Discussion paper on the safe use of 'external' climbing frames on tower cranes

1 Introduction

1.1 On 21st May 2000 the top of a luffing tower crane collapsed at Canada Square in the Canary Wharf area of East London. Tragically, three of the erection crew died in the collapse.

1.2 The collapse occurred near the end of an operation to raise the height of the tower crane with an external climbing or jacking frame. The Health and Safety Executive (HSE) understands that at the time this was only the second collapse of a tower crane during climbing anywhere in the world. The first occurred in San Francisco on 28th November 1989. As part of the investigation into the East London incident, HSE looked at different types of climbing frame used in the UK and past operational experience, including the San Francisco incident and other types of accident involving climbing frames (for example during assembly). This review has led HSE to conclude that there might be general lessons to be learned about the safety of climbing frames.

1.3 The purpose of this discussion paper is try to identify issues for discussion that are relevant to the design, manufacture, assembly, use and maintenance of external climbing frames. These issues arise from HSE's wider consideration of tower crane climbing and should not be read as having a bearing on the cause of any one particular incident. The paper does not address issues such as the selection of an appropriate tower crane, the identification of an appropriate location or the planning of the installation. These matters are covered in relevant British Standards and HSE Guidance. There are also internal climbing systems for tower cranes installed in building cores; these systems work on a different principle and are not considered in this discussion paper.

1.4 This paper is aimed at those with particular responsibilities for the safety of climbing frames but has been written for a wider audience including those who commission and design 'high rise' buildings and other structures. The construction of these buildings and structures may involve the use of tower cranes.

2 Overview of externally fitted climbing frames

2.1 An externally mounted climbing frame is a device designed to increase the height of an installed tower crane without the aid of another crane. Climbing frames may be used with both 'luffing jib' and 'saddle jib' tower cranes. The frame is installed around the mast of the tower crane and incorporates one or more double acting hydraulic cylinders to raise the top of the crane so that new mast sections can be inserted and pinned or bolted in place. The frame is largely open at the front to permit the passage of the new mast section. For convenience, the description given below is for climbing frames fitted with a single hydraulic cylinder.

2.2 The climbing frame is connected to the top of the crane below the slewing module, upon which the crane rotates. The base of the hydraulic cylinder assembly is positioned on the mast of the crane and usually reacts against special climbing lugs on the mast. The top of the crane including the slewing module, main jib, counterjib together with counterweights and crane cab is then disconnected from the mast and the hydraulic cylinder ram is used to raise it a sufficient distance in order to insert a new mast section, so increasing the crane height.

2.3 The frame incorporates sets of guide rollers or wheels which act on the faces or corners of the crane mast and restrain lateral movement during climbing. The guide rollers or wheels and the crane mast will generally resist any overturning forces developed during a climbing operation.

The rollers or wheels are intended to keep the top of the crane vertically aligned during the climbing process.

2.4 Although the basic principle of climbing (sometimes referred to as jacking) is similar for different crane types the designs of climbing frames vary in detail. Design differences may arise from:

- the shape and fixing arrangements for the crane mast sections
- the method of supporting new mast sections; and
- the arrangements for raising the hydraulic cylinder.

The cylinder may be raised in a single stroke or in stages using a temporary support beam or shoe to hold the top of the crane; the beam or shoe rests on part of the mast. A summary of a basic 2-stage climbing procedure is attached at **Annex 1**. A schematic drawing is included illustrating the point in the procedure where the cylinder ram is approaching maximum extension and a new mast section is ready to be pulled into the gap created in the mast.

2.5 HSE's overview of crane climbing operations suggests there may be potential for severe accidents during both the assembly and use of external climbing frames. The whole top of the crane is disconnected from the mast that normally supports it and the load is transferred through the hydraulic cylinder to reaction points on the mast (climbing lugs). The hydraulic cylinder assembly may have to support a dead weight of as much as 100 tonnes, depending on the crane in use. The climbing frame as a whole has to cope with the significant static and dynamic forces involved in climbing.

2.6 There is a reliance on the erection crew to follow a safe procedure. They need to concentrate throughout the operation, relying on their experience of that climbing system and visual clues to identify important changes in conditions. Critical issues might include:

- establishing and maintaining the 'balance' of the crane under changing conditions with potential for significant out of balance moments to develop
- the correct location of the cylinder assembly on the climbing lugs at all stages of the climb
- the secure positioning of any temporary supports between strokes of the cylinder
- preventing deliberate or unintended slewing of the crane.

2.7 The areas where HSE believes that risk may arise are summarized in **Annex 2**. These include risks during the assembly and dismantling of the climbing frame – several serious accidents have occurred at this stage.

2.8 In principle, the climbing of tower cranes seems to be a high hazard operation. HSE's research into accident statistics indicates that to date recorded accidents involving climbing frames have been fairly rare events. However, climbing operations are not common compared with other construction activities. When accidents occur they invariably have serious consequences. HSE has learned of three serious accidents that occurred in 2001. The first incident in Italy resulted in the death of an erector during the assembly of a 'climbing cage' on a partly erected tower crane. In the second incident, which happened in Australia, a site worker was killed when the 20t counterweight of a crane fell off while the crane was being erected with the use of a climbing frame. The last incident happened in Korea and resulted in the death of two erectors and injuries to others on the ground when a tower crane collapsed during erection using a climbing frame; few official details are available about this event.

