Abridged version

KAWASAKI STEEL TECHNICAL REPORT
No.15 (October 1986)

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1 Introduction

The container cranes [1,2] recently installed at the container berths at Rokko Island, Kobe possess all capabilities required for the Sea-Land Services yard system. These cranes have a significantly larger span and backreach than those of conventional container cranes, and are capable of handling 40′ and 45′ containers to and from 40 000-DWT container ships, clearing five containers high stacked on the deck. In conjunction with increased crane size, the cranes are designed to have operating speeds exceeding those of existing high-speed cranes.

At the end of 1984, the three crane units were completely assembled at the Harima Works of Kawaden Co., Ltd., a Kawasaki Steel Corporation affliate, in Kako-gun, Hyogo-ken. Each fully-assembled crane was picked up by a 3000-t floating crane at the fabrication yard and transported to the site. The cranes commenced commercial operation at the beginning of 1985 and have been operating smoothly since. Of the three cranes, two were installed at Rokko Island, and the third at Port Island.[3-5]

In the following are given the newly developed technical features in a review of the specifications of the cranes, an outline of the transportation and installation of the cranes, and a report on results of stress measurements under actual load conditions following installation.

2 Specification and Construction

2.1 Outline of Specifications

The container crane is of the semi-rope trolley type. A general view is shown in **Fig. 1** and main specifications in **Table 1**. High speed crane operations are controlled by a thyristor-Leonard system which features excellent speed control performance. Specifications of this control are shown in **Table 2**. A hoisting speed of 50 m/min is attainable with the rated load and 120 m/min with no

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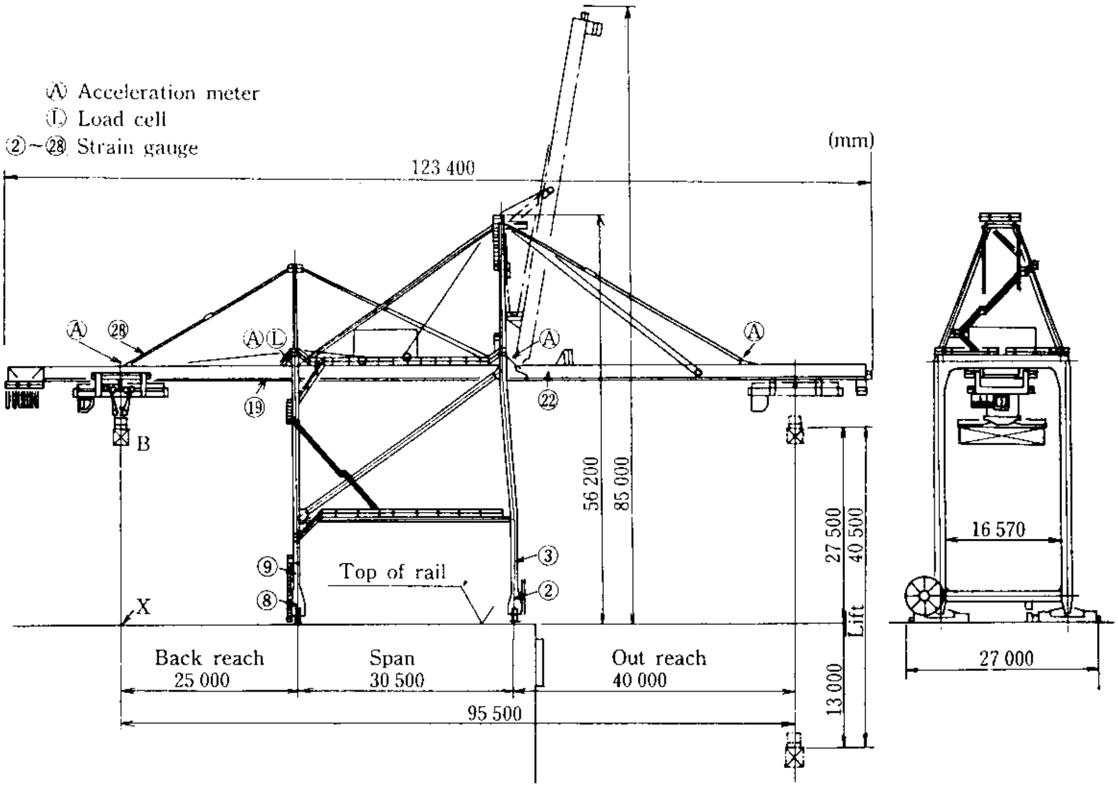

Fig. 1 General view and stress measurement points

Table 1 Specifications of the container handling crane

1	Type	Semi-rope trolley type gantry crane
2	Max. ship size for container handling	40 000 DWT container vessel
3	Rated load	40 tf container
4	Lifting load with spreader (lifting beam)	55.5 tf
5	Travelling rail span	30.5 m
6	Travelling distance of spreader	
	· Out reach from sea side rail	40 m
	· Back reach from land side rail	25 m
	· Total distance	95.5 m
7	Lifting height of spreader	
	· Upward from top of rail	27.5 m
	· Downward from top of rail	13 m
	· Total lifting height	40.5 m

applied load. Variable intermediate speeds are automatically regulated in accordance with the magnitude of load.

