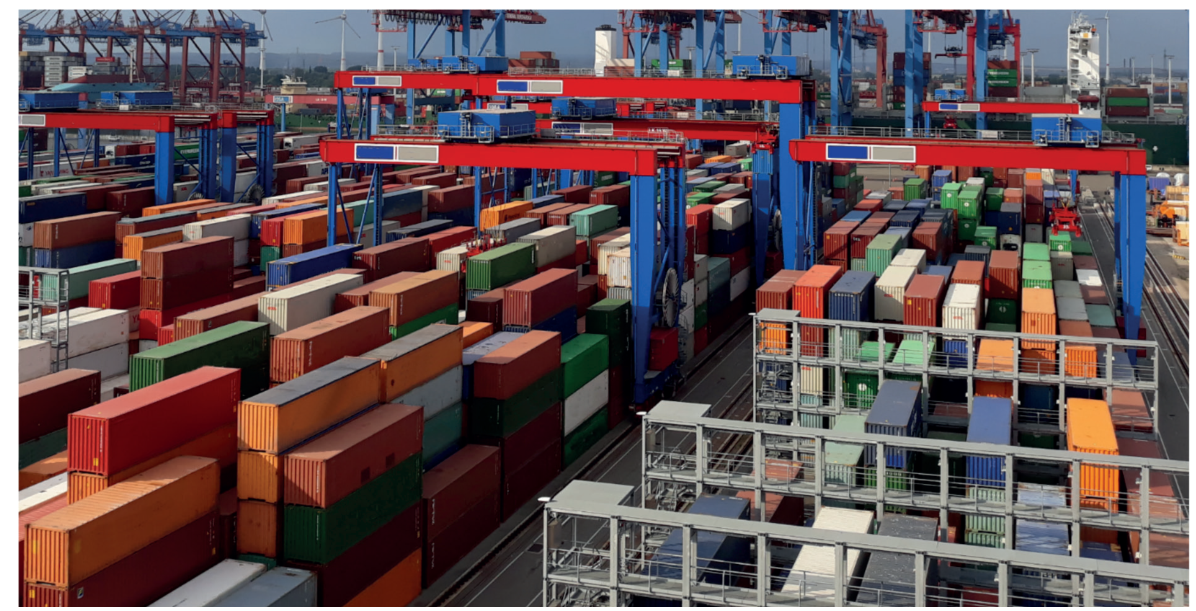


Image credit: Künz.

4.2 Straddle Carriers

SC fleets typically need to be automated in one phase. Automation may also require changes to terminal layout and operating procedures. Procedures for ship-to-shore (STS) operation, landside interface and reefer operation may change significantly. Alternative processes may also need to be introduced to handle empty containers and non-standard cargo that cannot be taken into automated areas.

Change management of personnel needs to be considered from the outset of a transformation process. The professional profile of personnel operating and managing automated SCs is markedly different from that required to run a manual terminal.

Image credit: Kalmar.

Individual terminal sections consisting of quay cranes, horizontal transport zone, storage area blocks and landside connection to road trucks are successively closed off and automated, while other sections remain operational during the conversion. A typical timeframe for an automation conversion can be 12 to 18 months.

Converting to automated SC operation may thus include parallel operation of manual and automated machines, requiring special safety arrangements. Assigning separate sections for manual and automated SCs is one approach to addressing this challenge.

Instead of acquiring new automated SCs, retrofitting existing diesel electric SCs may be technically and economically feasible by installing the necessary automation components such as navigation and sensors systems. Electric or hydraulic steering will be controlled by onboard automation systems instead of from the cabin, and sensors and data links are added for control, monitoring and system diagnostics.

Some terminals operate with mixed fleets with machines of different ages and, for example, a combination of 1-over-2 and 1-over-3 machines, which poses some additional challenges for retrofit automation.

