The Incinerator Crane

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Abstract
The paper discusses the different operational requirements of the incinerator crane and describes a logical method for determination of the proper size crane to be used. A review of crane components, with some detail on the more critical items, is included.

Incinerator Cranes
The modern municipal incinerator plant with its large capacities and continuous operation dictates the utilization of material handling equipment that enables uninterrupted flow of refuse through the incinerator process. The overhead electric grab bucket incinerator crane is the best vehicle for handling the refuse, after dumping into the storage bins, through the necessary rehandling and mixing, and then to the furnace hoppers. Without question, the crane must be considered of major importance in planning and developing the overall facility. Every effort must be made to provide extreme reliability in this handling system. Reliability can only be realized by specifying and obtaining equipment sized and designed specifically for the service.

What is an incinerator crane? It is the electric powered prime mover located over the storage bins and hoppers that maneuvers a grab type bucket carrying refuse (Fig. 1). Multi-directional movement, laterally, longitudinally and vertically, of this bucket enables transfer of material to all necessary locations. For those unfamiliar with crane terminology the vertical movement is the hoist; the lateral movement is known as the trolley, and the longitudinal movement is the bridge. The monorail type of incinerator crane does not have the bridge motion, but all other features are identical (Fig. 2).

Many factors must be considered when developing the crane requirements. Among the more important are:
1) Tons of refuse to be burned.
2) Tons of refuse to be stored.
3) Types and weights of refuse.
4) Basic layout of bins, furnaces and hoppers.
5) Approximate plan and elevation dimensions.
6) Number of cranes tentatively required.
7) Peak load hours.
8) Possible plant expansion.

With the above information known, preliminary sizing of the cranes through cycle calculations, may be accomplished. Various methods can be used but all must consider:

a) A specific amount of refuse must be delivered to the furnace on a continuous, predetermined basis.
   1) This operation involves relatively long travels of all motions of the crane as the refuse is taken from the storage bins to the furnace hoppers.
   2) In addition to feeding the hoppers, mixing and re-handling of refuse in the storage bins is a major consideration.

b) Mixing varies with the types of refuse received, seasons of the year and climatic conditions. This operation consists of short movements mostly on motor acceleration and deceleration.

2) Rehandling in larger plants becomes a major problem during peak dumping periods. In some major cities, as much as 50 per cent of each hour must be spent in rehandling refuse from the side of the storage bin nearest the dump ramp to allow continuous dumping during an 8-hour period. This operation imposes similar cyclic and motion conditions to the mixing operation. When the rehandling is conducted properly it can be a replacement of the mixing function.

c) Invariably, refuse when dumped into the bin, follows a rather steep angle of repose. The bucket cannot become fully loaded when closing under this condition and moving less than a full bucket from the bin to the hopper is not practical. Unless during the rehandling or mixing operation, material is properly prepared for the charge, repeated passes must be made to obtain a full bucket load.

These points are emphasized as they do have an important affect on the crane and plant operation. A cycle calculation leading to establishment of crane capacity must be based on the three conditions outlined above. Any recommendation based on obtaining a full bucket with each pass, with no allowance for mixing and re-handling, or on a certain number of full buckets with proper travels and a percentage allowance for accelerations and decelerations of motors will result in an undersized and inadequate crane. A percentage assessment for acceleration and deceleration cannot be made. Realistic data is known from calculations as well as experience and these must be used. Conservatively, rehandling involves at least 60 to 75 per cent, and sometimes more, on motor acceleration and deceleration. The feeding cycle, depending on length of travel, can be as low as 20 to 25 per cent for this same acceleration and deceleration. Proper application and consideration of the acceleration and deceleration effects cannot be stressed too greatly.

The actual conditions under which the various crane motions can operate must also be developed. Here the plant layout is the guide. It may be possible to operate the crane with overlapping of motions depending on the physical arrangement. This will allow faster overall handling but much is still dependent on operator experience.

Selection of speeds of the various motions and the size bucket used should be based on the cycles required to perform all operations. The amount of refuse that can be handled in a bucket can be easily determined. Naturally, the average weights of all materials must be used, and these are usually known. The total load is determined from the product of the cubage capacity of the bucket and the cubage weight.