2.2 Outline of Construction

A "semi-rope trolley type" crane is a self propelled type in which the trolley itself is equipped with a traversing mechanism, while the hoisting equipment is installed in the machine room fixed on the rear girder. In order to gain the wider service area of the crane, the back reach and span of the crane have been greatly increased, as shown in **Table 3**, over that of conventional high-speed high-performance container cranes. Ship hatch covers and stacking frames can be placed at the rear yard of the container crane. In response to this increased crane structure size, trolley traversing speed has been increased from the conventional 150 m/min to 180 m/min. Containers and general cargoes can be handled inside the span and back reach of the crane even when the boom is raised to its parking position. Power is fed to the crane through flat-type cabtire cables taken up by cable reels installed on the sea-side leg. For power feed to the trolley, the festoon cable system is used.

In the following are outlined new concepts incorporated in the crane, and general construction of the equipment.

2.2.1 Steel structure

(1) Construction

As shown in Fig. 1, the crane structure conists of a raisable boom on the sea side, fixed girder on the land side, cross-braced upper frame assembled on the gantry construction, tension link (for boom sup-

Table 2 Motions and controls

	Speed	Motor			Control	Brake
		Out put	Rating	Type		
Hoisting	50-120 m/min	230 kW ×2	Cont.	· Shunt wound · Forced ventilation	Thyristor leonard speed control with field control	· DC magnet brake · Motor lifting brake for emergency · Dynamic brake for emergency
Traversing	180 m/min	60 kW ×2	Cont.	· Shunt wound · Totally encl. · Fan cooled	Thyristor leonard voltage control	· DC Magnet brake
Travelling	45 m/min	19 kW ×8	30 min	· Shunt wound · Totally encl. · Self-cooling	Thyristor leonard voltage control	· Motor lifting brake
Boom hoisting	8 min/cycle	110 kW	30 min	· Shunt wound · Forced ventilation	Thyristor leonard voltage control	· DC Magnet brake · Motor lifting band brake for emergency · Dynamic brake for emergency

Table 3 Comparison of the features between the super crane for Rokko Island (A) and the conventional high speed crane (B)

	A	B
Max. ship size for container handling	40 000 DWT	30 000 DWT
Rated weight of container	40 tf	30.5 tf
Travelling rail span	30.5 m	16 m
Out reach	40 m	36 m
Back reach	25 m	11 m
Total trolley traversing distance	95.5 m	63 m
Total lifting height	40.5 m	37 m
Total horizontal length	123.4 m	84 m
Total height with boom raised	85 m	75.4 m
Traversing speed	180 m/min	150 m/min

port), and back stay (for cantilever girder support). The boom and girder are made up of plate-welded double I-shaped cross sections reinforced by bracings to form an economical mono-girder construction. Traversing rails are fixed on the outside of the lower part of the girder on which the trolley travels hanging from the girder. Because of the limitations of crane wheel loads on the dock rails, total crane weight has been cut as far as practicable by positive use of high tensile steel such as SM58Q and SM50 for the gantry structures, in particular where the structural dimensions are not governed by fatigue strength resulting from stress cycles.

(2) Pin Construction

In the construction of both sea and rear legs, pin connection is mainly used instead of bolt connection, facilitating assembly work.

(3) Pipes

In the diagonal and horizontal brace members joining the legs, mast on the land side, and cross-bracing members, steel pipes have been used to reduce the surface area subject to wind pressure and to reduce fabrication labor costs.

(4) Machine Room

This room, of welded steel sheet construction, is installed on the girder at the center of the gantry structure. The room accommodates a hoisting device, boom hoisting device, and electric control panels. In addition, an overhead travelling crane with a high lift reaching ground level is installed for maintenance purposes.

2.2.2 Mechanical equipment

(1) Trolley

The trolley is of the self-traversing type with two sets of traversing equipment, each consisting of a motor, an enclosed speed reducer, and two miter gear boxes installed on each side of the trolley frame to drive all wheels. On the frame is installed a sheave distance adjusting device constituting a container anti-sway device. An operator's cab is installed under the trolley frame at a position affording the crane operator good visibility.