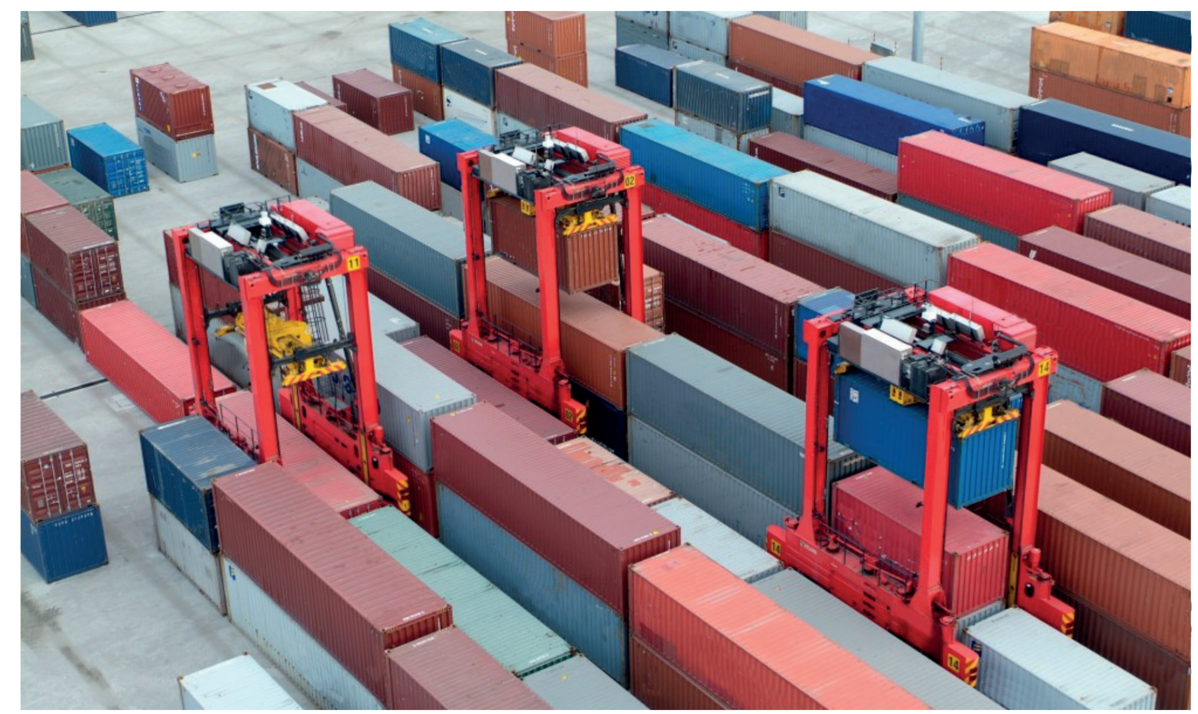
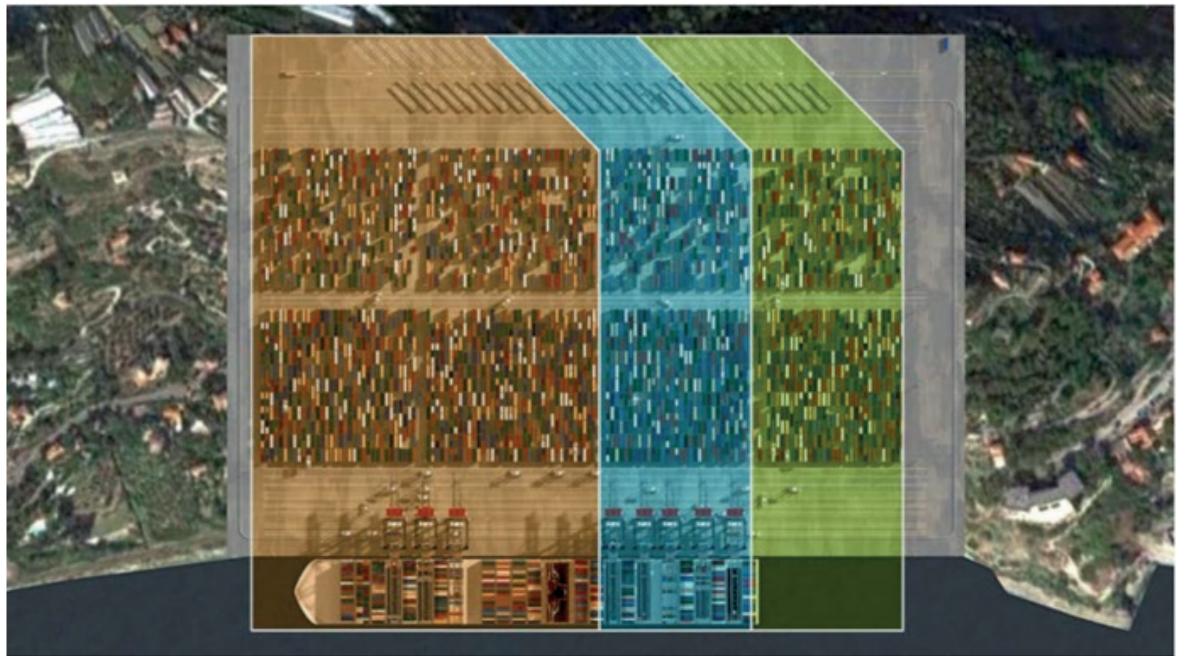


Image credit: Kalmar.



SC automation conversion by sections. Source: Konecranes.

DEGREE OF AUTOMATION

For waterside interface, the operation of SCs is typically fully automated. Picking and placing containers from/to ground under the STS backreach (or between STS legs) does not require any assistance from a remote operator, apart from in exceptional cases. The STS crane, however, is typically still operated by a human driver.

For truck interface, dedicated safety fencing is typically required, ensuring that the truck driver and the automated SC are not present at the same time while the truck is being handled. Unloading the truck by SC may be fully automatic, while truck loading typically requires some form of remote operation using, for example, a local radio controller or camera-assisted control.

Operation in the stacks is fully automatic. The container positions in the stack and the driving lanes in the stack could be gradually shifted to reduce wear of the paved surface.

4.3 Intermodal Cranes

Most intermodal cranes are equipped with a cantilever outreach to separate rail car loading/ unloading, stacking and truck or chassis handling. Today there are retrofits available to automate intermodal cranes. Special attention must be given to people and vehicle recognition systems to ensure that no load will be moved over a person. Otherwise similar topics as outlined in the RMG section above apply.

