TOWER CRANE LIFE EXPECTANCY

AN EXAMINATION OF RECENT TRENDS TO ESTABLISH AGE LIMITS

Jim D. Wiethorn, P.E.
Matthew R. Gardiner, P.E.
Anthony E. Bond, P.E.
Edward P. Cox, P.E., PhD
Ray A. King, E.I.T.

TOWER CRANE LIFE EXPECTANCY

AN EXAMINATION OF RECENT TRENDS TO ESTABLISH AGE LIMITS

Over the past decade there have been increased discussions and attempts around the world to set and/or legislate a maximum service life of tower cranes, and in some cases mobile cranes based solely on their age. As a result of the recent publication *Crane Accidents: A Study of Causes and Trends to Create a Safer Work Environment, 1983-2013*, Jim D. Wiethorn, P.E., the Specialized Carriers and Riggers Association (SC&RA) approached Haag Engineering Co. to evaluate and compare the basis of these claims to our experience in crane accident analyses and Crane Study results. SC&RA submitted questions which their membership wanted addressed that relate specifically relate to the ages of the cranes. As part of our analysis, we examined the Crane Study results with respect to the crane ages at the time of the incidents to the actual causative factors of the accidents, with an emphasis on tower cranes. Additionally, we researched and addressed a variety of issues raised in support of and rebuttal to proposals for regulations in various parts of the world. The purpose of this analysis was to determine if any correlation exists between crane accidents and ages of cranes, to evaluate whether basis for these claims would suggest an age limit for such equipment.

HISTORICAL RESEARCH

The earliest known policy to stipulate calendar ages of cranes as a limit to their service lives was enacted in **Singapore** during October 2006, although development of the regulation first began in April 2004. The guidelines address imported tower cranes with both current registration and those seeking first time use in the country. The statutes governed the introduction of *used* tower cranes from other countries that met the following criteria.

1. First Time Use of A Tower Crane:
    - *Model and type-approved for use in Singapore and accompanied by a recent (not more than 2 years) inspection certificate from the statutory authority from the country it was used.*
    - *Any tower crane not manufactured in Singapore that is 5 years or older shall be subjected to an inspection by a third-party inspection agency acceptable to the Commissioner for Workplace Safety and Health.*
    - *Used tower cranes are not permitted in Singapore if the unit is 1) from a country that does not have requirements on statutory inspection; 2) the crane is 15 years or older (date of manufacture); 3) or the tower crane has an inspection certificate from a country that was last issued more than 2 years ago.*

2. Existing Tower Crane Certificates:
    - *A tower crane not manufactured in Singapore whose existing certificate is 8 or more years old shall undergo a third-party inspection before each installation.*
    - *If the tower crane is 15 years or older, it will not be allowed to be used unless the owner obtained a letter from the manufacturer certifying that the crane can be safely used for a longer period of time.*
    - *Tower cranes 20 years or older will not be allowed for use.*
    - *Non-destructive tests shall be carried out by an accredited testing company in accordance with the Singapore Accreditation Council, SINGLAS (Singapore Laboratory Accreditation Scheme) guidelines for the particular scope of testing.*

Other requirements include a crane layout plan (clearly showing zones of influence) in conjunction with AE (Architect/Engineer) certification that the crane was erected in accordance with the plan; confirmation that the crane operator is registered and that the lift supervisor, riggers, and signalmen have approved zones of operations. Further, all personnel so noted are required to sign the plans confirming clear understanding of their responsibilities. Additional guidelines include a requirement that all foundations and braces be designed and their installation is confirmed by a professional engineer. The professional engineer also must confirm that the tower crane was installed/erected in accordance with plans.

In 2007 Mr. Dale Curtis, P.E., submitted a petition to **Cal/OSHA** recommending a change to Section 4884 of the GISO (General Industry Safety Orders), amending it to require that all hammerhead and luffing tower cranes older than 20 years not be climbed and/or tied to any structure. Furthermore, he also proposed that cranes older than 20 years be used only as freestanding tower cranes and that any tower crane older than 30 years not be used on construction sites. Mr. Curtis cited the following problems as being common to older tower cranes:

1. Operating manuals for older tower cranes are often incomplete and do not show accurate values for foundation reaction forces and other forces needed for the engineer to design struts to tie-in to the adjacent structure.
2. The manufacturer's technical and service bulletins are often not included in the operation manual.
3. Technical support may be unavailable if the manufacturer is no longer in business.
4. The crane owner is not always able to furnish a competent technician for either climbing or dismantling the crane. The crane user/contractor may therefore have to locate a competent technician elsewhere.