(2) Hoisting Device

This consists of two motors provided with a magnet brake and an emergency-use motor lifting brake, two drums, and a totally enclosed speed reducer. Two wire ropes are paid out respectively from the two drums, pass through the rope equalizer sheaves equipped with load anti-sway devices located at the rear end of the girder, reach the shiftable sheaves on the trolley, come down to the spreader sheaves and again come up to the trolley sheaves, and then are wound onto the drums (spreader tilting device) located at the front end of the boom.

(3) Boom Hoisting Device
This device consists of a motor provided with a magnetic brake, a drum, and a totally-enclosed speed reducer. The drum is of a cone shape and has an emergency-use band brake at the drum end. The band brake is released by an electro-hydraulic lifter, but if motor revolution exceeds 115% of the specified value, power is cut and the brake is actuated by a weight, thereby ensuring safety.

(4) Travelling Device
At the four corners under the gantry structure are installed travelling devices each consisting of eight wheels, two motors, and two helicalworm reduction gear boxes. Of the total of 32 wheels, 16 are driven. Each motor which is provided with a motor lifting brake is positioned high above ground level to minimize the potential effect of high waves. Each equalizer beam incorporates crane anchoring devices (at four locations in total) to immobilize the crane during storms. In addition, two rail clamp wagon units are trailed by inside trucks, one each on the land side and sea side rails.

(5) Rail Clamp
These clamps are of the vice type, and serve to tighten the rail flanks by powerful springs; the clamps are released by hydraulic cylinders. The combined force of two clamps can withstand the pressure of winds of 35 m/s. Unexpected power failure or depression of the emergency button automatically actuates the clamps.

(6) Spreader Tilting Device
The device consists of a drum which winds the hoisting rope ends, a speed reducer, motor, and brake; it is installed at the front end of the boom. Sets of spreader tilting devices are provided for each of two systems of hoisting ropes. Rotating these two drums in the same or reverse direction causes difference in the lengths of the two hoisting wire ropes of the spreader, thereby tilting the spreader forewards or backwards, or right or left, for correct positioning of the spreader on containers.

(7) Boom Clamp
A clamp is provided at the top of the mast on the sea side to lock the boom and mast against strong winds. The clamp, actuated by weight, grips a steel plate provided on the upper flange of the boom structure when the boom is raised to its parking position. When clamped, the boom will remain immobile even under storm conditions. The clamp is released by an electro-hydraulic lifter.

(8) Overload Prevention Device
This safety device has a load cell incorporated in the hoisting rope sheaves provided on top of the rear leg to shut off power supply to the hoisting device at an overload of 125%.

(9) Tilt Prevention Device
The four corners under the legs are each provided with a turnbuckle type tilt prevention device, which is pin connected to the eye-plate set on the ground, thereby preventing the tilting of the crane under storm conditions (60 m/s wind). Together with the crane anchoring device incorporated in the travelling equalizer, this tilt prevention device serves as a safety measure for storms.

(10) Hoisting Beam and Spreader[6-8]
The hoisting beam has at each of its four corners an ISO-rated twist lock pin which can be manually connected to the spreader. On this beam are installed a basket for taking up the power cable and a platform for boarding the ship. The spreader, which has been customer-supplied, is of a telescopic type and is provided, at its four corners, with a flippers which serve as container guides and with twist lock pins for connecting the spreader to the container, so that containers can be handled regardless of length. The spreader is operated by an automated hydraulic system.

3 New Technical Developments

3.1 Load Anti-Sway Device

When the trolley is notched off to a stop from full speed, the swaying of the suspended container is of large amplitude. Swift damping of this sway brings about accurate positioning of the container and eventually contributes to the improvement of container handling efficiency. A schematic diagram of the anti-sway system is shown in **Fig. 2**. This system is composed of two sheave distance adjusting device units, located on each side of the trolley. These alter the angles of ropes supporting the hoisted load, and a hydraulic damper cylinder assembled to rope turning sheaves located at the rear end of the girder. A hydraulic circuit diagram of the sway damping hydraulic system is shown in **Fig. 3**. When a suspended container begins to sway, a difference in tension occurs between the front-and-aft hoisting wire ropes. The tension of the wire ropes is transmitted to the rope turning sheaves at the rear end of the

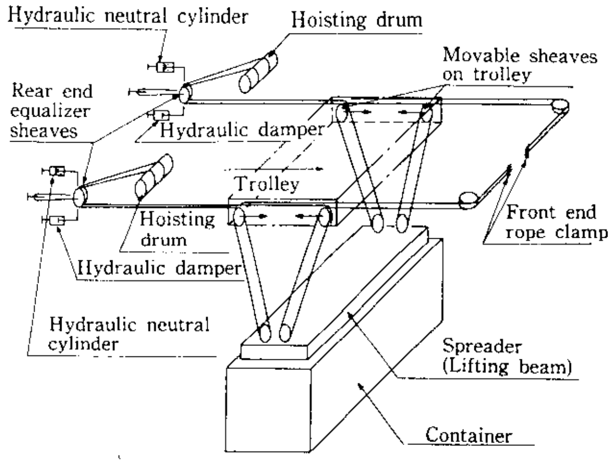

Fig. 2 Anti-sway system diagram[1)]

girder. A pair of rope turning sheaves has a construction to perform horizontal equalizing motions, and each sheave moves the same distance in the reverse directions with respect to the neutral point. The hydraulic damper-cylinder which is connected to one sheave expands or contracts with sheave movements caused by the wire rope tension.

