

Training documents

Influence of wind on crane operation



LIEBHERR

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When the wind blows.

Wherever people are working, mistakes are made. With crane operation the wind conditions can present a potential danger that should not be underestimated. The crane driver must ensure that the crane is not exposed to any wind that could exceed the limits set by the crane manufacturer. It is also necessary to make the correct decisions and implement the correct measures at the right moment to ensure that the crane will never become unstable due to wind influences.

If there is a danger then the crane driver must implement the actions that have been defined by the contractor. Thus the crane driver decides in emergency situations on-site, whether the wind is too strong and the work must be halted. It is therefore important to be warned about prolonged and large-scale gathering storms in good time. Especially dangerous however are localised squalls, which can arise in conjunction with heavy showers and thunderstorms for example.

This training document serves to inform crane drivers, project planners and also crane companies and should provide examples of handling options for crane operation in windy conditions. To start we will introduce you to the basics of wind loads. As we proceed we will show how wind loads and finally special load cases, such as when erecting wind-power turbines, can be calculated. Likewise we will show you what information is required for this.

We have designed this documentation such that the reader can acquire the relevant information through self-study in accordance with their level of knowledge. Examples and problems serve as illustrations and provide the opportunity for practice. Furthermore, you can find useful advice and aids for day-to-day work with the crane. The training documentation does not claim to be complete and does not replace the operating instructions and the load chart book for the Liebherr crane in question. We can only urge caution here when working with heavy plant and offer our forty years plus experience as a leading manufacturer of cranes.

Liebherr-Werk Ehingen GmbH



How should you work with this document ?



Character explanation

Questions on course material in the previous paragraph.
(Compare your own answers with the solutions at the end of the document)



Important note / information about current topic.



Designates a dangerous situation about current topic.

Note:

The left and right margins of every page serve for making your own notes on the course topic. These personal notes should serve to assist with understanding and repetition, along with those already provided.

Working instructions:

- First read through the text of a chapter carefully.
- Reprise the content of the chapter with the help of the printed notes and your own notes in the margins.
- Answer the questions posed at the end of the chapter (without referring back if possible).
- The solutions to all questions can be found at the end of the document.
- If you are not able to answer the questions without referring back to the text then work through the chapter once again.
- Only then should you move on to study the next chapter.
- At the end of the document check to see if you have achieved the study goals listed here.

Study goals:

After having worked through this document you should:

- Know the various influences of the wind on crane operation.
- Be able to name the terms for wind force calculation.
- Be able to calculate the wind load for a standard load case and a special load case.
- Be able to calculate the maximum permissible wind gust speed.



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Term definitions

N	Newton (Unit for the force)
C_w	Wind resistance factor (Drag coefficient)
A_p	Projected surface of a body (m ²)
A_w	Surface area exposed to wind (m ²)
v_{max}	maximum permissible 3 second gust speed (m/s) at maximum lifting height.
v_{max_TAB}	maximum permissible 3 second gust speed (m/s) for maximum lifting height, which are specified for the load values in the load chart.
v_{act}	Actual measured wind speed
$v(z)$	The average value for the wind speed over a period of 3 seconds at a height of z above the ground (m/s).
p	Dynamic pressure (pressure on a body as a result of wind exposure in N/m ²)
F_w	Wind load (Influence of force on a body as a result of wind exposure)
m_H	Hoist load (t) (incl.fastening equipment and hook block and possible hoist rope section). The hoist load may reach no more than the maximum chart value of the load chart.



Every description of the wind speed in this document always refers to the wind gust speed, as this is always higher than the normal wind speed. As a result, the wind gust speed must always be used as the basis for the calculation.



Influence of wind on crane operation

1. Introduction and presentation of problems

Often wind and occurring gust of winds are an underestimated factor in accidents with mobile cranes or crawler cranes. When lifting loads with large surfaces exposed to wind such as rotor blades or complete propeller units for wind power plants (WPP) the standard values provided by EN 13000 (see appendix chapter 7.3), which are the basis for the crane calculations, can be significantly exceeded.