2.9 Within the UK, HSE estimates that:

- there are around 800 tower cranes available for use
- towards the end of the 1990's the number of separate operations involving climbing frames was of the order of 20 per year
- since the turn of the century the number of separate operations involving climbing frames has been of the order of 60 per year
- the increasing use of climbing frames for the erection of tower cranes probably reflects the number of 'high rise' buildings under construction, the decrease in available space to erect tower cranes by more traditional methods (such as the use of mobile cranes) and the cost of alternative methods.

2.10 HSE considers that the frequency of climbing frame usage is growing and the potential for harm to erectors, site workers and the public can be considerable if things go wrong. Therefore, designers, manufacturers and users should consider carefully the circumstances under which the risks to individuals could become significant and identify the appropriate measures to control them.

3 Purpose of this discussion paper

3.1 This discussion paper is intended to:

- set out issues which HSE considers may be important in minimising the risks arising from the transportation, assembly, dismantling and use of climbing frames (see Annex 3)
- encourage discussion and feedback on these matters
- contribute to the development of future Technical Standards, guidance and codes regarding the climbing of tower cranes
- lead to improvements in the safety of climbing operations.

HSE is not making firm recommendations for improvements in climbing operations at this stage but takes this opportunity to remind duty holders of current advice on good practice in the relevant British Standards, in particular BS 7121: Safe Use of Cranes.

3.2 <u>HSE wishes to point out that the contents of this discussion paper are without prejudice to the findings of any particular investigation including that of the Metropolitan Police/HSE into the accident in East London. The inclusion of any issue in this discussion document does not imply that the matter was directly relevant to the cause of any incident. The discussion paper is aimed at all designers, manufacturers and users of externally mounted climbing frames. It is intended to assist them in minimising the risk of further accidents during climbing operations and in discharging duties placed on them by relevant health and safety legislation.</u>

3.3 HSE appreciates that the vast majority of designers and manufacturers are based outside the UK. We therefore invite addressees to consult with their colleagues overseas, especially designers and manufacturers, and include their views in any response to the discussion paper.

4 Response from industry

4.1 It is for those who design, manufacture, operate and use climbing frames on tower cranes to ensure that they are safe in all reasonably foreseeable conditions. HSE believes that the risks outlined in **Annex 2** and the issues listed in **Annex 3** to this discussion paper should be considered. The list is not exhaustive.

4.2 HSE would like to receive your response to the risks outlined and the control measures put forward in this paper. If you do send us your response you should be aware that it may subsequently be published by HSE although not attributed to a specific person or organisation.

4.3 Responses to this discussion paper should be sent by 16 May 2003 to:

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Annex 1 Summary of a typical climbing procedure

A1.1 A review of the different manufacturer's instructions for climbing frames suggests that the basic procedure can be summarised as below. However, as the procedure for each type of frame differs, details will vary from one design to another. One common feature is that prior to assembly, climbing frames are relatively flexible structures and the loading, transportation and unloading of them, which will involve lifting operations, needs to be carefully planned and carried out in accordance with the manufacturer's instructions.

Assembling the climbing frame

A1.2 The climbing frame is usually in two parts and has to be assembled by the erectors around the tower crane mast. Each part is lifted into position by the crane, connected to the slewing module and then bolted together, making sure that the guide rollers or wheels are located in the correct position on the mast. If the climbing frame has already been installed it may have been 'parked' above the highest tie to the structure under construction. In which case it will need to be raised to the underside of the slewing module by the crane and fixed into position. The frame includes external walkways for the erection team to use during climbing.

Lifting a new mast section to the climbing frame

A1.3 At the start of each climb or jacking stage the tower crane driver positions the crane jib to pick up a new mast section from the ground, by slewing and altering the radius of the crane where necessary. With some designs of climbing frame the new section is lifted up onto a platform which projects forwards from the climbing frame; in other cases the new section is suspended from a built-in overhead gantry projecting from the climbing frame.

Locating the climbing frame onto the climbing lugs

A1.4 The upper part of the climbing frame is physically attached below the crane slewing module and the lower part of the hydraulic cylinder assembly reacts against the mast. In some designs the reaction point is at special lugs (referred to in this document as climbing lugs) welded onto the crane mast. In other cases a special support shoe sits on a cross member of the mast. In either case, the cylinder assembly may not be positively secured in place to the mast. The climbing lugs or support shoes act as reaction points for the hydraulic cylinder assembly enabling it to lift the crane top when required.

'Balancing' the crane

A1.5 The jib is 'made square' with the mast (zero slew) and the jib radius of the crane is then adjusted to that recommended by the manufacturer or supplier. The manufacturer's instructions may require the use of a balancing weight on the crane hook. Alternatively the recommended radius for balancing may be based on the self weight of the jib and hook block and a balancing weight is not required.