After the trolley has stopped, the container begins swaying towards the center of the trolley, and the damper-linked sheave, to which differences in the wire rope tension have been transmitted, begins to move, while most of the kinetic energy of the sheave is absorbed by the hydraulic damper. Thus, the swaying motion of the container rapidly diminishes. The damping characteristics of the system are automatically varied depending upon the weight of the suspended load. The sway damping hydraulic system is also provided with a neutral cylinder, which uses an accumulator as its pressure supply source in order to maintain the turning sheave at the neutral position.

The sheave distance adjusting device on the trolley consists of screw rods and drives. As the screws are rotated, the sheaves fitted to the nuts are moved. When the sheave distance is extended, wire ropes form an inverted triangle and the anti-sway effect increases. The sheave distance is changed automatically to prevent the wire ropes from interfering with other containers during on-board container handling.

Conditions for satisfactory anti-sway performance are set as follows:

An ISO 1A type (8 × 8 × 40 ft) container is hoisted at a height of 10 m above the travelling rails. The trolley moves traversely at a speed of 180 m/min. The controller is then notched off to "0" and the subsequent swaying amplitude should be within the values mentioned below:

(1) The absolute sway magnitude first recorded after an elapse of 5 seconds is not to be over 50 cm.
(2) The absolute sway magnitude first recorded after an elapse of 10 seconds is not to be over 10 cm.

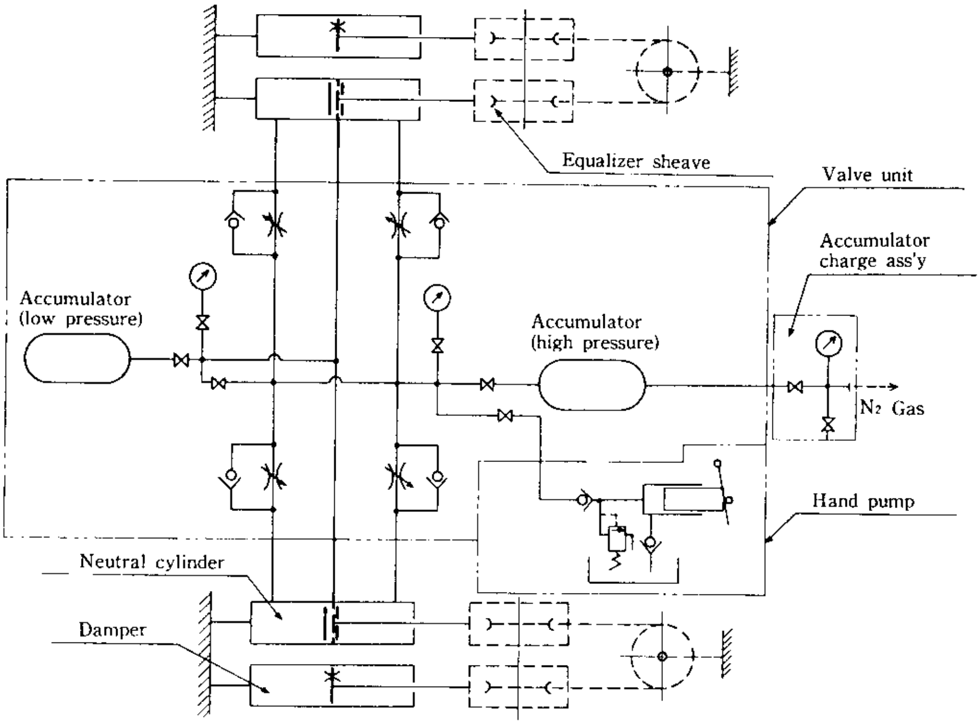

Fig. 3 Sway damping hydraulic system

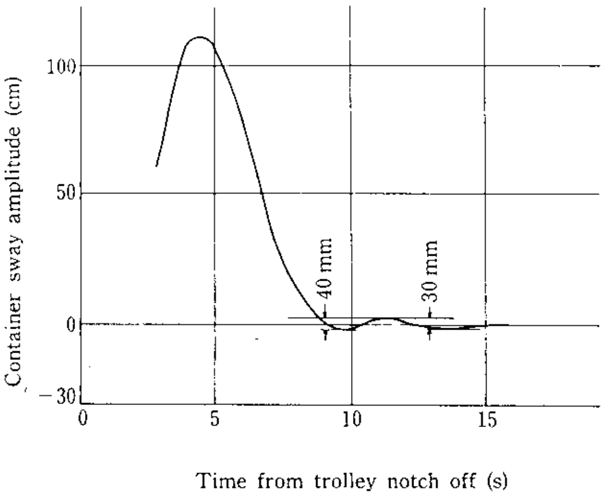

Fig. 4 Sway damping diagram

(3) After 10 seconds, swaying has been damped and amplitude does not increase.