5. The crane owner may not have high-wear original equipment manufacturer (OEM) replacement parts readily available. Thus, questionable material and salvage parts may be used to replace worn-out parts.
6. Owners of some older tower cranes write "bare-rental" contracts in which the crane user (contractor) assumes responsibility and liability for on-going maintenance, engineering for tie-in struts, climbing and dismantling expenses. Some crane users do not or are not financially able to take-on these responsibilities.
7. Almost all tower cranes which are climbed/raised to higher configurations are subsequently tied-in to the adjacent structure. Tie-in collars for old cranes often appear to be worn out and without new connection components. Some collars appear to have been salvaged from other tower cranes. Older collars may require engineering services to show additional strengthening necessary. Some engineering firms do not have the expertise to recognize these problems.
8. When cranes are climbed to increased heights, the old climbing cages and related components should be in "like-new" condition. It is almost impossible for crane owners to provide older climbing assemblies in good condition.
9. Many years of usage contribute to metal fatigue which can negatively affect the safe operation of tower cranes. The amount of fatigue in older tower cranes is not always evident without thorough examination.

The Cal/OSHA Division's evaluation and response to the petition was as follows:

> *The Division's evaluation, dated and received on December 12, 2007, indicated that it is not aware of accidents as a result of aging tower cranes. Tower cranes are required to be inspected by a licensed crane-certifying agency as well as by the Division. In addition to the inspection, the annual certification must include detailed non-destructive testing of the critical tower crane parts. If safety deficiencies are found on the tower crane, the crane will not be certified until the deficiencies have been corrected.*
>
> *The Division reported that a tower crane manufacturer's representative was contacted regarding the condition of older tower cranes, and the representative indicated that the condition of a crane is more dependent on how well it is maintained, rather than its age. Furthermore, the Division noted that older cranes are generally designed more conservatively (i.e. "overbuilt") than newer cranes which are computer-designed; thus older cranes may have longer service lives.*

> *The crane certification program and the permitting system used by Cal/OSHA have been effective in preventing accidents involving tower cranes. If there are older tower cranes with safety deficiencies, they can be handled on an individual basis with the existing standards. Therefore, the Division recommends that the petition be denied.*

The Division was very precise in identifying numerous sections of ASME B30.3-Tower Cranes, which addressed virtually all of Mr. Curtis' concerns, as well as the implementation of those requirements by licensed professionals in California in denying the request.

The **Crane Industry Council of Australia** (CICA) published an interesting corollary to the Singapore regulation in May 2012 relative to the new Safe Work Regulations being introduced in most of their states. Concerning the effects of eliminating barriers to used crane imports, CICA stated, "It cannot be underestimated just what an impact this decision in the mid 1980's had on the Australian crane industry. The concept of self-regulation was in its infancy and not understood by the majority of crane operators….The used cranes issue has changed forever the structure that was accepted at the time, but enabled certain segments of the crane industry to import sub-standard cranes that have lowered the levels of safety." The document addresses serious problems with sub-standard imports and even counterfeit cranes. CICA stated, "It can be construed; we are the dumping ground for cranes that have passed their economic life in Asia, or for that matter, any other Country in the World. No other Country to our knowledge supports such an open ended situation with regards to the age, or condition, of used imported cranes."

CICA recommended consistent, stringent independent inspection procedures and verification of past maintenance history for cranes less than 10 years of age; cranes between 10 and 20 years old; and, cranes in excess of 20 years old.

A different approach to addressing the ages of tower cranes was proposed on May 15, 2013, when the **Ontario Ministry of Labour (MoL)** issued a profile of proposed changes to Ontario Regulation 213/91 of the Occupational Health and Safety Act (OHSA) for improving tower crane safety. The far-reaching amendment to the Regulations was 156.1 New - Design. The design requirements would mandate that all existing tower cranes be updated to meet more current standards as follows:

(1) A tower crane that is being put into service in Ontario for the first time,

   a. *shall be designed and manufactured in accordance with the European standard EN 14439:2006 or EN 14439:2009, Cranes – Safety – Tower Cranes;*
   b. *shall meet the requirements in the document, Electrical Specification for Tower Cranes, ESA SPEC-00X-13, published by the Electrical Safety Authority; and,*

c. *shall have control equipment incorporating solid state devices, a programmable logic controller and/or software systems in operating and control circuit, designed and installed to meet circuit performance classification that is control reliable meeting category 3 or better in accordance with,*
    i. *ISO 13489-1, Safety of Machinery-safety related parts for control systems, or*
    ii. *EN 954-1:1996, Safety of Machinery-safety related part of control systems – Part 1: General Principles for design.*