The number of cycles for feeding the furnace is determined from the formula:

\[ \text{number of cycles} = \frac{2000}{T \times \frac{W}{\text{ton/hour}}} \]

where \( T \) = ton/hour
\( W \) = live load, pounds

The total cycles required for rehandling and mixing cannot be developed from a specific formula. An experience factor can be applied; usually it can vary from...
25 to 50 per cent of the total time each hour during the critical dumping shift. Many variables in building design and collection truck dumping schedules can affect this percentage.

Once all cycles are known, a total time of operation can be determined. A summation of the various cycles will show whether the proper bucket size and speeds have been selected. Caution must be recommended that an operator fatigue factor must be added to the total cyclic requirement period. A rule of the thumb has been to allow 20 per cent for fatigue time.

A typical cycle calculation, considering all pertinent factors, is shown in Table I. It displays a logical development for sizing a crane for a 250-ton plant. Data, including total time graphs for the various operations; inclusion of fatigue factors and summation of all motions are illustrated.

**Table I**

**Typical Cycle Calculations**

1. **General Data**
   - a. Total Tons/24 Hours: 250
   - b. Tons/Hour: 10.4
   - c. Material Weight/Cu Ft: 15

2. **Bucket Data**
   - d. Bucket Capacity: 2 Cu Yd
   - e. Bucket Wt. w/Equallzer: 4962 lb
   - f. Rope to Close: 25 ft. 0 in.

3. **Suggested Speeds**

<table>
<thead>
<tr>
<th>Motion</th>
<th>FPM</th>
<th>FPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding</td>
<td>300</td>
<td>5</td>
</tr>
<tr>
<td>Closing</td>
<td>300</td>
<td>5</td>
</tr>
<tr>
<td>Bridge</td>
<td>240</td>
<td>4</td>
</tr>
<tr>
<td>Trolley</td>
<td>300</td>
<td>5</td>
</tr>
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</table>

4. **Average Distances**

<table>
<thead>
<tr>
<th>Motion</th>
<th>Feed Hopper</th>
<th>Rehandle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoist</td>
<td>50 ft</td>
<td>10 ft</td>
</tr>
<tr>
<td>Trolley In</td>
<td>20 ft</td>
<td>12 ft</td>
</tr>
<tr>
<td>Bridge In</td>
<td>70 ft</td>
<td>25 ft</td>
</tr>
<tr>
<td>Bridge Out</td>
<td>70 ft</td>
<td>25 ft</td>
</tr>
<tr>
<td>Trolley Out</td>
<td>20 ft</td>
<td>12 ft</td>
</tr>
<tr>
<td>Lower</td>
<td>50 ft</td>
<td>10 ft</td>
</tr>
</tbody>
</table>

5. **Crane Rating**

   - Bucket Wt: 4770 lb
   - Equalizer Wt: 192
   - Cable Wt: 240
   - Total Dead Load: 5202
   - Live Load: 990 (15 lb/cu ft x 66 cu ft Heaped Capacity)
   - Total Load: 6192 lb

   Use 3 1/2 Ton Capacity Rating

6. **Cycle Calculations for Feeding Furnace**

<table>
<thead>
<tr>
<th>Motion</th>
<th>Distance</th>
<th>Accel.</th>
<th>Velocity</th>
<th>Decel.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close</td>
<td>25¹</td>
<td>4.0 Sec.</td>
<td>3.0 Sec.</td>
<td>- Sec.</td>
<td>7.0 Sec.</td>
</tr>
<tr>
<td>Hoist</td>
<td>50¹</td>
<td>4.0</td>
<td>7.5</td>
<td>1.0</td>
<td>12.5</td>
</tr>
<tr>
<td>Trolley</td>
<td>20¹</td>
<td>3.0</td>
<td>2.0</td>
<td>3.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Bridge</td>
<td>70¹</td>
<td>5.0</td>
<td>9.0</td>
<td>5.0</td>
<td>19.0</td>
</tr>
<tr>
<td>Lower</td>
<td>3¹</td>
<td>-</td>
<td>1.0</td>
<td>-</td>
<td>1.0</td>
</tr>
<tr>
<td>Discharge</td>
<td>25¹</td>
<td>1.5</td>
<td>3.7</td>
<td>1.0</td>
<td>6.2</td>
</tr>
<tr>
<td>Raise</td>
<td>3¹</td>
<td>-</td>
<td>1.0</td>
<td>-</td>
<td>1.0</td>
</tr>
<tr>
<td>Bridge</td>
<td>70¹</td>
<td>5.0</td>
<td>9.0</td>
<td>5.0</td>
<td>19.0</td>
</tr>
<tr>
<td>Trolley</td>
<td>20¹</td>
<td>3.0</td>
<td>2.0</td>
<td>3.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Lower</td>
<td>50¹</td>
<td>1.5</td>
<td>7.8</td>
<td>3.0</td>
<td>12.3</td>
</tr>
</tbody>
</table>