If existing runway and power supply can be used in an automation project, it can be considered as a minor modification to the yard. If, however, a new crane runway has to be installed, this will have a major (initial) impact on operations.

The modernized GCT Deltaport rail yard. Source: Künz.

However, there are examples of how this has been implemented, where small cranes have been replaced by larger ones to improve productivity. In general, both situations may allow for the introduction of remote-controlled or automated operations.

Naturally, it is important to ensure a safe working environment for yard personnel. It is recommended to combine such an approach with the introduction of a people and vehicle recognition system. People are often required to move along railway cars to prepare them for loading, truck drivers are not always able to make use of safe areas such as kiosks, and the loading/ unloading of trucks is usually carried out in the cantilever outreach. Automated stacking areas should be fenced off (pictured above).

Picture H: correct cable pulling direction horizontally

5. INFRASTRUCTURE SYSTEMS, MODULES

5.1 Stationary electrification infrastructure

- High voltage ring around the terminal
- Substation to transform high voltage into low voltage
  - One substation typically supports between eight and 12 RTGs; with an average of two RTGs per block, up to six blocks can be supplied by one substation
  - Substations can be 40" containers or stationary buildings
  - Substations contain measurement systems for analysing grid power
  - One main circuit breaker and each block has its own circuit breaker
  - Data node included
  - Measurement data collected at the data node
- Battery systems to support substations
  - Stabilize the grid
  - Cut off energy peaks
- Substations supply power to container blocks equipped with conductor rails or stationary plug solutions for cable reels
  - The conductor rail is mounted on the steel support structure
  - The feed point depends on the length of the block due to the required voltage dropace.

5.1.1 TYPES OF RTG/RMG ELECTRIFICATION

RTG/RMG electrification by plug-in system with conductor rails

Plug-in systems are suitable for smaller terminals with fewer block changes.

Function

- Connect manually to stationary conductor rails
- Conductor rails can be used to supply power to collector trolleys, which is a moveable part of the RTG/RMG crane. Power for motors, data for driver cabin are supplied by conductor rail and data communication rail
- Possible to upgrade positioning and data transmission system
- Auto-steering system combined to conductor rail steers crane automatically in appropriate positions during full-speed travel
- Off-track protection prevents damage to steel structures and connection points (collector trolley) on crane
- Generators supply power to crane during block changes

Operation

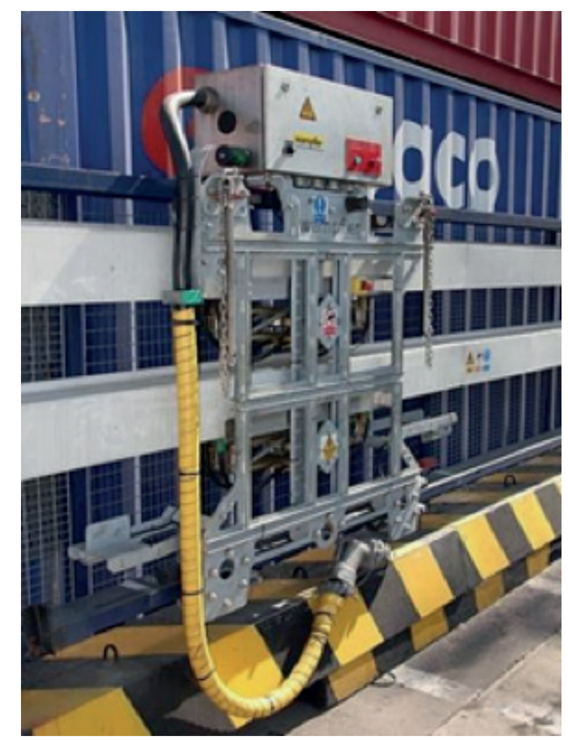
- Generator supplies power to crane
- Crane drives to position where current collector trolley is located
- Crane switches over from generator power to grid power
- Crane is ready for operation in grid power mode
- Crane drives into the electrified container block
- Auto steering system supports driver and steers crane automatically
- Positioning system continually monitors crane position

Benefits

- Reduced fuel consumption, emissions and noise pollution
- Reduced generator maintenance costs due to reduced use
- Possible to switch RTG back to diesel if necessary
- Travel speed not limited by conductor rails

Disadvantages

- Every container block requires one to two collector trolleys
- Stationary infrastructure required



RTG electrification by automated connection system with conductor rails

This electrification approach is suitable for mid-size and large container terminals, where RTG cranes often move between container blocks.

Function

- Automatically connect to stationary conductor rails
- Conductor rails can be used to supply power to collector trolleys, which is a moveable part of the RTG/RMG crane. Power for motors, data for driver cabin are supplied by conductor rail and data communication rail
- Possible to upgrade positioning and data transmission system
- Sensors ensures a safety connection
- Synchronizing device executes seamless switchover from generator/battery power to grid
- Auto-steering system combined to conductor rail guides crane automatically to desired position during full-speed travel
- Off-track protection prevents damage to steel structures and connection points (collector trolley) on crane
- Generators supply power to crane during block changes