(2) After a SPECIFIED DATE, a tower crane, other than one described in ss.(1), that is erected on a project,

a. *Shall be designed and manufactured in accordance with CSA-Z248-04; and,*
b. *Shall comply with the requirements in ss. (1)(b) and (c).*

In response to the proposed regulation, the **Ontario Formwork Association** (OFA) issued a commentary to the New Design requirements which cited numerous problematic issues including cost of the upgrades, responsibility for the design following upgrades, manufacturer resistance to upgrades of existing designs, and availability of technicians to service the latest electrical and electronic upgrades. Further, OFA noted that the EN standards state that they are not intended to and do not apply to cranes built prior to issue date of the new standard. Additionally, the OFA stated that the MoL should be examining the qualifications, knowledge, schooling and work ethics of existing maintenance personnel as a source of addressing tower crane safety, and last referenced the decision of Cal/OSHA where it established logic that well-maintained cranes have a long operating service life.

On December 10, 2013, Mayor Bloomberg and Buildings Commissioner Limandri announced new legislation to limit the calendar age of cranes operating in **New York City**. The announcement stated that the "25 year age limit will remove older cranes from operation and improve the safety of crane operations at construction sites. Cranes would be removed from service based on the original date of manufacture, or based on the age of the crane's oldest component, whichever is greater." Further, "crane owners would be required to outfit all cranes with load cycle counters to record data regarding every lift that a crane performs, which the City of New York believes is critical to setting maintenance schedules and overall operability over a crane's service life". The announcement of the pending new regulation stated:

"New York City has some of the toughest crane regulations in the world, and we enforce crane regulations more stringently than anywhere else," said Mayor Bloomberg. "Since 2008, the City has adopted more than 25 new construction safety laws, conducted tougher inspections and raised licensing standards for crane operators. This legislation builds on those efforts by

ensuring only state-of-the art, highly reliable equipment is transforming New York City's skyline."

According to the report, since 2008, the Department has increased its oversight of crane operations across the City, including expanded inspection checklists, more training for crane inspectors, updated exams, stricter licensing requirements and several new laws and requirements, such as:

- *Requirement of national certification and mandatory re-testing every five years for licensed crane operators;*
- *Requirement of detailed plans for the erection/dismantling of a tower crane;*
- *Requirement of a safety meeting before the erection, jumping, and dismantling of a tower crane;*
- *Requirement of tower crane workers to receive a 30-hour safety training course;*
- *Requirement of an inspection and certification by the engineer of record prior to jump or climbing;*
- *Prohibition of the use of nylon slings unless recommended by the manufacturer; and*
- *Requirement of a third-party engineer inspection of a tower crane before an approval for erection.*

THE ARGUMENT

The restriction of service life due to age of a crane appears to have originated in the Asian Pacific where there had been no prior restrictions on used cranes brought in from various countries. It was the most obvious issue addressed by CICA in that Australia was basically a "dumping ground" for old and worn out cranes which had exceeded their economic life and for counterfeit cranes. In prior years, maintenance and testing records were not required, resulting in thousands of cranes being imported into their country at the expense of safety. When records were supplied for cranes from other countries, language barriers limited document review regarding proper testing and maintenance. It is well documented that Singapore has progressed in the development of new local crane manufacturers, and the protection and support of those companies may be at least one underlying motive for implementing age limits on imported cranes. However, like Australia, Singapore is a growing country with what appears to be limited control of crane imports until the mid-2000s when the new regulations were implemented which addressed a more controlled and regimented layout, design and erection of tower cranes. Singapore further enhanced their new standards by requiring personnel involved in the erection and use of a tower crane to sign the layout plan demonstrating their understanding of their respective responsibilities. New York has improved crane safety during the past decade by implementing necessary inspection procedures for various tower crane procedures. However, New York also has included a new nuance by imposing a new requirement for load cycle counters. New and more sophisticated technology on cranes appears to be the position of the Ontario MoL for safer crane operations. This is a simple and logical conclusion, but will more technologically savvy cranes be safer?

Proper maintenance, documentation and ongoing inspection and testing of cranes, remains the foundation for crane longevity as noted by Singapore, Australia, Cal-OSHA, and the City of New York. The alternative to allowing insufficient maintenance and inspection/testing is limiting the age of a crane; however, abuse and improper operation of any mechanical equipment has no age limit and can cause severe damage over a short period of time. Certainly structural, mechanical, hydraulic, pneumatic, and electrical degradation is inevitable as a crane ages. Crane maintenance is more intense with an aged crane since components naturally wear with use, because metal fatigue develops with repeated severe cycles, and because systems become inoperable, break due to impact or misuse, and deteriorate from environmental conditions.