   TOTAL SECONDS WITHOUT OVERLAP... 94.0

   TOTAL SECONDS = 66.5 WITH OVERLAP

(Con't)
7. CYCLE CALCULATIONS FOR REHANDLING AND MIXING

<table>
<thead>
<tr>
<th>Motion</th>
<th>Distance</th>
<th>Accel.</th>
<th>Velocity</th>
<th>Decel.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close</td>
<td>25'</td>
<td>4.0 Sec.</td>
<td>3.0 Sec.</td>
<td>- Sec.</td>
<td>7.0 Sec.</td>
</tr>
<tr>
<td>Hoist</td>
<td>10'</td>
<td>3.0</td>
<td>-</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Trolley</td>
<td>12'</td>
<td>3.0</td>
<td>-</td>
<td>3.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Bridge</td>
<td>20'</td>
<td>4.0</td>
<td>-</td>
<td>4.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Discharge</td>
<td>25'</td>
<td>1.5</td>
<td>3.7</td>
<td>1.0</td>
<td>6.2</td>
</tr>
<tr>
<td>Bridge</td>
<td>20'</td>
<td>4.0</td>
<td>-</td>
<td>4.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Trolley</td>
<td>12'</td>
<td>3.0</td>
<td>-</td>
<td>3.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Lower</td>
<td>10'</td>
<td>1.5</td>
<td>-</td>
<td>2.5</td>
<td>4.0</td>
</tr>
</tbody>
</table>

TOTAL SECONDS WITHOUT OVERLAP = 49.2
TOTAL SECONDS = 34.2 WITH OVERLAP

8. CALCULATIONS TO CHECK SUITABILITY OF CRANE

a. Total Cycles/hr Req'd. to Feed Furnace

\[
\text{Cycles} = \frac{\text{Tons/HR} \times 2000 \text{ lb/Ton}}{\text{lb/Cu Ft x Cu Ft Plate Line Capacity}}
\]

\[
= \frac{10.4 \times 2000}{15 \times 36}
\]

\[
= 25 \text{ Cycles}
\]

b. Total Cycles/hr. for Rehandling and Mixing

Assume ................. 30 Cycles

The number of cranes required does become a matter of serious consideration both from an operational and economic viewpoint. It is possible that one large crane could do the work of two smaller units but the ratio of work done is not a direct proportion. In some instances, a smaller, high speed crane will actually out perform a larger but slower crane. When we discuss speeds for incinerator cranes we cannot compare these with those used on industrial hook type cranes. To accomplish the cycles involved, incinerator crane bucket speeds are considered slow at 220 FPM. A major city has standardized on bucket speeds of 450 FPM using a 3-yard unit. For the average plant speeds of 300 to 350 FPM are normal.

In approaching specific details covering mechanical, structural and electrical aspects, only one recommendation can be made. Select features that experience has shown will provide maximum reliability and durability. Shock loads, repeated stops and starts, and abrupt reversals are the rule, not the exception. Service can be described most aptly by one word...severe. No existing national specification covers this type of service. It is not our intent to suggest or introduce detail specifications here, but it is our recommendation that serious consideration be given to this by this Society in the future. Individual Engineers and Cities have done commendable work towards this end. For your consideration, we believe some of the features that must be incorporated in any incinerator crane include the following.