Operation

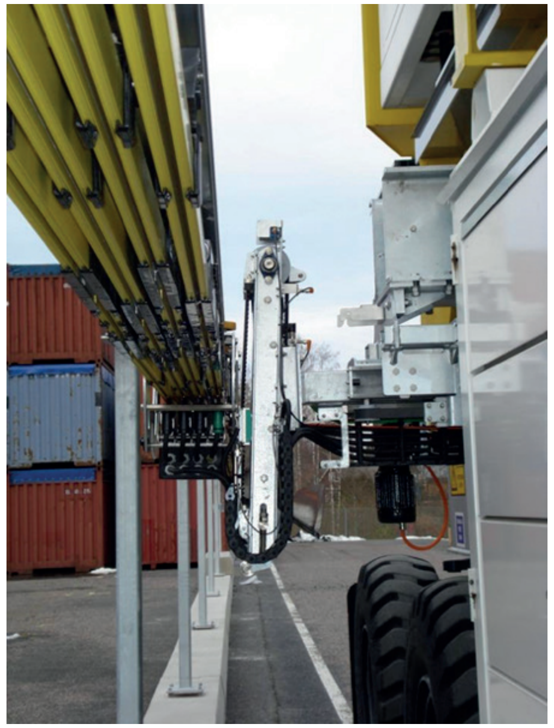
- Generator/batteries supply power to crane
- Crane drives to position to extend telescopic arm
- Sensors identify correct position
- Telescopic arm, (supported by sensors), extends and connects to conductor rail
- Synchronizing device switches from generator/battery power to grid power
- Generator switched off
- Crane is ready for operation in grid power mode
- Crane drives into electrified container block
- Auto steering system supports driver and steers crane automatically
- Positioning system continually monitors crane position

Benefits

- Automatic entry and exit of conductor rails
- Travel speed not limited by conductor rails
- Reduction of fuel consumption, emissions and noise population
- Reduced generator maintenance costs due to reduced use
- Possible to switch RTG back to diesel if necessary
- For battery-powered cranes, smaller stationary conductor rails can be installed (cost reduction)
- Mobile battery storage basis for a smart energy management

Disadvantages

- Stationary infrastructure required



RTG/RMG electrification by cable reel

Function

- Connection to the grid via cable
- Connection fix or via plug
- Plug can be connected automatically or manually
- Cable includes fibre optics (FO) for data transmission
- The RTG do not need a generator if the cable is fixed
- If cable reel fitted with a plug, generator is needed for a block change

Operation

- Fixed cable
  - the cable adapted the length automatically according to the position of the crane
  - A block change is not possible.
- Manual plug version
  - Crane powered by generator to stationary socket
  - Cable laid in the strain relief
  - Plug connected to the socket
  - Crane switches over from generator power to the grid
  - Crane drives in the block supplied by the grid
  - Cable adapts length automatically according to position of crane
- Automatically plug version
  - Crane powered by generator or battery to stationary socket
  - Sensors recognize the correct position
  - Plug connects automatically to socket
  - Crane switches over from generator power to the grid
  - The crane drives in the block supplied by the grid
  - the cable adapted the length automatically according to the position of the crane

Automated cable reel connection.

Benefits

- Reduction of fuel consumption, emissions and noise population
- Reduces generator maintenance costs due to less use
- No stationary infrastructure is required

Disadvantages

- Travel speed is limited to cable reel
- Crane needs to drive back to the plug prior to block change

5.2 Communication solutions

Proper and safe data transfer is especially important when introducing remote-controlled or automated solutions. Video data in particular has to be transferred as real time data to be able to control equipment remotely. At present, this is easiest using fibre optics. Bus bar systems allowing the transfer of high amounts of data are in development and they are expected to become available relatively soon.

When considering wireless technologies for free-ranging equipment (e.g. SCs), it seems likely that Wi-Fi protocol will have a role to play in the automation of ports, due to its relatively wide-coverage and broad-bandwidth. Use of Wi-Fi requires careful design in challenging port environments. As the fourth generation of mobile telecommunications technology, the role of 4G/LTE in an automated port tends to be more important. The option of using 4G/LTE private networks offers opportunities to manage networks more effectively. Since the bandwidth to uplink direction of 4G is limited, transmitting many high-resolution video streams is still a challenging task. However, the rapid development of 5G technology and broader bandwidths is likely to address this issue.

5.3 Identification/Location systems

Sophisticated sensors are mounted on cranes to detect the position of moving parts, load, and target destination. These systems include encoders and scanning laser rangefinders.

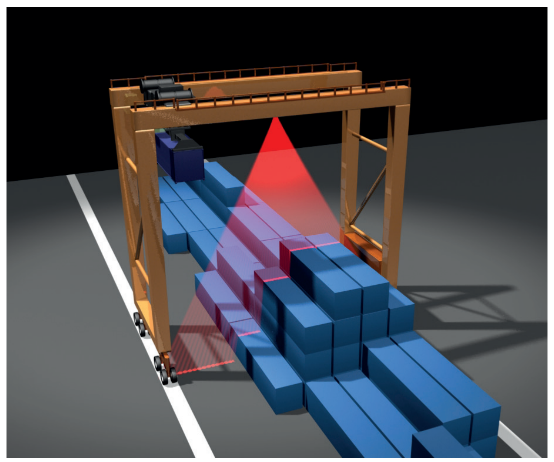


Image credit: Konecranes.