With aged cranes, the original crane manufacturer often discontinues support a series or line of cranes. With mergers and acquisitions, the acquiring company often refuses legal responsibility for the design of cranes manufactured by an acquired company even though they will fabricate spare parts according to drawings contained in the purchased assets. Knowledgeable maintenance personnel for components of aged cranes also may become hard to find, and at some point, the crane may require complete overhaul. These issues and conditions increase maintenance costs and reduce the economic service life of a crane. Component replacements, system modifications, and continued aging of the crane, at some point may dictate a risk assessment before allowing continued crane operation. Risk assessment should be conducted on a crane by crane basis.

However, as with any manufactured item, specific maintenance requirements must be met to achieve the ultimate service life of that piece of equipment. Proactive maintenance of cranes and crane systems can eliminate component and system failures. Preventative maintenance needs to be performed routinely per manufacturer schedules. Preventative maintenance inevitably increases the service life of a crane. Manufacturer maintenance schedules should be followed as standard practice since preventive maintenance produces the desired results of maximized component life, reduced component failure and reduced overall cost. Failure to follow manufacturer maintenance requirements will reduce the service life of any equipment.

Inspection requirements and maintenance schedules vary widely for the various crane components. For example, manufacturers require that maintenance personnel regularly perform inspections on hydraulic systems by checking filters, filter indicators, and the hydraulic fluid reservoirs daily. Manufacturers typically require that the hydraulic fluid be changed every two years or when the crane is remobilized to another job site, since particulate contamination of hydraulic fluid can cause premature hydraulic component failures. Particulate contamination within hydraulic fluid is an obvious concern, since hydraulic components are machined precisely and have very tight clearances between moving parts. The hydraulic fluid lubricating film keeps moving parts within hydraulic components separated and reduces wear. Many hydraulic components have mechanical clearances of only a few thousandths of an inch. Such tight clearances between moving internal parts make them highly susceptible to damage caused by particulates in the hydraulic fluid. Failure to heed to manufacturer inspection and maintenance schedules for hydraulic systems can reduce greatly the service life of the hydraulic components. Even so, worn hydraulic components are replaceable, and accelerated hydraulic system wear may not reduce the overall service life of a crane.

Components of cranes that endure regular movement through crane operations, cylinders, winches, motors, pumps, and other components, wear with use. Typically, these components operate for long periods before either rebuilding or replacement becomes necessary. These components have a combination of bearings, bushings, seals, and/or piston (wear) rings that require replacement. Winch brake systems have brake linings and/or friction discs that also need replacement. Excessive wear of these crane components causes losses in performance and efficiency. In other words, these components lose responsiveness and tend to develop sluggish movements, sloppy movements, slower speeds, increased vibrations, and slippage during crane operation. These are indications that crane component maintenance is needed. Manufacturer service manuals address these performance inefficiencies within the trouble-shooting sections of their manual, as well as required actions to eliminate ineffectiveness of these components. Following these manufacturer recommendations will maximize component life. Manufacturers usually provide lists of replacement parts within their manuals to facilitate regular maintenance practices. If some component is worn excessively and cannot be rebuilt, replacement of the Original Equipment Manufacturer (OEM) component will not reduce overall service life of the crane.

Structural deterioration is very long term issue. Design codes and historical performance typically result in structures being exceedingly robust. American Welding Society (AWS) design criteria assume that welded connections are flawed from the onset of fabrication and that fatigue crack initiation life is gone from first use. (Total fatigue life is the sum of initiation life plus propagation life.) These design criteria for dynamic structures assume that fatigue cracks evolve from entrained flaws and that service life is governed solely by crack propagation. Inspection criteria usually are defined such that multiple inspections are done during that period while crack growth is in the subcritical region. That is, if an existing structural crack is not detected during one inspection, there will be several subsequent inspections at later dates which should detect the crack long before it becomes catastrophic. Often, no catastrophic failure occurs even with a sizable crack present within a structure. Fatigue cracks which form in structural members should be visually obvious during routine inspections. In critical applications, inspection intervals are specified such that multiple inspections occur prior to the crack growing to critical size. Likewise, large structural displacements during operation should alert crane personnel that a structure is failing. Large deflections and progressive buckling symptoms often occur prior to catastrophic collapse.

Common commercial inspection techniques (mag particle, fluorescent particle, dye penetrant) readily detect surface cracks at sizes much smaller than critical size. However, quality inspections cannot be conducted on structures encrusted with dirt, grime and thick layers of paint. Inadequate inspection procedures and improper surface cleaning are the greatest causes of cracks reaching critical size and causing structural failures. Even when inspection practices are inadequate, opening, closing and rubbing of crack surfaces causes spalling or cracking of the paint, dislodges grime and forms readily visible rust stains.