**Machinery Details**

Gearing and wheels must be hardened. The hardness range should be in the 500 to 600 Brinell area. Achievement of hardness must be through accepted practices. Gears and pinions must be designed for compatibility of mating, and long life. Along with hardness, resistance to shock loading and reversals must be an inherent factor in design with appropriate increased design service factors. Drums should be of steel, properly grooved and hardened to withstand the abrasive action prevalent in the incinerator atmosphere. A surface hardness in the 500 Brinell range is necessary to render suitable drum life.
Selection of bearings cannot be over emphasized. Anti-friction roller types give the best performance. Bearing life should be qualified on a 10-year operating life minimum. As a point of interest we can describe one incinerator plant where the closing cable travels on average of 275,000 feet in one day. Translated into drum revolutions this is approximately 46,000 per day. With a gear ratio of 20 to 1 this magnifies into 920,000 revolutions at the motor pinion. One bearing failure means that a furnace, and a plant, cannot operate. We suggest bearing life must be compatible with that service. A rating of 30,000 to 40,000 hours B-10 is therefore logical.

Shafts and axles must consider the aforementioned extreme shock and reversals that are prevalent. Impact loads of 50 per cent and over can be expected. Design and manufacture must be developed accordingly. Axles carrying either bridge or trolley wheels must be of the rolling type with substantial roller bearings located on each side of the wheel. All machinery must be easily accessible for service and maintenance. The consideration of noise reduction of gearing through design and lubrication is recommended.

Structure

Even though the nominal rating of the crane is light in tonnage capacity compared to industrial cranes, the heavy duty incinerator crane has the highest ratio of dead weight to live load capacity. A 4-ton, 40 ft span, heavy duty incinerator crane will weigh as much as 70 to 75,000 lb. A class C industrial type crane with five times as much capacity and a span that is double that described above weighs no more. The structure must be designed to not only take the full weight of the trolley plus the live load but it must also be designed to withstand the heavy shocks and impacts which are always prevalent. Welded plate box girders of ample depth and width are needed to retain deflections within allowable limits and to withstand the extreme torsional stresses that are present in the operation. Recommended limits of deflection, based on the more rigid crane specifications, are 0.001 inches per inch of span.

The proper incinerator crane has access platforms and service platforms both on the drive and idler sides of the crane. These are necessary for safety and proper servicing. Safe access from the front to the rear of the crane through the use of handrails and platforms should be considered.

Electrical

The electrical features incorporated in the modern incinerator crane are really the story of its success or failure. Inadequate electrical components are the greatest cause of crane shut-downs.

Motors, by the nature of operation, dictate the use of wound rotor slip ring types. The extreme duty cycle requirements with many starts, stops and reversals gives positive assurance of extreme heat. Motors specified with ratings such as 30 minute − 75 C, or 60 minute − 75 C, are a definite invitation to trouble. Motor analysis, be it by the RMS method or any other, has shown that a 120 minute rating with the proper class B, F or H insulation is usually the acceptable minimum. The recent changes in NEMA motor frame sizes have a definite advantage of cost savings but unless the required thermal capacity and motor ruggedness can be achieved there can be no excuse for their use under the guise of standardization. Specifically then, "standardization" cannot be a criteria, it must be "suitability for the application".

Here we must inject points of primary concern in the reasons for motor heat. In the cycle where the furnaces are being fed, the various motions are long enough to allow motors to run on velocity for periods of time, thereby getting some cooling affect (See Section 6 of Table 1). The rehandling cycle, however, normally allows nothing but acceleration and deceleration of the motors. Motors are running at reduced speed under increased torque and extreme heat is a result. Section 7 in Table 1 shows typical times for these motor functions.

Recent standardization of alternating current motors by the Association of Iron and Steel Engineers, and subsequent use of these motors on incinerator cranes should be followed closely. Characteristics are somewhat different than those prevalent in motors used to date, including a 325 per cent pull out torque instead of 275 per cent. Even these AISE motors must be checked very thoroughly to determine whether they have sufficient thermal capacity in their normal horsepower and thermal ratings for this particular service.