Automatic position indication systems perform real-time measurements of the gantry, trolley, and hoist position, so as to compensate for factors such as rope stretch and wheel slippage. The automatic landing system uses laser scanners on the trolley to measure the position of the spreader (the container pickup assembly) relative to the container below.

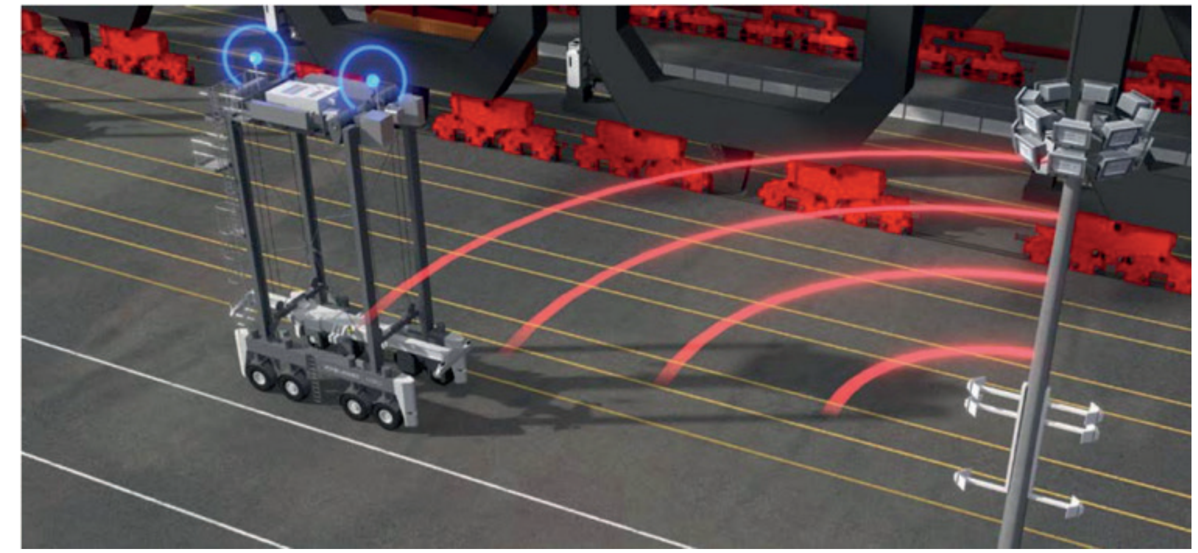
Gantry position along the rails can be determined using an antenna which picks up signals from transponders embedded in the surface. Possible rebar in the ground needs to be at least at 50mm below top of surface but preferable at 80mm below top of the surface (for flush installation of the transponders).

When rubber-tired equipment is considered, various location system technologies are currently used. For example, various satellite positioning systems (e.g. GNNS or GPS) are widely used for RTG automation.

Transponder technology makes it possible to provide accurate and reliable position information at critical areas where satellite positioning systems are limited. A pattern of transponders must be installed based on e.g. SC driving routes. The odometry sensors and inertial system is used to accurately guide vehicles via defined tracks towards subsequent marks. The same principle can be implemented if a grid of reference marks is made e.g. using permanent magnets.

Radar navigation can also be used with e.g. automated SCs. Radar navigation is based on a network of passive radar beacons installed around a terminal yard. A radar unit on the top of the SC tracks the position of these beacons. Navigation requires a line of sight to at least three beacons at any given time. Compared with magnet and transponder navigation, a radar-based system requires less infrastructure investment.

It is also possible to use so-called "local ground-based replicas of GNSS-style positioning". This system is not necessarily designed to replace GNSS. It is best thought of as a locally integrated extension of GNSS services for areas where GNSS fails. It can be seamlessly integrated with GPS or operate independently when GNSS is unreliable or unavailable. Instead of satellites, it uses a network of small, ground-based transmitters. This navigation also requires a line of sight to its transmitters.



An automated SC navigation system. Source: Konecranes.

5.4 Terminal Operation Systems (TOS)

Several advanced TOS are available on the market which provide functions to control the operation in the yard as well as interfaces to interact with container handling equipment (CHE).

TOS pre-calculate and create stacking (RTG, RMG) or transport jobs (SC) for CHE and will control the execution of respective jobs and/or a certain sequence of jobs.

Typical features of a TOS influencing the operation of CHE could be:

- Definition of standard handling and sequence of stacking activities for CHE
- Management of stacking/put-away rules in the yard
- Determination of container target positions on the yard
- Definition of working areas for handling equipment
- Pooling of CHE in working areas
- Load balancing of jobs over equipment per working area
- Position detection and calculation of travel distances
- Send and control stacking and transport jobs to selected CHE
- Calculate necessary shifting jobs

In brownfield automation projects, automated handling equipment needs to be integrated with the TOS system as well as into existing conventional equipment still in use. In a conventional terminal environment with human operated, non-automated equipment, the typical interface between the TOS and the handling equipment would be a job control monitor installed on a vehicle mounted terminal (VMT) in the cabin of a crane. The operator sees his or her next job(s) on the monitor, and can select, execute and confirm tasks accordingly.

When it comes to automation of the stacking equipment, specific new conditions need to be considered concerning the integration with TOS.