A1.6 The 'balance' of the crane is then generally checked by removing the pins or bolts joining the top of the mast and the mast head immediately under the slewing module. The erectors check the alignment of these two parts of the crane as the hydraulic cylinder is raised by a small amount. If they judge that the two sections are vertically aligned the crane is considered to be 'balanced' and climbing can begin. If they are not exactly aligned the radius of the crane is slightly adjusted until the erectors judge them to be aligned.

A1.7 'True' balance would ensure that the forward overturning moment is exactly balanced by the backwards overturning moment of the crane. In that position, there should be very little force acting on the guide rollers or wheels. Once the balance of the crane has been determined it may not be checked again during the rest of the climb.

A1.8 During normal operation of the crane the balance point will be located in the centre of the mast. However, during a climbing operation the balance point for the crane will normally be at the rear of the mast since typically that is where the hydraulic cylinder is located. As the free height of the crane increases the mast may have a tendency to lean backwards slightly if the hydraulic cylinder is located at the rear. This may be taken into account in selecting an appropriate indication of the 'balancing' position; the manufacturer's instructions will normally explain how this is to be done.

Extending the hydraulic ram for climbing

A1.9 The ram of the hydraulic cylinder is then extended, lifting the top of the crane in order to create an opening large enough to admit the new mast section. Depending on the design of the frame, this may be done in one or more strokes of the ram using a temporary support beam between strokes. Hydraulic oil is fed under pressure to one side of the cylinder (the ram side) to lift the climbing frame and the other side (the annulus side) to lower it. Once the temporary beam is swung in place to support the weight of the crane top the ram is retracted and the hydraulic assembly is repositioned on the next set of climbing lugs so the rest of the climb can proceed (see paragraph A1.11). Eventually, a gap is created between the mast head and the uppermost mast section which is sufficient to enable the erectors to insert a new mast section through the opening in the front face of the frame.