Such standard values are the so-called **wind resistance factor** (c_w) for example or the value for calculation of the so-called **projected surface area** of a load. Both values together provide information about the force over the actual **surface area exposed to wind** of a load. In the case of large surface area loads (special load cases) in particular, the wind speeds given in the load charts can be inapplicable for the crane work. A new lower wind speed, compared with the original permissible wind speed, must be calculated for this special load case.

Wind influence on the load

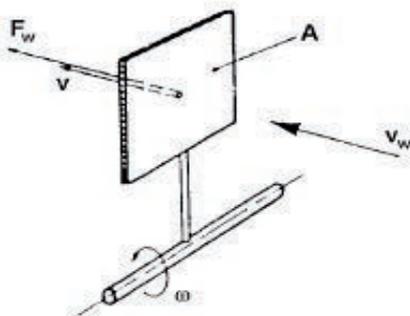


Fig. 1: Resistance principle

What role does the wind play in the exceedance of these standard values?

If wind meets a surface then it exerts a force on this surface (**resistance**) that works in the wind direction.

Resistance principle

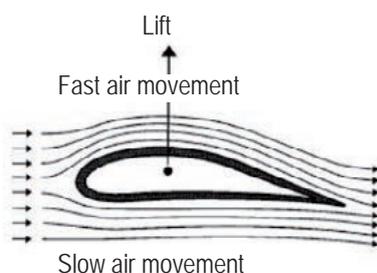


Fig. 2: Lift principle

So-called **lift** additionally applies in the case of an aerofoil or a rotor. The surface/length of the upper side of an aerofoil is larger than the underside. The air on the upper side must therefore move faster than the air on the underside. This causes under-pressure on the top side and over-pressure on the underside. As a result of the lift arising from this the aerofoil is pressed upwards.

Lift principle

The force of the wind thus creates a load. This can be an applied or relief load. The trigger for this is the so-called **resistance principle** and the **lift principle**.



1. 1 Wind influence on the crane and the load

This has a similar effect on the crane:



Fig. 3: Wind from front and rear



Fig. 4: Wind from the side



Risk of accident!

The wind from the front does not reduce the loading of the hook, hoisting cable, hoisting cable rollers and hoisting winch because the load continues to work with its gravitational force (see chapter 4.1.1). With wind from the front these assemblies can be overloaded through load lifting up to the load torque limiter (LMB) shut-off! The load reduction caused by the wind from the front can overload the complete crane with the boom guying, if it has been loaded up to the point of LMB shut-off beforehand! The crane driver must therefore know the weight of the load and must not exceed the max loading capacity!