Inspection requirements can increase due to environmental conditions. Cranes operated in coastal regions, even for short durations, can experience deleterious corrosion attack. Chlorine from salt water and fog is particularly insidious to structural components. Cranes close to the shoreline need more frequent inspections of its structural components. Corrosion rates for metals increase the closer metals are to the shoreline, since the amount of salt in the air is greatest near the ocean. Winds carry salt air and moisture inland and provide an environment in which salt accumulations form on metal surfaces of cranes. Salt accumulation on metal surfaces, along with high humidity, accelerate the reactions which cause corrosion. Corrosion rates are higher when high humidity keeps the surfaces damp longer. Over time, and even beneath paint films, chlorine corrosion will degrade steel members into dust. Therefore, more frequent periodic inspections and regular maintenance of crane structural components are necessary to prolong the service lives of these cranes operating near a shoreline.

National consensus standards address inspection and maintenance emphasizing the importance of these requirements. ASME B30-*Safety Standard for Cableways, Cranes, Derricks, Hoists, Hooks, Jacks, and Slings,* includes in all its volumes INSPECTION, TESTING, AND MAINTENANCE as part of the requirements for the use of that equipment. ASME B30.3-2012 expanded its requirements to include a new category, 3-2.1.5-MAJOR INSPECTIONS which addresses nondestructive testing and disassembly of specific components on a five-year schedule for more thorough examination normally not included in other inspections. Cal/OSHA referenced ASME

B30.3 in their decision not to implement age restrictions. Cal/OSHA decided proper maintenance, inspection and testing would suffice to assure crane integrity. If proper maintenance and testing protocol is established and performed on a crane as recommended by the manufacturers and by national standards, the economic service life of a crane will end when the costs of inspection, testing and maintenance exceed the income the machine can produce. Certainly, proper inspections, testing and maintenance are the cornerstones of proper crane operations and equipment longevity.

Some jurisdictions, including the City of New York, want to incorporate service life cycle-counters on cranes. Life cycle analysis and prediction becomes much more complicated when loading events do not have equal or symmetric magnitudes per cycle. Asymmetric loading events probably is why crane manufacturers currently provide no end of service life definitions for their equipment. However, attempts are continuing in other critical applications to devise methods and instruments which count and predict accumulated fatigue damage. Earliest applications included data recorders for strain gages applied at critical locations in military aircraft. Systems continued to evolve which utilized instruments which discriminated between damaging and non-damaging events. Other systems with greater sophistication calculated the relative damage per event and predicted residual life. Part of the challenge has been to identify which locations were most effective to monitor. In aircraft, critical locations are known as the result of very sophisticated design and analyses procedures. In other equipment, usually designed based on historical performance behavior or from the use of accepted design manuals (e.g. AISC Steel Design Manual), critical locations are not known specifically.

Likewise, older cranes which have been operating for many years present particular challenges because the extent of accumulated damage at any structural location is unknown and no load histories exist. Without knowing the extent of accumulated damage, no predictions or measurements of remaining service life are possible. This renders application of cycle counting in older cranes unrealistic. First, no data exists on prior use, so accumulated fatigue and overload damage is unknown. Second, maintenance during the life of a crane can vary substantially, particularly cranes operated under divergent conditions, cranes owned by several different entities, and cranes operated by many different people. The current state of maintenance also is contingent on daily inspections, actions and lubrication performed by the company using the crane during any specific interval. During bare rentals, national standards designate the crane user (lessee) to be responsible for all inspections, maintenance and required testing. The crane owner has little or no control while the machine is in the possession and control of others. Timely and proper documentation by the user during a bare lease is mandatory to ensure all inspections be conducted and conditions be evaluated properly. These records become part of the crane historical data and a basis for future maintenance and repair.

Suggestions regarding the means by which to count cycles in cranes include counting the number of "picks" and recording load line forces, strains on the boom, and tower strains. Although instrumentation can be devised which will measure forces, strains, accelerations and deflections, no consistent algorithm exists by which to convert reliably any of these factors into accumulated damage or residual life. In fact, installing such instrumentation into an older crane would result in erroneous data and instill false confidence. With no historical data to input, the instrumentation will consider an older crane to be a new with a full complement of service life left to be consumed. Reliance on such instrumentation would potentially supplant the use of vigorous and competent inspections and lead to missed opportunities to discover cracks and other mechanical damage.