Plotting of measured values of sway damping in the commercial operation test, shown in **Fig. 4**, indicates that the above conditions have been satisfactorily fulfilled.

The above anti-sway device was put into practical use, using the kinetic equation for optimum damper characteristics, after a series of model simulations of the kinetic system of the suspended moving load.

Mechanical anti-sway devices for container cranes are broadly divided into two groups. One involves anti-swaywire rope provided separately from the hoisting wire rope to forcibly restrain sway motion, and the other utilizes the conversion of load sway into a tension difference in hoisting wire ropes to absorb generated kinetic energy. Kawaden Co., Ltd. adopted the latter type in which the weight increase is less and performance is better. It has been difficult to obtain a satisfactory value of the optimum damper characteristics, since amplitude is affected by the degree of trolley traverse deceleration and wind, changes in the friction coefficient between the sheaves and the wire ropes, and the method of measurement. Furthermore, since the center of gravity of the suspended container is not in accord with the center of the inverted triangular-shaped wire ropes reeved between the trolley and the spreader, rotary motion of the container has been a frequent problem. The problem, called rolling phenomenon, has been solved by installing hydraulic dampers between the sheaves and the frame of the lifting beam, and by reeving the wire ropes in such a manner as to obtain the optimum damping effect. (Utility model pending[9])

3.2 Hoist Rope Sag-Prevention Device

Since the total traversing distance of the trolley is 95.5 m, excessive sag of the hoist ropes fore and aft of the trolley becomes a serious problem in view of container handling efficiency. This problem has been solved by installing two small trolleys, each of which travels fore and aft of the main trolley (the trolley is here called the "main trolley" to differenciate it from the small trolley) and by synchronizing the small trolley with the motions of the main trolley. A schematic drawing of the hoisting rope sag prevention device is shown in **Fig. 5**. This device consists of two small trolley unit, drums (A and B) each fitted with a brake, and wire ropes. An assembly of drums A and B is bolted onto the girder. In normal operation, the brake of drum A is applied while the brake of drum B is not. Synchronized with traversing motion of the main trolley, the respective small trolleys move at half the main trolley speed, so that one small trolley can always be positioned at the midpoint between the main trolley and the sea-side or land-side end. When the boom is raised, traversing distance becomes shorter and sag prevention measures are not required. Therefore, the fore and aft small trolleys are removed to sea-side and land-side ends of the girder respectively, and the brake of drum A is released while that of drum B is applied to secure the small trolleys, thereby rendering the small trolleys temporarily unrelated to the transverse operation of the main trolley. (Patent pending)

3.3 Crane Height and Rail Span Adjusting Devices

Because of the unstable soil conditions of the man-made Rokko Island, it was feared that the land side crane foundation would, over time, lose its correct alignment.