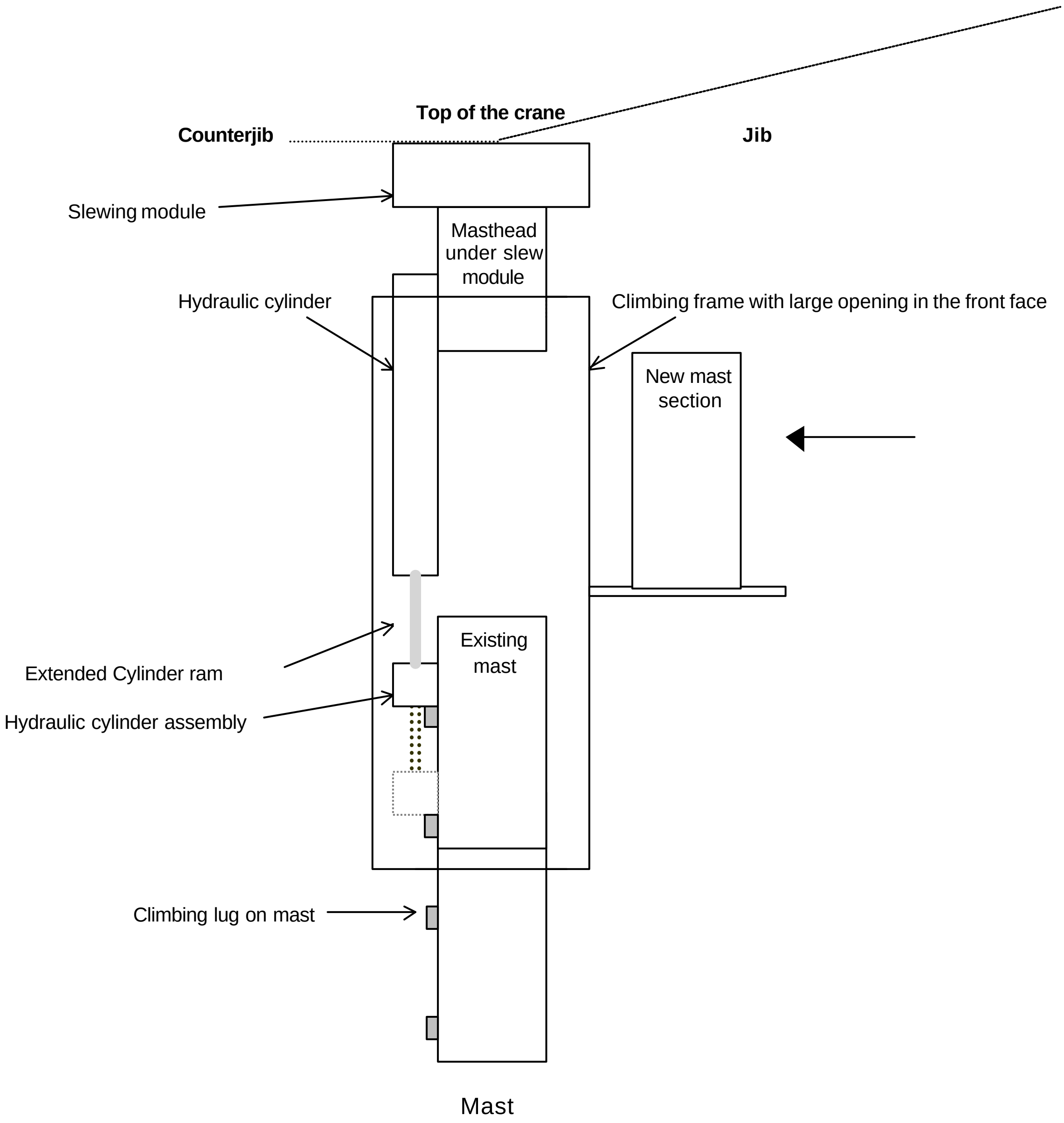
Inserting the new mast section

A1.10 When a new tower section has been moved into line above the top of the mast it has to be secured to the mast head. The erection team attaches the new section to the underside of the slewing module with temporary fixings; the new section is now suspended from the mast head. The crane top and new section are then lowered onto the top section of the mast and secured with permanent pins or bolts (depending on the design). In some designs, the temporary fixings may be slightly smaller than the permanent fixings. The temporary fixings give a little more flexibility than the permanent ones so it is easier to adjust the fit of the new section.

Preparing for a new climb

A1.11 Before the procedure can be repeated, the hydraulic cylinder assembly must be seated on the next set of climbing lugs (or other reaction point on the mast). The cylinder ram and assembly is retracted and held clear of the mast to prevent it fouling the lugs (where fitted). On some designs a specific device is used to hold off the cylinder assembly. When the hydraulic cylinder assembly has been seated on the higher climbing lugs and the fixings to the mast head checked the crane can be slewed, if necessary, to pick up the next mast section.

Schematic diagram of a climbing operation with a 2-stage ram



Details such as temporary support beam not shown

Annex 2 – Possible risks during climbing

Risks during assembly and dismantling of the climbing frame

A2.1 Information arising from investigations in Europe indicates that serious accidents have occurred because:

- a part-erected climbing frame has been disconnected from the lifting appliance before fully bolting it up and connecting it to the mast head or ensuring it was adequately supported by the mast e.g. on support shoes
- a platform (or other ancillary parts of the climbing frame) has become detached when not properly secured in place.

Erectors may also be at risk of falling from walkways or ladders during the assembly or dismantling process and people at ground level may be at risk from falling parts or tools.

Loss of support for the climbing frame

A2.2 The correct location of the hydraulic cylinder assembly on the climbing lugs or other reaction point on the mast will normally be critical. The mass of the crane top will have to be supported at this point and reaction forces transferred to the mast during the climb. Similarly, any support beam or shoe used to hold the top of the crane temporarily between strokes of a multi-stage cylinder should be deployed in the correct position.

A2.3 If it is possible for the cylinder assembly or support beam/shoe to be misplaced (or accidentally displaced) during a climb the consequences might be serious. Displacement of a cylinder assembly from the climbing lugs could occur for example if the hydraulic ram is mistakenly retracted at a point in the climb when the top of the crane is being temporarily supported by the new mast section. That may occur unintentionally if the new mast section is misaligned when it is lowered onto the top of the mast (see paragraphs A2.9-A2.10)

Risks from wind loading

A2.4 Climbing of tower cranes is usually required where tall structures are under construction. The wind speed and direction can vary significantly in time and position around the construction site and neighbouring structures. Manufacturers or suppliers will normally specify a maximum wind speed for climbing. If the wind speed is substantially greater than the specified maximum at critical points in the climbing cycle the wind loading on the jib could give rise to an overturning moment sufficient to cause failure. Anticipation is the key. In some circumstances, strong gusts of wind in the middle of a climb might be give rise to substantial loading on the climbing frame unless the erection team can take rapid action.

Alignment and slewing of crane jib

A2.5 There may be a risk of structural overloading and failure if:

- the jib of the crane is not correctly aligned with the front face of the mast before climbing begins; or
- the crane is slewed at any stage during the actual climbing operation, either inadvertently (e.g. by wind loading) or deliberately.

Information available from the Occupational Safety and Health Administration report into the 1998 San Francisco accident suggests that the immediate cause of that accident was probably the failure of the mast as a result of the crane slewing while a new mast section was being fitted. It was postulated that the erection team had attempted to slew the crane in order to make it easier to push a new mast section into the opening in the climbing frame. However, it cannot be stated with any certainty why the crane was slewed as all the erection team were killed in the incident.

'Balancing' the crane

A2.6 The climbing instructions provided by different manufacturers suggest that when a crane is in true 'balance' the guide rollers or wheels should exert no significant force on the mast. However, it appears that normally the 'balance' is only checked at the start of the climbing cycle (and then indirectly) by checking the alignment of the mast head and mast. The fixings holding these two sections together are removed and the two sections are parted by a few centimetres. There seems to be the potential for significant variation in setting this balance point. The erection team may not keep to the supplier's recommended balancing radius for a variety of reasons including:

- the existence of temporary wind effects
- the mast not being vertical
- the balance weight specified by the supplier not being available or not in use because of space restrictions on site
- variations in judgement about the correct alignment of the two sections.