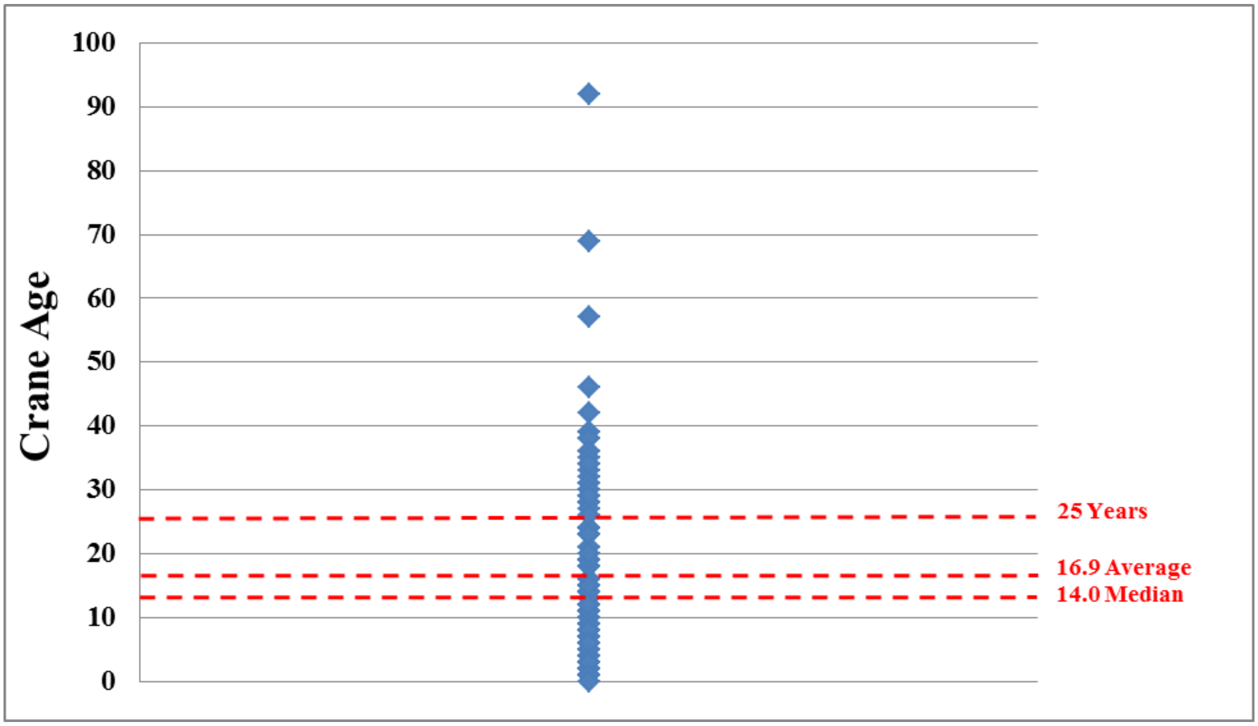
Ultimately, some "end of life" criteria must be defined. We have discussed this specific issue with multiple crane manufacturers and designers, and currently no ends of life definitions are available. Although sophisticated life-extension technologies exist for older equipment, implementation often includes extensive inspection, refurbishment and replacement of components. Life extension programs are cost effective for capital-intensive equipment such as aircraft and power plants, but probably not for cranes.

Finally, fatigue manifests as the result of cyclical loading, and has no direct correlation with the calendar age of a crane or of any of its components. A recent example occurred in New York City when a boom hoist wire rope failed as a result of fatigue after only 6 months of use. The incident occurred as a result of the type of use, and was completely unrelated to calendar age of the wire rope. Instead, it was the result of lifts resulting in high stress cyclical loading. Different crane components have different useful service lives, depending on how the crane is used and how well the crane is inspected and maintained. Twenty-five years is not only an arbitrary "shelf-life" for a crane, it could very easily mislead crane users into a false sense of security with cranes under 25 years of age.

CRANE STUDY RESULTS

During July 2014, we published the results of a study of crane accidents that dates back to 1983. Our analysis and experience was based on the evaluation of over 800 crane accidents since 1987. The study involved complete analysis of 507 crane accidents at the time of publication. As part of our study, we identified the manufacturing date of the crane for each incident, as well as the age of the crane at the time of the incident in order to determine if there was a correlation. Of the accidents included in our study, we were able to identify the exact age of the crane 125 times.