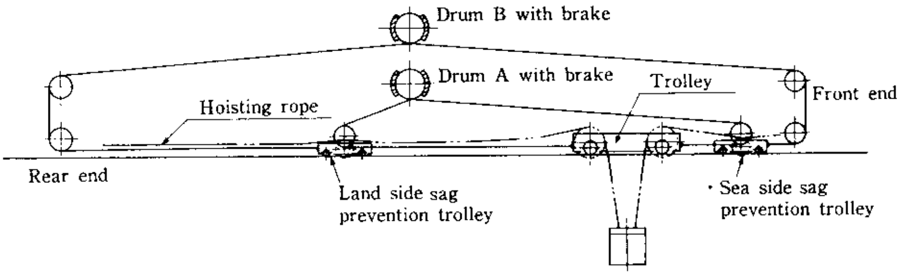

Fig. 5 Hoist rope sag prevention device diagram

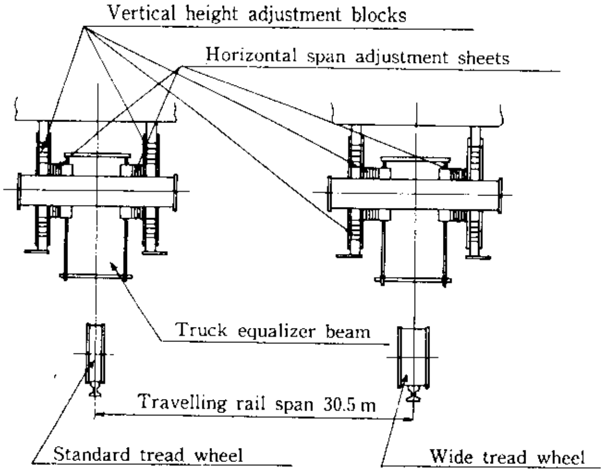

Fig. 6 Crane height and span adjustment device

To cope with crane rail unevenness and to make it possible to correct any tilting of the crane in the future, the crane legs are provided with adjustable steel blocks at each of their corners to permit adjustment of up to 400 mm at both the sea and the land side, for a maximum level difference of 800 mm between the land- and sea-side rails. Further, to cope with rail span variations in the future, the tread width of the land-side wheels has been made twice the standard width. In addition, truck center adjusting plates have been provided so that the position of the entire travelling system can be adjusted in the direction perpendicular to rails. This adjustment system can cope with a maximum rail span variation of 460 mm. A schematic diagram of this device is shown in **Fig. 6**. (Patent pending)

3.4 Electrical Equipment

3.4.1 Outline

The container crane receives 6600-V 3-phase power from the ground feeding point through cable reel-type cabtire cables. Voltage is lowered by three transformers (for power, for auxiliary machines, and for lighting) installed on the crane, and is supplied to various electrical facilities. Devices for performing main functions of the container crane, that is, hoisting, traversing, boomhoisting and travelling, are controlled by two thyristor-Leonard system sets. Hoisting and travelling are controlled by a thyristor-Leonard system which is operated by change-over circuit instructions given by the master controller. Traversing and boom hoisting similarly make common use of the other set. A single line wiring diagram is shown in **Fig. 7**.

3.4.2 Hoist control

For the hoisting device, field control is used in combination with ordinary variable-voltage type speed control. When the rotation speed of the motor has reached the base speed, after the crane has picked up a load and begun lifting operation, the hoisting device automatically checks the load current of the motor and judges whether acceleration is required or not. This device has been set so that if the load is below the rated load, acceleration is automatically raised to a level up to 2.4 times faster than the rated speed, depending upon the load. Naturally the speed can be slowed by the master control lever.

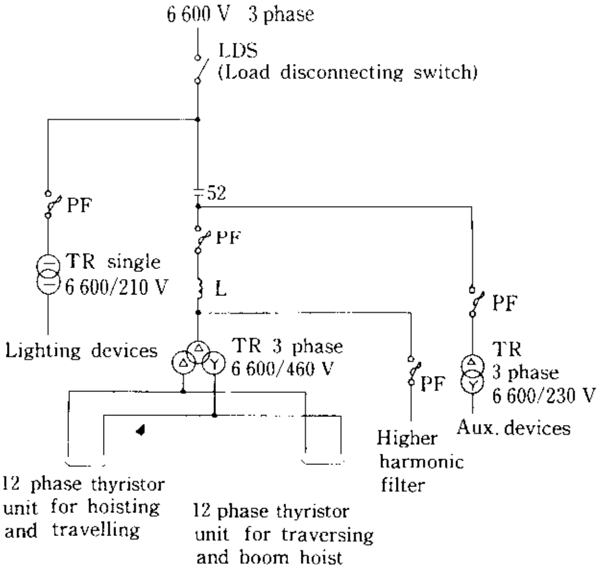

Fig. 7 Single line diagram

3.4.3 Countermeasures against harmonic waves[10)]

For the main drive of the super container crane, that is hoisting, traversing, boom hoisting and travelling, a 12-phase rectifying-type thyristor-Leonard system has been used for the first time in Japan. In the past, Ward-Leonard speed control systems were frequently used as main drives for container cranes, but in recent years thyristor-Leonard control systems have more often been used because of their ease of maintenance. As their use has increased, however, problems with the thyristor-Leonard system have been reported at several container terminals. These problems are caused by harmonic waves which have frequencies several times higher than the source power frequency and occur during rectification by the thyristor. In particular, the problem with the power factor improvement condenser has posed a problem which can not be overlooked. When the super cranes were newly installed, necessary conditions were stipulated by the client that six cranes should be able to operate simultaneously with a voltage distortion factor not over 3% at the power receiving point of the berth. This problem has been solved by employing a 12-phase rectifying type thyristor-Leonard system instead of conventional 6-phase rectifying system to prevent the generation of the 5th and 7th harmonic waves. In addition to this, a filter has been used to absorb the 11th or higher harmonic waves.