A2.7 If the 'balancing' operation is carried out when the wind is blowing, the crane radius may have to be adjusted to counteract the wind loading on the jib. Any subsequent change of direction in the wind during the climb may affect the 'balance' of the crane. Obviously, the effect on 'balance' would be most pronounced when the change of direction approaches 180 degrees. The greater the wind speed the greater the change in wind loading on the crane jib and the potential out-of-balance forces acting on the climbing frame and mast. If the wind is blowing strongly, the out-of-balance forces may give rise to substantial loads on the mast or climbing frame. These forces might be sufficient to cause an overturn.

Structural failure

A2.8 The San Francisco incident also showed that a crane mast might be subject to overload by reaction forces from the climbing rollers or wheels under certain conditions (see paragraph A3.8).

Misalignment of the new mast section

A2.9 There is potential for problems when trying to move the new mast section into the climbing frame and fitting it to the mast head and mast. If the erectors have difficulty aligning the new mast section various measures may be adopted to get the section to fit, which might affect the crane balance.

A2.10 If the new mast section is misaligned when presented to the top of the mast and corrective action isn't taken the mast head (and the top of the crane above it) could be left resting on top of the mast without proper engagement. In that case, there would probably be no load on the hydraulic cylinder. This could be a highly dangerous situation. The unloaded cylinder assembly could become unseated from the climbing lugs and the mast head would no longer be restrained. Also, the balance point of the crane could then shift from the line of the hydraulic cylinder to the centre of the mast. The backwards overturning moment might then increase significantly. The use of smaller diameter temporary pins to secure the new mast section to the mast head may exasperate this problem.

Hydraulic hammer

A2.11 Normally a check valve will be fitted into the port supplying the ram side of the double acting cylinder to prevent hydraulic oil escaping from the cylinder and the climbing frame it supports failing in the event of a pipe burst. However, the check valve can cause problems with erratic oil flow leading to unexpected and sometimes uncontrolled movements of the load. To lower the climbing frame the check valve has to be opened. The check valve will only open and let out oil out of the ram side of the cylinder when oil pressure is applied to the other (annulus) side of the cylinder. If, due to the weight of the climbing frame, the oil on the ram side is forced out quicker than the oil can flow in on the annulus side of the chec k valve will snap shut. Once the valve is shut it stops flow out of the ram side and allows pressure to build up again on the annulus side and the cycle is repeated. The result could be violent bouncing of the climbing frame as it judders down subjecting the climbing system to dynamic loading.

Fit of climbing frame

A2.12 If the tolerance of the fit between the climbing frame and mast sections is not well controlled during manufacture or the frame is not well maintained there might be a risk, in extremis, that the guide rollers or wheels can become displaced from the mast, with potentially serious consequences.

Lifting operations

A2.13 There would appear to be risks associated with lifting the climbing frame, during which the jib of a luffing crane will be at a very steep angle. In addition, there are conventional risks associated with lifting loads such as the climbing frame or new mast section.

Risk of falls of people or materials

A2.14 Erectors can be at risk of falling when uncoupling lifting tackle from the climbing frame and new tower sections. Also, the erection team use external working platforms, walkways or ladders built around the climbing frame to prepare for a climb. If platforms are not provided with robust edge protection (e.g. guardrails and mid-rails) and ladders are not in protected positions the erectors may be at risk of falling. There will also be a risk to those at ground level from items such as pins, bolts, hammers and other tools accidentally dropped by the erection team.

Cumulative risk of failure/overturning

A2.15 The effects mentioned in paragraphs A2.4-A2.12 might be additive in some circumstances increasing the risk of failure of overturn.

Annex 3 - Issues relevant to the safe use of climbing frames on tower cranes

A3.1 Designers, manufacturers, suppliers and users should reflect on the risks indicated in Annex 2. It is suggested that, in developing appropriate control measures, the issues set out in this Annex ought to be considered.

A3.2 In general, safe operation of external climbing frames is best achieved by:

- design and construction to current best practice, identifying critical steps and taking full account of all foreseeable operating conditions, misuse or errors;
- thorough initial and periodic examination and inspection and regular maintenance programmes;
- safe assembly and operating procedures taking account of site conditions;
- use of competent personnel trained in the use of these operating procedures.

Design considerations - general

A3.3 Designers of climbing frames (and designers of cranes intended to be used with climbing frames) should take account of all relevant forces likely to act on the climbing frame, hydraulic cylinder, guide roller or wheel and housings, support beams and the mast during all reasonably foreseeable operating conditions. HSE considers that the relevant forces may include:

- the dead load of the slewing module and crane top to be supported by the climbing frame and its hydraulic cylinder
- foreseeable eccentric loading of the hydraulic cylinder rod during use
- out of balance loading
- dynamic loads
- fluctuating loads (associated with a risk of fatigue cracking)

Design features may reduce some of these forces, for example dynamic forces arising from hydraulic hammer could be reduced by load control valves such as a counterbalance valve but consideration would need to be given to calibration and maintenance to preserve initial integrity.