As a first step of automation, to ensure the accuracy of driver performance, additional information can be transmitted from cranes' PLCs to TOS during job confirmation, such as actual spreader position, GPS location, twistlock status etc. The next steps of automation gradually transfer many of the tasks of the driver to automation software (FMS/ECS).

5.4.1 Fleet management systems (FMS/ECS)

The FMS could either be part of a TOS system, or developed as another independent system integrated with TOS, for example in combination with the remote operating system (ROS). Fleet management system, sometimes also called equipment control system (ECS), is conceptually a software layer between the TOS and the CHE.

Such a system could also be designed in combination with a yard block controlling system, for example when a certain area on a brownfield terminal should be converted to automated operations while another continues to be operated conventionally.

The FMS needs to have an interface to remote control stations as well as to each crane system in that case of automated CHE.

Once an FMS is designed to control an entire yard, it should be considered that a brownfield terminal could also operate a mixed CHE fleet with older and newer cranes and different levels of automation in any area of the yard.

In this case the FMS should be capable of handling cranes with operators in cabins, remote operators and partially automated cranes simultaneously.

5.5 Remote operations and remote-control

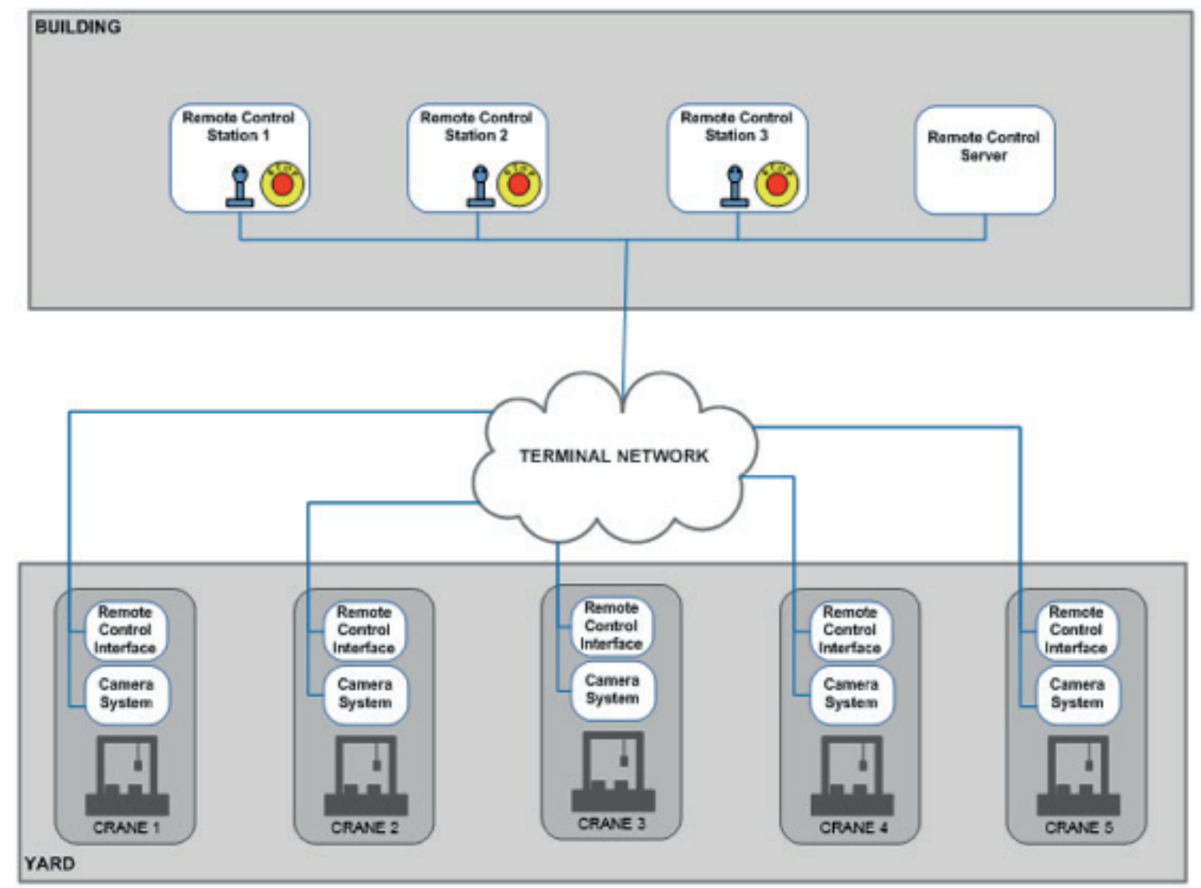
A Remote Operation System (ROS) enables operators to control container cranes from the safety and comfort of a remote location. ROS delivers a complete crane control solution from operator login, carrying out operations, to operator logout. The Remote-Control Station (RCS) location can be anywhere as long as the RCS prerequisites are considered, such as network requirements.

RCS assists operators in carrying out their control tasks by presenting task-dependent information on a customized human-machine interface.

It is recommended to locate RCS and a server cabinet in a terminal building. Each crane should be fitted with cameras and an interface system linked to each crane's PLC.