3.4.4 Programmable controller[11]

A programmable controller has been used in a container crane for the first time in Japan. The previous control circuits using relays have been changed to a control circuit using a programmable controller in order to satisfy requirements for increased complexity, diversification, and high performance of sequence control as well as for the future expansion of the control systems, such as adoption of crane monitoring systems. This change has proved a success resulting in improvement of reliability and simplification of maintenance of the container crane. Further, to ensure better operational safety, conventional contact relays have also been used in the emergency circuits, important interlocks; and protective circuits; these relays are designed to function in parallel with the control circuits built into the programmable controller.

3.4.5 Lighting facilities

In the past, sodium vapor lamp was not considered sufficiently strong against vibration and was considered generally difficult to use with container cranes. As a result of measurement of the vibration conditions of these container cranes in operation, the light emitting tubes used contain less sealed sodium amalgum as an anti-vibration measures, thereby also achieving energy savings.

4 Assembling, Transportation and Erection

Since Rokko Island is near Kawaden's Harima Works quay, and the navigation route lies in the calm Seto Inland Sea, it was planned from the start that each of the completely assembled cranes would be transported in a single unit by a heavy sized floating crane and installed at the site. The erection method of a large sized quay crane has gradually changed since around 1975 from a method of piece-by-piece transportation, site assembly, and erection which required a lengthy construction period and entailed construction costs, to a large block construction process. At present, the method of single-unit transportation of a completely-assembled crane has become the mainstream. Examples of the large block construction process executed by Kawaden are given below.

(1) Whole components broken-down into several large blocks for transportation and site assembly; for instance, unloaders supplied to Philippine Sinter Corp.[12]

(2) Upper half completely assembled and lower half broken-down into several blocks for transportation and site assembly; for instance, unloaders installed at J-berth, Chiba Works, Kawasaki Steel Corp.[13]

(3) Whole components completely assembled for roll-on/roll-off operation, assembling work at site not required; for instance, unloaders supplied to Passar and Philphos in Leyte Island, the Philippines.[14]

The super crane was made into three blocks; upper block, lower block, and truck assemblies. Each block was assembled, erected, and fitted out completely in the shop including electrical wiring and piping work. A partial functional test was also conducted before shipment. The completely-assembled ready-for-use crane structure was then picked up by a floating crane, transported for some six hours by sea to the site, where it was simply put down onto the tracks, completing the installation in one hour. Through this completely-assembled single-unit transportation, various advantages were gained, such as shortening of the erection period, ensuring of high quality, reduction in construction costs, and improvement of safety during erection. The in-transit crane is shown in **Photo 1**.

5 Stress Measurement

The crane structure is designed, with due consideration to conceivable external forces which are considered most disadvantageous to the member in question, and loading cycles to be incurred during container handling operations. The strength calculation of the steel structure of the crane must conform to the procedure set forth in JIS B 8821,[15] in which the container crane is classified into group III. Conceivable external load is multiplied by amplification factors determined according to crane group classification. For group III cranes, impact factor $\psi = 1.4$ and duty factor $M = 1.1$ are applicable. In addition, a wind load of 16 m/s or a seismic load when the crane is in service, or a wind load of 55 m/s when the crane is out of service, must be added as external forces.

Of loading conditions as set forth in JIS, i.e., A, B, and C, the following B and C are applicable to outdoor cranes and must be taken into consideration. That is, out of stress values generated by the load combination of B or C, the most disadvantageous value is to be adopted:

$$\begin{aligned}\text{Loading condition B} = {} & M[\psi(\text{hoist load}) \\ & + (\text{dead weight}) \\ & + (\text{horizontal load}) \\ & + (\text{wind load in service})] \\ \text{Loading condition C} = {} & (\text{hoist load}) \\ & + (\text{dead weight}) \\ & + (\text{seismic load or} \\ & \qquad \text{buffer load}) \\ & \text{or}\end{aligned}$$