A3.4 Out of balance' forces acting on the climbing frame and crane mast could be influenced by such factors as:

- errors in achieving a 'true' balance of the crane prior to the start of climbing taking into account wind speed and direction at that time
- frictional effects at the guide rollers or wheels
- variations in wind speed and direction during climbing
- lack of verticality of the mast
- deflection of the mast with increased free standing height above the highest tie to the structure
- movement of the new mast sections (and even the erection crew) from the front of the mast into the climbing frame

A3.5 There should be a sufficient appreciation of the effects of wind speed and direction. Operating instructions will need to specify the usual jib radius to achieve balance, with or without an added balancing weight. It appears to be calculated assuming still air. Designers will wish to check that the assumptions made in their calculations are met under operating conditions e.g. the actual weight distribution of the crane top.

A3.6 Designers should recognise that many of these forces are likely to be additive. All foreseeable forces should be taken into account together with a material factor when assigning an aggregated safety factor to the climbing frame. Some of the effects are easy to calculate or infer from design codes; others may be less determinate and will need to be assessed e.g. roller or wheel friction, balancing error and dynamic amplification. In assigning an appropriate safety factor, designers should take into account the intended function of the climbing frame, which involves both the lifting of plant and people. Key technical design information and drawings ought to be readily available, making clear the assumptions about foreseeable loading and the tolerance of the fit between the climbing frame and mast of the crane.

A3.7 Designers will need to comply with relevant codes and standards and follow accepted practice to limit the stresses in members of the climbing frame and guide roller or wheel assembly so ensuring an adequate margin of safety is maintained. They should also specify appropriate materials for structural components and ensure that the design limits deflections of the frame to maintain alignment between parts.

A3.8 Information available from the Occupational Safety and Health Administration report into the 1998 San Francisco accident suggests that the vertical distance between upper and lower sets of guide rollers or wheels could be critical. The report suggested that the magnitude of the reaction forces on the mast increases as the vertical distance between the guide rollers/wheels decreases. It appears that the number and position of the guide rollers or wheels can also have an effect on frictional forces, tolerance of dimensional imperfections and resistance to rotational forces acting on the mast. Rollers or wheels acting on the faces of mast members may give rise to greater frictional forces when they act on the faces of the main mast members but may offer less resistance to rotational forces when they act on the corners of those members. For these reasons, manufacturers should carefully consider the number, positioning and distance between guide rollers or wheels.

A3.9 Monitoring data available to the erection supervisor during climbing is clearly important. Therefore, designers should consider what information could be provided to the supervisor on the state of key parameters during all stages of the climbing operation. The supervisor would normally have direct readings of the wind speed at the crane top and hydraulic pressure in the cylinder. Additional information that might be critical could include:

- the reaction forces on the mast and thus imbalance (and its direction) which could be assessed by using load cells on the axles of guide rollers or wheels, for example
- a clear and accurate indication when the crane is square to the mast (zero degrees of slew)
- the verticality of the mast prior to the start of climbing

A3.10 The designer should calculate the maximum values of all the critical parameters and consider what practicable steps could be taken (for example warning devices) so the supervisor is aware of the need for corrective action to preserve an adequate margin of safety. Consideration should be given to the best location for monitors and displays in order to minimise errors.

A3.11 Designers and manufacturers should consider how the erection supervisor can monitor the correct positioning of the climbing frame for example to check that climbing lugs or support shoes are properly engaged. It might be feasible to use pins which could only be inserted when the lugs or shoes have been positively engaged.

A3.12 The erection supervisor needs to know that these features have been maintained in position during a climb, in particular that the cylinder assembly remains fully seated on the climbing lugs (or support shoes) at all times.

A3.13 Effective measures are needed to avoid the deliberate or inadvertent slewing of the jib during climbing as that can jeopardise the crane. Suitable arrangements might include the provision of a positive locking device to prevent unintentional slewing and interlocking the slewing motor with the power supply to the hydraulic motor of the cylinder. HSE understands that some of the interlocking devices provided on cranes are easily damaged and can be bypassed by hard wiring the hydraulic cylinder motor into the crane's electrical supply. This suggests that any interlock needs to be of robust construction and difficult to bypass.

Design considerations – risk of falls from walkways, platforms and access ladders

A3.14 Designers should ensure proper consideration has been given to preventing falls from access walkways, platforms and ladders. Protected ladders and suitable edge protection in the form of robust guardrails and mid-rails will often be feasible to prevent accidental falls. Normally, reliance should not be placed on erectors using fall protection equipment such as safety harnesses. If it is not practicable to provide adequate edge protection in specific circumstances designers should specify suitable fixing points for fall protection equipment.