The Remote-Control Operation System typically consists of:

- One or several RCSs
- One RCS System
- One ROS interface per crane
- Several cameras per crane



The operator uses the HMI on the RCS to control a crane from a remote location. To provide situational awareness to the operator, the RCS HMI provides live video streams from the remote-controlled crane combined with e.g. graphical information.

The operator controls the crane via hardware and software controls. The hardware controls should include an emergency stop push button, master controllers for controlling crane movement and buttons for frequently used crane functions.

The **ROS camera** system on each crane typically consists of certain cameras that permit the remote operator to view the relevant operation scenarios. There are different options for cameras:

- Pan – Tilt – Zoom (PTZ) cameras: Custom PTZ logic is programmed to provide important overview to the operator. Can consist out of tracking the spreader, zooming to target positions and showing important areas on the main screen.
- Zoom cameras: Used to zoom into important areas. Custom zoom-logic can be programmed.

- Fixed Dome cameras: Mainly used for overview on, for example, train lanes, truck waiting zones, gantry driving. These cameras cannot move or zoom.
- Spreader cameras: mounted on spreader to make spreader operations easier. These cameras cannot move or zoom.

ROS usually provides functionality like Any-to-Any and Pooling.

Any-to-any is the ROS infrastructure that enables any RCS to connect to any remote controllable crane within the scope of the setup. A remote operator sitting at one of the RCSs can select and take control of any of the aforementioned cranes.

Any-to-any will dynamically create a safety connection between the operator's RCS and the crane the operator is controlling, including emergency stop.

Pooling functionality allows ROS to handle remote control tasks indicated by the Crane. This can be tasks required for unplanned intervention (for example in case of a system fault). These tasks will be collected and distributed to desks available and suitable for the remote-control tasks. Doing so, this increases efficiency per operator.

Assignments are typically performed on a First-in First-served basis. I.e. a desk that is available for pooling as first (i.e. longest time logged in while not connected to any crane), is the first that receives a new assignment.

An example of a remote-control task is a request from an automated crane for a manual intervention. When an automated crane encounters an exceptional condition that it cannot solve by itself it will request a manual intervention (MI) by a remote operator from ROS.

A prerequisite for pooling is the any-to-any infrastructure which is used to establish a connection between the RCS and the target crane listed in the remote-control task.

Ratio of operators to CHEs

When CHEs are operated remotely without pooling (1:1), control stations need to be equipped with TOS job control monitors. In this case remote operators work in the same way as physical drivers in cabins, although crane drivers sit remotely. TOS job control monitors typically display a list of upcoming jobs on-screen from which the operator selects. This provides some flexibility for the operator, for example during truck handling if trucks arrive at a handover position out of sequence.

In automated applications where a small number of remote operators control a fleet of cranes (e.g. 1:4), an FMS is advisable to manage and control jobs coming from the TOS. The FMS will dispatch incoming jobs from the TOS to cranes and then alert remote operators to take control of specific cranes to perform the next urgent task. In this operation mode, the job forecast for each crane in the TOS has to be reduced to one, thereby removing flexibility of the FMS to select from a list of upcoming jobs.

Remote control with automated cranes

For CHEs to perform certain activities independently in a fully automated way without a remote operator, the FMS needs greater capacity and be able to split every job into automated and remote-controlled sequences respectively.

In this case the FMS will wait for the crane to complete the automated sequence and alert the remote operator only for the remaining part of the job. The table below shows a typical split of RTG crane activities between automated and remotely operated modes when moving a container from stack to an external truck.

No.	Activity	Gantry	Trolley	Hoist	Spreader	Mode
1	Lift spreader to upper position			x		Auto
2	Adjust spreader				x	Auto
3	Travel to target bay	x				Auto
4	Move trolley to target row		x			Auto
5	Land spreader on container			x		Auto/Man
6	Close twistlocks				x	Auto/Man
7	Lift spreader to upper position		x		x	Auto/Man
8	Move trolley to truck lane			x		Manual
9	Land container on truck				x	Manual
10	Open twistlocks					Manual
11	Lift spreader to upper position			x		Manual

On completion of a stacking or transport job by the dedicated CHE, including manual and automated sequences, the FMS will close and confirm the job and send the target position of the relevant container to the TOS.

Table 2: motor cable selection chart

5.6 Automation System Diagnostics

For all automation solutions, it is essential to diagnose faults quickly. In the case of system or hardware faults, this is possible on the basis of error message systems of the components used. However, if a process error shows an incorrect value from a measurement, such an analysis is only possible if the corresponding information for the individual process steps is available. With diagnostics it is possible to defend functions against safety critical fault modes and signal deviations.

For automation solutions in container terminals, rapid diagnosis of faults is crucial to avoid a costly disruption to operations. Introducing automation may be affected by unexpected events, in which case it is important to understand the causes of such events and address them accordingly. Another criterion is the continuous optimization of the automation process.

To achieve this, appropriate detailed data are needed. One way to achieve this is to introduce process logging. It is important that all intelligent components involved in the automation process log their individual process steps and make this information centrally available in a time-synchronized manner.