Earlier, reference was made to the incorporation of a fatigue factor in the cycle calculations. This factor should not be included in determination of the correct motor for very obvious reasons. It's possible that a conscientious operator may not take this fatigue time; or furnace demand may not allow it during peak load periods. It must also be remembered that motors on incinerator cranes are always operating under load which is contrary to a hook service crane. A typical 2 yd grapple weighs 5000 lb and the refuse will weigh approximately 1000 lb. It can be seen that the hoist motors are always under heavy load.

Control has been fairly well standardized for some years. Full magnetic variable speed with countertorque or off-point countertorque on the holding and closing motions and reversing-plugging on the bridge and trolley is used in most plants to date. This type of control has been quite serviceable and will be used by many in the
future. Important features that must be included in this type of control include:

1) Mill type contactors.

2) Control schemes that give a responsiveness to both speed and load. The characteristics of the operation of the bucket and the extreme different digging conditions that exist dictate that this feature always be furnished. A control scheme, based on timed acceleration is incapable of satisfying the motor demands as it operates on fixed time increments while ignoring actual load and speed conditions.

Some recent incinerators have utilized Static-Stepless Control. This control promises to be the most successful when it is applied properly. Important features of this control include the infinite amount of speed steps available within the limits of the speed range and the vastly reduced amount of maintenance through the elimination of the majority of moving contacts and relays. Another very important indication of the desirability of Static-Stepless, properly applied with eddy current brakes, has been the virtual elimination of electric holding brake lining wear and substantially less motor heat. Positive direction of movement is another advantage.

Use of joy-sticks which combine two motions into one master lever has resulted in improved, or faster, cycle times and smoother, easier crane operation. These more sophisticated features are being accepted rapidly. The user need have no reservations as to maintenance of this equipment as qualified service and training personnel are available to familiarize them properly.

Electric brakes should be the standard adopted by the crane industry. These are the Association of Iron and Steel Engineers - NEMA de rectified, magnetic shoe type brakes. Standardization of mountings and brake wheel dimensions exist throughout the industry. Again, experience has shown that suitable torque ratings based on full load motor torque should be 200 per cent for the holding and closing motions, 50 per cent for the trolley and 200 per cent for the bridge. The bridge brake can be either the hydraulic or the combination electric-hydraulic type with the electric brake serving as a parking unit.

Resistors must be the nonbreakable type because of the heat, as well as extreme vibrations and shock loads that exist. Motor and control characteristics must be known to size resistors properly but a minimum resistor rating of the 170 series (15 seconds in the circuit out of every 30 seconds) has been satisfactory.

Limit switches are a definite requirement on the hoist motion. A final limit stop of the motor circuit type gives the best assurance that the bucket cannot be run into the trolley. This limit switch should have a plugging action which drives the bucket in the lowering direction when contact is made with the switch. Slow-down switches such as can be accomplished with geared type mechanisms are also recommended.

Rigid steel angle, or rubber covered festooned, span conductors are an important feature that must be considered. If angles are used, double collector shoes are vital to continuous operation. Either system should be located outside the idler or rear girder, with ample platform area for maintenance. The festooned system, rapidly coming into prominence (See Fig. 3), has the important advantage of elimination of collector shoe maintenance, and simplicity. Mainline conductors of the rigid steel or aluminum angle type have proved most successful. Again, however, only double shoe systems must be used.

All cranes must be supplied with the various overload, under voltage and short circuit protective devices. Knife switches for control and power circuits and disconnect switches to meet all maintenance requirements and safety codes should be included. Control enclosures which are easily accessible, but still prevent entrance of dirt and dust must be supplied.

\[\text{FIG. 3 FESTOONED SYSTEM OF CONDUCTORS.}\]

\[\text{Lubrication}\]

The service to which an incinerator crane is subjected dictates the use of an automatic lubrication system. A separate one pump system for the bridge and another for the trolley has been extremely suitable and reliable to date. If the gear case design is such that splash lubrication can be assured to the bearings inside the gear case, the automatic grease lubrication need not be extended to these bearings.

\[\text{Crane Cab}\]

The crane cab has been a source of continuous interest and concern not only to the user but to the manu-
factory. No two plants seem to be the same in design as far as elevations and plan dimensions are concerned. Consequently, a different vision problem exists in each. Efforts of standardization of cabs by manufacturers have met with some success but this has not been complete. The only design criteria must be that the operator must conveniently see the bucket when it is in the bottom of the storage bin as well as when it is over the hopper. Sufficient vision must also be provided to ensure that the operator will not run the bucket into the collection trucks when they are unloading at the dumping ramp. Most recent incinerator cranes have been equipped with air conditioners with varied results. There is no question that the conditioner does result in greater operator convenience and efficiency.