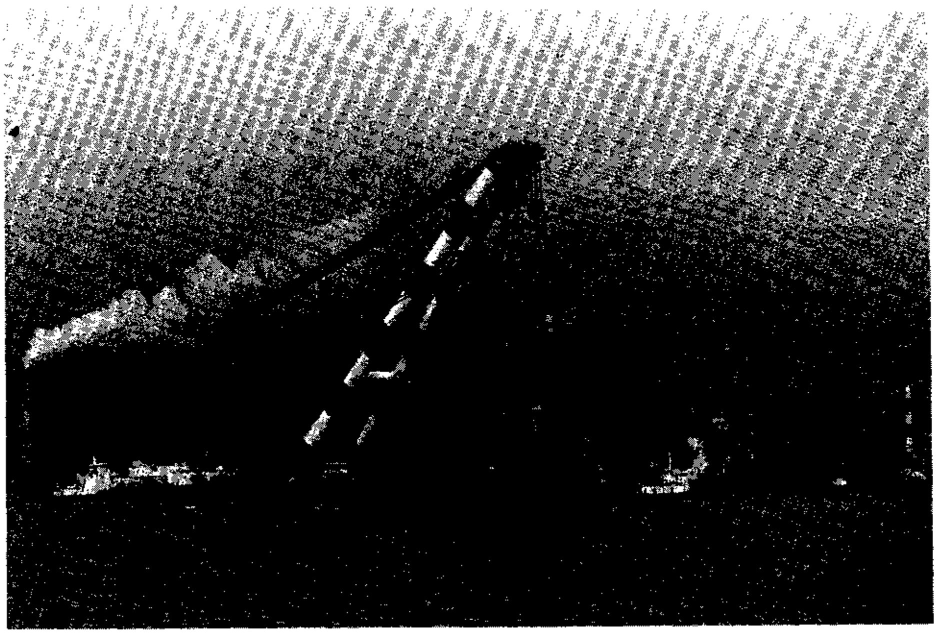

Photo 1 Transportation by floating crane

= (dead weight)
+ (wind load out of service)

As actual stress values for container cranes were available, stresses caused by the rated load was measured on the following points after site erection of the crane:

(1) Stress generated at the main structure during operation
(2) Stress generated at the main structure due to foundation unevenness
(3) Horizontal force applied during operation
(4) Impact value due to container pick-up and acceleration/deceleration.

Table 4 Stress ratio and impact factor as container is picked up

Hoisting speed (m/min) / Meas. point (Fig. 1)		2.42 (1st notch)	14.2 (2nd notch)	25.9 (3rd notch)	37.1 (4th notch)	50.2 (5th notch)
Stress ratio*	8	1.25	1.27	1.30	1.37	1.54
	9	1.20	1.20	1.29	1.31	1.40
	19	1.14	1.18	1.25	1.42	1.53
	28	1.20	1.21	1.25	1.43	1.59
Impact factor by load cell Ⓛ		1.16	1.22	1.29	1.36	1.44

$$* \text{ Stress ratio} = \frac{\text{Max. stress as container is picked up}}{\text{Static stress by hoisting load}}$$

In all, 57 static strain gauges and 54 dynamic strain gauges were attached at 26 and 15 locations respectively on the steel structure. Impact factors were measured by the load cell incorporated in the hoisting sheave on the land side leg. In addition, accelometers were set at five locations to determine vibration characteristics (see Fig. 1). In this measurement, horizontal forces and impact factors actually applied in the design of the crane were confirmed. Since the results of measurements constituted a very large volume of data, only the impact factors which are of the greatest interest to crane engineers are shown below. The gauge locations and trolley stop positions in Fig. 1 show impact factor measurement positions. When a container was picked up at point X, the impact factor was measured by the load cell and this factor was compared with stress ratios at various points. The results are shown in **Table 4**. Further, impact factors and stress ratios when a container is accelerated in hoisting or lowering at points B and I are shown in **Table 5**. For impact values due to acceleration/deceleration in hoisting and lowering, values measured by the load cell and stress ratios at various members were about the same as the set value 1.4 at the time of engineering. The impact value generated at the pick-up of a container from the ground at the 3rd notch speed, which is a standard container pick-up speed, was equivalent to the set value. Even at the 5th notch speed (full speed), which exceeded the set value, sufficient safety was confirmed

Table 5 Stress ratio and impact factor as container is accelerated

Trolley position (Fig. 1)		Lifting: 5th notch		Lowering: 5th notch	
Meas. point (Fig. 1)		B	I	B	I
Stress ratio	2	—	1.42	—	1.43
	3	—	1.32	—	1.32
	8	1.43	—	1.38	—
	9	1.36	—	1.35	—
	19	1.46	—	1.42	—
	22	—	1.33	—	1.20
	28	1.50	—	1.44	—
Impact factor by load cell Ⓛ		1.40	1.44	1.33	1.38

with respect to allowable stresses.

6 Conclusions

The container cranes which have been supplied to Kobe Port Development Corporation are largest container cranes in Japan handling 40 ft and 45 ft containers from 40 000 DWT container ships. In addition to the larger dimensions of the container crane, new technical improvements such as a hoist rope sag prevention device, load anti-sway device, and crane height and rail span adjusting devices were developed. Further, to shorten the construction period, the factory assembled cranes were sea-transported in a single unit.

The container cranes performed smoothly in initial stage operation after commissioning and continued smooth full operation after going into 24-h continuous operation in March 1985. The safety of the container crane has been confirmed by stress measurements as well as seismic response analysis.

As container ships become still larger in the future, container yard systems will encounter various new demands, while the "total cost minimum" goal will remain a major task for crane manufacturers. Against this background, the authors intend to pursue further technical improvements in this field.

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