5.6.1 What is diagnosed?

On-board diagnostics are typically embedded into electronic control systems that consist of sensors, controllers, actuators and communication links. Controllers are normally programmable. Electronic control systems operate mechanical systems including hydraulic, pneumatic and electro-mechanical sub-systems to make machines perform desired tasks. Three levels of diagnosis tend to be identified:

1. Diagnosis of the control system (sensors, connectors, cables, CPU, RAM, I/O electronics, actuators and communication sub-systems)
2. Diagnosis of the mechanical system (fluid quality, fluid levels, fluid pressure, temperatures, bearing wear-out, etc.)
3. Monitoring efficiency and output quality (successful container picks, path tracking accuracy)

Seven-layer architecture (OSA-CBM) can be used to partition the diagnostics sub-system into modular and interfacing entities.

1. Data acquisition (sensor module that outputs calibrated sensor signal values)
2. Data manipulation (signal processing; e.g. mean value calculation or frequency spectra)
3. Condition monitoring (e.g. range checking, alerts)
4. Health assessment (diagnostic processing; e.g. fault condition evaluation)
5. Prognostics (e.g. estimation of remaining useful life)
6. Decision support (e.g. 'limp home' instructions and automatic reconfiguration)
7. Presentation (user interface)

In terms of on-board diagnostics on automated equipment, the simplest diagnostics activity is to implement a data acquisition layer to provide data for remote off-board diagnostics such as cloud environments. If large amounts of data need to be transferred, it may be preferable to include a data manipulation layer to provide only partial parameters of measured signals. The more sophisticated onboard diagnostics and problem solving required, the more layers that need to be implemented.

6. INFRASTRUCTURE AND YARD LAYOUT

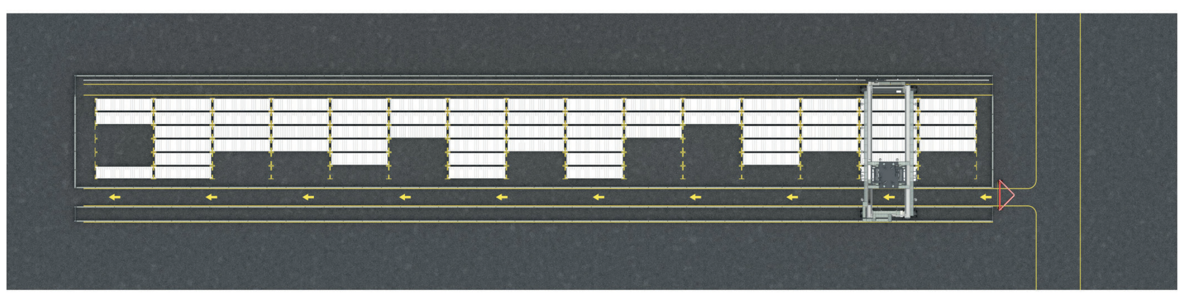
Automation conversion also requires changes to the infrastructure of a terminal, for example:

- Fencing and access control for safety
- Navigation infrastructure for the CHEs and possibly also for STS cranes
- Interchange points for waterside interface (quay cranes) and truck and rail handovers
- IT environment and wireless networks
- Lay-out changes due to safety

In many brownfield container terminals, facilities are located across sites due to original design or simply due to organic growth. In automated terminals, all facilities requiring manually assisted operation need to be located at the perimeter of automated zones due to safety reasons. This ensures that automated areas are dimensioned appropriately and guarantees smooth access of personnel without disrupting operations. Access control, safety systems and physical fencing for these functions needs to be considered when planning conversion to automation.

The design of truck traffic, safety fencing and gates are typically terminal-specific. Special attention must be paid to the driver guidance, gates and the driver waiting areas. For operation efficiency, road trucks are typically able to drive safely in and out of the truck lane at designated places along the truck lane.

Another key safety consideration is container handling during loading/unloading. Safety is improved by for example anti-truck lifting system which prevents a locked chassis from being accidentally lifted, and e.g. stack profiling system which prevents containers being accidentally knocked off the stack.



A typical ARTG layout. Source: Konecranes.

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ABOUT THE AUTHORS AND PEMA

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This paper was prepared by Alois Recktenwald, Siemens, and Kari Rintanen, Konecranes, with contributions from Kalmar, Kuenz and other PEMA members.

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Chief among the aims of the Association is to provide a forum for the exchange of views on trends in the design, manufacture and operation of port equipment and technology worldwide.

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Company Number/ Numéro d'entreprise/ Ondernemingsnummer 0873.895.962 RPM (Bruxelles)

Registered office:
p/a EIA, rue d'Arenberg 44, 1000 Brussels
Belgium

Management and finance office:
Via G.B Pioda 14, CH-6900 Lugano, Switzerland

PEMA Secretariat:
Baird House, 15-17 St Cross St
London EC1N 8UW, United Kingdom

PEMA – Port Equipment Manufacturers Association

Registered Office: p/a Glaverbel Building, Chaussée de la Hulpe 166 Terhulpsesteenweg,
B-1170 Brussels, Belgium
President & Finance Office: Paradiso, CH-6900,TI, Switzerland
Secretariat Office: c/o Baird House, 15-17 St Cross St, London EC1N 8UW, United Kingdom
Secretariat Contact Details: Tel +44 (0)7766 228958 | Email info@pema.org

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