Some new incinerators incorporate in-plant communications systems in the crane cabs. Reliable systems are available and their use is encouraged. The location of the various control masters, other electrical equipment such as disconnect switches and push buttons for the mainline contactors or the manual magnetic disconnect switch must receive very serious consideration. A convenient and comfortable operator's seat is a necessity. Finally, convenient entry and egress from the cab must receive serious attention. A retractable ladder is one desirable solution.

Buckets and Grapples

Buckets, with or without teeth, have been used in the majority of incinerator plants. Depending on the type of refuse, a grapple may be more desirable. The grapple has the capability of handling more refuse with the same yardage rating than a bucket. It also has better digging characteristics. A serious drawback was the problem of cleaning up the bin but the bucket manufacturers have developed cleanup scoops that are easily attached or detached.

Equalizers used with the buckets are of three types, the A, the B, and the straddle A. The latter is usually the most suitable because of its rather wide anchor points and because the overall bucket height becomes less.

Direction of Bucket Opening and Hoist Drums

It is always a controversy about the direction of the opening of the bucket or grapple and the relationship of the holding and closing drums. The direction of the bucket opening should be such that will enable the easiest method of obtaining a full load from the refuse pile. This direction is usually parallel to the long axis of the storage bins.

As far as the drum location is concerned, two schools of thought exist, one being that the drums should be in the same direction as the lay of the bucket on the refuse pile. The dumping ramp is usually parallel to the crane runway and the angle of repose is down and away from the dumping ramp level. The bucket lays at an angle approximately normal to the angle of repose. The cable should be acting on the drum grooves in the same normal direction or more explicitly, the cable should be working in and not against the grooves. The other school of thought states that the drums should be located so that the grooves are in the direction of the bridge travel so as to prevent groove wear when the bucket is in motion along with the bridge in a longitudinal line. A drawback to this conclusion is that if the control is proper on the crane, swinging of the bucket should be minimal and groove wear would not be a factor.

Spare Parts

Contrary to all our experiences such as when buying an automobile, spare parts for an incinerator crane must receive serious consideration from the first thoughts about the crane. Very few components are available as shelf items. It is therefore recommended that an ample supply of spare parts be carried not because failures are expected but because component failures cannot be eliminated. A rather full supply of electrical replacement parts, including motors, should always be available. Bucket or grapple teeth as well as sheaves and holding and closing cables should always be in reserve.

Building Considerations

Engineers must be cautioned that sufficient space must be provided for the crane in the building. Squeezing the crane can only result in imposing restrictions on the crane manufacturer that can be detrimental to the overall operation. Parking areas for servicing the crane are important. Ample side and overhead clearance must be given. Considerations of ample structures to carry the crane or cranes, with the high impacts and shock loads really affords protection to overall building and crane life. Crane rails utilizing the continuous rail and restricted float principles eliminate need for expansion sections while affording a better overall system. This rail, with its tight joint between rail ends eliminates the usual impact that exists when wheels pass over the joint. It also has the desirable self-adjusting ability not present when hook bolts are used. Costs between the older hook bolt and standard rail joint system and the one described above are comparable.
Conclusions

The engineer must consider the crane as a vital part of the incinerator plant. Sizing of the crane to perform all functions on a continuous basis is one of his major responsibilities. The extremely severe operating conditions cannot be underestimated. Equipment must be specified that can assure the municipality of rugged and long life without excessive maintenance.

Encouragement, and time, should be given to the engineer to study the refuse handling requirements in as many plants as feasible. Although there is a similarity among all, each can contribute something to better and more successful operations in the future. The continuing developments of the crane manufacturers should be followed closely as much can be contributed from this source too.