Design considerations - operating instructions

A 3.15 Clear operating instructions (in the appropriate language) should be provided to the crane operating company covering the safe use of the climbing frame and the actions to be taken in the event of an emergency. The instructions should indicate the types of crane with which the climbing frame can be used and should go through each important step of the climbing operation, and transportation, assembly and disassembly of the climbing frame. Erectors need to know about any steps in the climbing operation that may be critical. These steps are likely to include:

- the 'balancing' procedure
- the correct location of the hydraulic cylinder assembly, support shoes or intermediate support beam on the mast
- checking key limiting parameters such as wind speed and direction, maximum free standing (i.e. unrestrained) crane height and mast verticality

The consequences of error should be made clear.

A3.16 The operating instructions should state clearly the normal radius for balancing with different configurations of balance weight, jib length and crane type (saddle or luffing jib). It would also be advisable to explain what action should be taken if a critical condition occurs during climbing, in order to achieve a safe recovery. One condition the erection crew may have to confront during a climb is a sudden increase in wind speed beyond the maximum permitted. What should they do in these circumstances? Information on recommended site inspection, maintenance, examination and testing regimes would also be valuable.

Certification of training by suppliers

A3.17 Clearly, the erection supervisor is a key person and must be competent in the assembly, use and disassembly of the particular type and model of climbing frame concerned. Other members of the team may have important roles in ensuring the safety of the climbing frame as well. It is recognised that there are significant variations between the detailed designs of different types of climbing frame. Therefore, given the specialised nature of climbing, it may be desirable for suppliers to offer certified training for their different types of climbing systems. Such training could include a practical assessment of competence.

Manufacture of the climbing frame

A3.18 It is expected that the manufacturer uses a quality system to ensure that the climbing frame parts are made to the design specification. Manufacturers will need to be satisfied that the materials used in the construction of the climbing frame are suitable for the design specification. However, the complete climbing frame ought to be subject to a thorough examination by a competent person before first use.

Operational considerations - assessing operational risks

A3.19 The crane operating company responsible for using the climbing frame should carry out a hazard identification and then evaluate the risks to their erectors. High consequence low probability events (such as falls from work platforms, failure of the climbing frame during assembly or failure of a guide roller or wheel during use) need to be considered as well as more probable events such as dropped tools. The aim should be to eliminate the possibility of these events occurring. If that isn't possible steps should be taken to reduce the risk as far as reasonably possible. **Annex 2** indicates possible risks which might arise during climbing of a tower crane.

A3.20 If the crane operating company needs to adapt the crane in order to use the climbing frame (e.g. by removing or adapting some of the mast fixings) the risk of weakening the crane should be taken into account. The company will need to consult the manufacturer or a suitably qualified engineer to ensure that the crane is suitable for this method of erection.

A3.21 The crane operating company should carry out a risk assessment as part of the preparation for any site work. This assessment should take account of local conditions. Issues to be considered could include:

- access routes for vehicles and people including highways, railways, rivers and air paths
- ground bearing capacity
- free unloading & storage areas (e.g. for the climbing frame and new mast sections)
- segregation of the work area from other construction activities and public spaces
- proximity hazards such as adjacent cranes, overhead electric lines, underground services, nearby structures and stacked materials
- local arrangements for obtaining detailed weather forecasts for the site
- the maximum wind speed to be permitted and likely variations in wind speed and direction in that location
- the specification of ties to the structure and likely effect on verticality and unrestrained mast height
- arrangements for communication; and
- the principal contractor's site rules.

A3.22 Control measures to deal with significant risks should preferably focus first on engineering controls rather than management systems and systems of work as these have the potential for human error. Also, priority should be given to control measures which protect all workers rather than individual protective equipment e.g. safe places of work with adequate guardrails rather than reliance on the provision of personnel fall protection. If fall protection has to be used, consideration will need to be given to safe deployment, use and examination of the equipment and to safe recovery of personnel in the event of a fall.

A3.23 If it is necessary to rely on systems of work rather than engineering control measures the consequences of human error (either by action or inaction) should be considered and minimised as far as possible. The crane operating company should ensure that human error is minimised for example by paying proper attention to such issues as lighting conditions, fatigue etc.

A3.24 The erection team might be at serious risk if an emergency arises during a climb (e.g. the wind speed exceeds the maximum permitted or there is a sudden loss of hydraulic pressure or electrical power). What control measures should be taken by the erection crew in these circumstances to return the crane to a safe condition? These events should be taken into account in the crane operating company's assessment of risk. Contingency arrangements should be developed for dealing with such events.

Information, competence and supervision

A3.25 The risk assessment should inform the planning process for each climbing job at a site. The assessment, taken together with the climbing instructions provided by the manufacturer or supplier, should then be used to develop a detailed statement of work procedures (method statement) for the safe transportation, assembly, erection, use and dismantling of the climbing frame at that site.