Our study indicated a range of crane ages from 0 to 92 years with the average age of 16.9 years and a median of 14 years. A total of 78.4% of the cranes involved in incidents were less than 25 years old, and we found no discernable pattern to indicate calendar age of the cranes was a contributing factor. We did identify several accidents associated with condition of the crane, although the circumstances had resulted from severe abuse or neglect, including one that had only two annual inspections in 15 years and little or no maintenance. Site supervision is required to confirm that all cranes brought onto a construction site have undergone current inspection requirements. Many construction companies require a complete annual before a crane is brought onto the site or have an independent inspection company perform the inspection for the company.



Incident Crane Age

We considered the factors associated with calendar age that can cause or contribute to crane incidents. These include wear, metal fatigue, material degradation and operational abuse. All crane manufacturers have inspection requirements to verify that wear and materials degradation are within specific limits. However, metal fatigue does not always present itself in a manner easily observable during a typical inspection. New York City, recognizing this, previously instituted stringent inspection requirements for critical crane components.

We also considered safety improvements through operational aids in newer cranes compared to 25-plus year old cranes. Our study examined the use of more advanced technologies and particularly, operational aids to assist operators during lifting operations. A lift is successful when the process is thought out and planned. A lift will not be successful because a crane is new. A lift is successful because all parties thought through the process, provided accurate information, and used a crane capable of performing the lift. It has been our experience that lifts become dangerous when the lift director or operator rely on the crane (computer) itself to ensure limits are not exceeded rather than conducting a proper and thorough analysis and devising a plan to ensure limits are not exceeded.

FINDINGS

Our experience, research, accepted engineering principles and study results do not support an arbitrary calendar age limit for mobile or tower cranes as proposed by several entities. Although the positions of the various organizations, governmental agencies and individuals vary, the core requirements for proper inspection, maintenance and testing mandated by ASME and OSHA remain embedded in their primary requirements for crane safety and ongoing operations. From an engineering perspective, there is no basis for setting a specific calendar age for cranes. Our study of crane accidents confirmed this fact. As noted in our discussion, all equipment must be maintained in accordance with requirements of the manufacturers to ensure proper operation and longevity. Implementing procedures to confirm proper conduct of specified maintenance, inspection and testing is paramount and must be confirmed by crane owners, users, inspectors and governmental agencies.

Answers to questions submitted by SC&RA on July 21, 2014 follow and are appended to this paper.

Respectfully submitted,

HAAG ENGINEERING CO.

Jim Wiethorn
Jan 5 2015 10:46 AM

Jim D. Wiethorn, P.E.

Anthony E. Bond
Jan 5 2015 10:47 AM

Anthony E. Bond, P.E.

Matt Gardiner
Jan 5 2015 10:48 AM

Matthew R. Gardiner, P.E.

Edward P. Cox
Jan 5 2015 10:48 AM

Edward P. Cox, P.E., PhD

Ray King
Jan 5 2015 10:49 AM

Ray A. King, E.I.T.

SPECIALIZED CARRIERS & RIGGING ASSOCIATION

Tower Crane Life Expectancy-Questions

(Submitted July 21, 2014)

1. Based on Haag's study, how many accidents/incidents were due to a crane's age?

None. Cases with which we have been involved that were associated with condition of the crane were associated directly with lack of maintenance or abuse during operations. No crane that was operated and had been maintained in accordance with consensus national standards has been involved in any accident which we have investigated.

2. How does a tower crane manufacturer define their cranes' "life expectancy" and does it vary from manufacturer to manufacturer?

Manufacturers do not define a "life expectancy" for their cranes. Crane designers may apply design criteria for load cycles predicated on the crane lifting at least 85% to 100% of its capacity during every lift with the understanding that such will not happen. This is particularly true of tower cranes which rarely make consistent lifts approaching allowable capacities. Proper maintenance and use will assure service exceeding any projected "life expectancy". Conversely, the lack of maintenance and operational abuse will reduce greatly the estimated "life expectancy". Both maintenance and operational issues cannot be controlled by the manufacturer; therefore, no life expectancy ever is addressed by the designer. Ultimately, some "end of life" criteria must be defined. We have discussed this specific issue with multiple crane manufacturers and designers, and currently no end-of-life definition has been devised. Although sophisticated life-extension technologies exist for older equipment, implementation often includes extensive inspection, refurbishment and component replacements. Life extension programs are cost effective for capital-intensive equipment, such as aircraft and power plants, but probably not for cranes. During a bare lease owners do not have control of the equipment; control of the inspection and maintenance; and, operational control during the lease period and must rely on the contractor renting the crane to perform the required tasks and operate within chart allowables.

3. Some cities and states have indicated a desire to have tower crane owners count crane "cycles". How can a tower crane owner count a crane's cycles?

Suggestions how to count cycles in cranes include counting the number of "picks", recording load line forces, recording boom strains, and recording strains on the tower.

Although instrumentation can be devised to measure forces, strains, accelerations and deflections, there is no consistent algorithm to convert reliably any of these factors by which to estimate cumulative damage or residual life. In fact, installing such instrumentation into an older crane will result in erroneous data and potentially instill false confidence. With no historical data to input, the instrumentation will consider the old crane to be new with a full complement of service life left to be consumed. Reliance on such instrumentation potentially would supplant the use of vigorous and competent inspections of crane components and lead to missed opportunities to discover cracks and other mechanical damage.

4. Does a tower crane's life cycle vary on usage? Please explain.

Yes. Refer to Question 2.

5. Does the manner in which the tower crane has been maintained and serviced have a direct correlation to the longevity and continued safe use of a tower crane?

Yes, in both positive and negative manners. OSHA regards replacement of a worn part with a "replacement in-kind" to be a safe maintenance practice. Replacement parts considered replacement in-kind must provide the same functionality and performance, but need not be geometrically identical or made from the same materials. So long as the replacement part is fit for its intended purpose, no engineering analyses are required, and the worn part merely is swapped for the replacement. Considering the number of component parts and the number of crane manufacturers no longer in business, the OSHA criterion is the best alternative to assuring safety and continued economic use. Retrofitting non-replacement in-kind parts is permitted, along with re-rating the maximum load, provided an engineering analysis justifies adaptation of different or alternatively designed parts.

6. Can proper inspections of the tower crane prolong its life expectancy?

Yes. Proper inspections and indicated maintenance are key elements to prolonging the life of a tower crane. Regular inspections documented accurately provide a road map of historical information regarding condition of the crane. Competent inspections at appropriate intervals also should detect cracking and other structural problems prior to development of a critical condition. It is imperative that bare leased equipment is properly inspected, repaired and operated during the lease and then documented in order that the owner of the equipment is aware of issues that could affect the longevity of the crane.

7. What key indicators affect the life expectancy of a tower crane?

Proper maintenance and timely inspections in conjunction with operations within allowable constraints are key factors to longevity and minimal wear. The most vulnerable period for a tower crane is during a bare lease when the lessee has complete control of the equipment and of its maintenance/inspections. Proper maintenance and timely competent inspections coupled with proper erection and disassembly by crews with appropriate experience and expertise are crucial to assure a long, trouble-free service life. Post-disassembly inspections, repairs and maintenance should verify the crane has no dangerous deterioration issues. It is imperative that bare leased cranes are properly maintained and documented during operation as the unit will not be re-assembled in the yard when returned from the work site.

8. Based on Haag's research, is there a direct correlation between a tower crane's age and accidents/incidents?

No. Study results have demonstrated no correlation between calendar age and accidents. Operation, maintenance, site preparation, erection, foundation suitability and adequate tie-in bracing are the factors which affect tower crane accidents.

9. Does the age of a tower crane directly relate to its life expectancy?

We have determined there is an "economic life" of tower cranes, as there is with all other construction equipment. Recent changes to ASME B30.3 includes a section *Major Inspections* which in addition to normal maintenance, requires specific elements of tower cranes be examined and even dismantled at 60-month (5-year) intervals. (Owners may decide to conduct inspections based on a specified hours of operation of such components.) The costs of regular ongoing maintenance plus replacement of worn or damaged parts and subsequent major inspections increase with age. These maintenance and repair costs ultimately reach or exceed the potential revenue that the equipment can generate. It then is no longer economically feasible to maintain and operate the crane.

10. Based on Haag's research, is there any engineering evidence to set an arbitrary time limit on the usage of a tower crane?

No. For properly maintained and inspected tower cranes, no definable time limit for equipment retirement age is supported or derived from any engineering principles. In fact, historical data show conclusively that exclusive of cost considerations, properly maintained and inspected tower cranes can remain in service indefinitely.

11. Singapore recently invoked an age limitation of 25 years on tower cranes. Based on Haag's research, have you found any documentation to support this limitation?

No. It is interesting to note that Singapore has adopted a very systematic approach to tower crane safety that mirrors that of ASME B30.3, including responsibilities, maintenance, assembly/disassembly, site layout, inspections, and certifications. Their limitation is applicable strictly to older tower cranes being brought into the country, cranes whose historical use and maintenance records are inadequate and cannot prove the cranes have been inspected properly on a periodic basis. Such tower cranes could not be permitted for erection in the United States under similar circumstances. No basis or reasoning was provided relative to the final 25-year age limitation which, as presented, has no scientific basis or engineering foundation.