A3.26 The erection team should be made up of suitably trained and experienced personnel; formal assessment of their competence would help to confirm their suitability. To be effective the method statement needs to specify clear roles for each member of the team. The erection supervisor in charge of the climbing operation should have sufficient authority and experience of using the specific type of climbing frame. Arrangements for effective communication among the team (and if necessary with adjacent crane drivers in case of danger) should be available.

A3.27 The climbing operation would normally be under the general supervision of an experienced crane co-coordinator who has the authority to stop the work if local conditions are unsatisfactory. This individual could see to it that the erection team are inducted in the general site precautions and the specific features of the method statement at the start of the job. It is sensible to give a copy of the method statement and the associated operating instructions to all those involved in the planning of the climbing operation. The method statement should be sufficient to provide the basis for a briefing or induction of each member of the erection team. The crane co-coordinator or principal contractor's representative would normally take the opportunity during the site induction to seek the views of the erectors about any arrangements for health and safety that may be relevant to them.

Specific operating procedures to be addressed

A3.28 The procedures covered by the method statement and climbing manual might usefully address the risks mentioned in Annex 2, including the:

- transportation of the climbing frame to and from the site and its offloading/loading
- safe assembly of the frame around the crane mast to avoid collapse or dislodgement of any part
- positioning of new mast sections on the ground to avoid or minimise the need to slew the crane between climbs

- positive inspection of the assembled parts of the frame by a competent person to check on safety critical features such as the tightness of bolts, the correct location of the guide rollers or wheels and the absence of damage
- establishment of a suitable exclusion zone to protect others
- arrangements for obtaining site-specific weather forecasts at relevant heights and for measuring real-time wind speed and direction
- responsibilities for monitoring other safety critical parameters including crane jib alignment, actual jib radius and permitted free height of the crane
- arrangements to prevent deliberate or inadvertent slewing during climbing e.g. by ensuring that any interlock for the power supply is in sound condition, the slew brake is correctly engaged and any positive scotch or other device to prevent inadvertent slewing is in place
- checks on the positive engagement of the hydraulic ram assembly on the mast (pins and lugs or support shoes) and the means of preventing disengagement during climbing
- checks to ensure that moveable parts have been secured before a climb, e.g. any temporary support beam or a trolley which allows the hydraulic ram assembly to be moved clear of the mast during setting up
- arrangements for providing a suitable balance weight (where indicated in the climbing instructions)
- procedure for balancing giving permitted tolerances from the balancing radius specified in the operating instructions and other parameters such as wind speed
- temporary fixing of mast sections and permitted arrangements for overcoming fit problems to move new mast sections into position
- contingency arrangements for recovering from emergencies during climbing and leaving the crane and climbing frame in a safe position
- safe dismantling of the frame.

A3.29 It would seem sensible for the erection supervisor to make formal checks of each key step in the procedure, positively confirming with the erection team (or by checking any monitors provided) that safety critical steps have been achieved.

A3.30 The crane operating company should assess the adequacy of the edge protection provided on access and working platforms by the manufacturer. If the edge protection is inadequate to prevent falls the crane company should consider taking up the issue with the supplier. If better protection is not feasible, reliance may have to be placed on the use of fall protection equipment. In that case, there should be an adequate system for training the operatives in the use of the equipment including checking anchorage points and proper inspection of the equipment before each use and at regular intervals.

A3.31 The working procedure might need to specify the use of lanyards or other means to prevent the accidental fall of tools such as wrenches and hammers.

A3.32 The arrangements for inspecting the mast and also testing and examining the crane after climbing has been completed should be explained to all concerned.

Examination, test and maintenance

A3.33 Climbing frames should usually be subject to initial thorough examination, unless there is certificate of conformity showing that it satisfies relevant safety requirements as supplied.

Thereafter, the climbing frame will need to be inspected before each use and subject to periodic thorough examination and inspection at appropriate intervals (e.g. every 6 months) or in accordance with a written scheme of examination.

A3.34 There should be a routine maintenance schedule for climbing frames in accordance with advice from the manufacturer with supporting records.

Other information

The following sources of information may be relevant:

- British Standard CP 3010 : 1972 Code of Practice for Safe use of cranes [mobile cranes, tower cranes and derrick cranes].
- British Standard BS 7121: Part 1 Code of Practice for the Safe Use of Cranes - General 1989
- British Standard BS 7121: Part 2 Code of Practice for the Safe Use of Cranes – Inspection, thorough examination and testing of cranes 1989 (under revision)
- British Standard BS 7121: Part 5 Code of Practice for the Safe Use of Cranes – Tower Cranes 1997
- HSE guidance note - Plant and Machinery/3 November 1976 - Erection and dismantling of tower cranes.
- The Lifting Operations and Lifting Equipment Regulations (LOLER) 1998 SI 1998/2307
- Machinery Directive 91/368 (as amended) essential health and safety requirements and Supply of Machinery (safety) Regulations 1992 (SI 1992/3073 as amended by SI 1994/2063)
- http://www.mee-inc.com/tower.html (summary of the San Francisco incident)
- http://www.workcover.vic.gov.au/vwa/home.nsf/pages/so_construction_general (summary of the Australian incident)