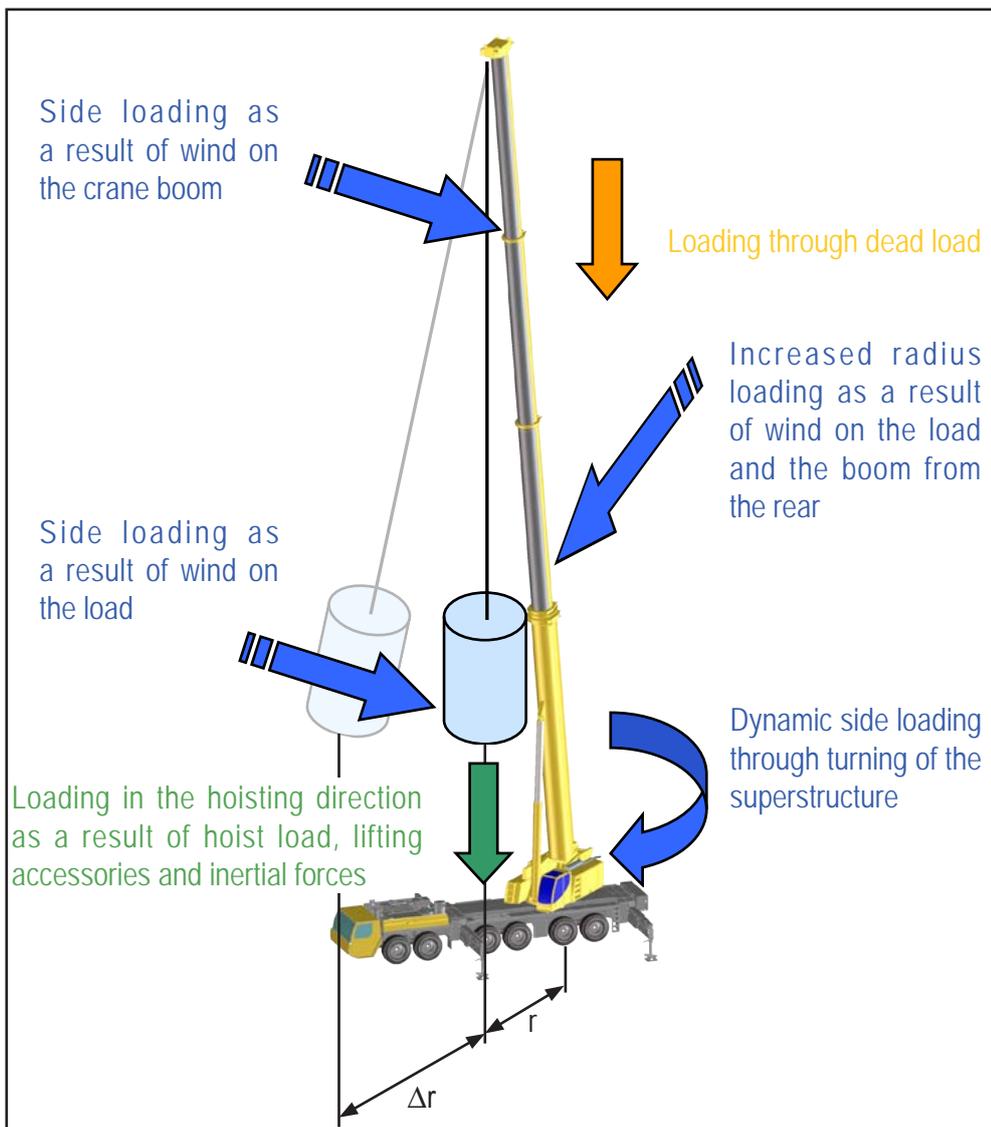


Influence of wind on crane operation

Wind from the side is particularly dangerous for the crane boom and the load. This is not determined by the LMB. This can result in the crane being overloaded.

The additional loading due to the wind from the side is not indicated by the load torque limiter (LMB).

Wind from the side



Possible loadings on the crane

r = Radius
 Δr = Increased radius through wind influence

Fig. 5: Loadings that can have an effect on the crane

If the wind hits the load then it swings in the direction of the wind. This means that the force of the load no longer acts vertically downwards on the boom. Depending on the strength of the wind, the surface area exposed to wind and the direction of the wind, the radius of the load may increase or impermissible lateral forces may act on the crane boom.

Wind influence on the load



Influence of wind on crane operation

Overview of wind hazards



	Wind from the front	Wind from the rear	Wind from the side
Boom	With wind from the front the boom system is relieved of load. The load indication is too low. The LMB shut-off actuates only with a load that is greater than the maximum permissible load capacity.	With wind from the rear the boom system is additionally loaded. The load indication is too high. The LMB shut-off actuates at a load that is less than the maximum permissible load capacity according to the load chart.	With wind from the side the boom system is side-loaded. The load indication is similar to the display when operating without wind. The LMB does not take side winds into account.
Load	The form and the deadweight of the load plays a large role with the influence of wind. The wind causes the load to swing and this in turn causes the crane boom to swing. This swinging (dynamic) of the boom causes the crane's loading to increase. In the limit range the LMB shut-off could be switching in and out constantly. With special loads such as with a rotor for example, the wind can have the effect of reducing the load due to the shape of the rotor.		

Unforeseeable factors

Superb crane quality and technology, many years of professional experience as well as good training of the crane driver and professional advance planning for the crane operation significantly reduce the risk of an industrial accident. However: Unforeseeable factors such as sudden gusts of wind are difficult and sometimes impossible to calculate accurately in advance. Terms such as surface area exposed to wind and wind projected surface area, c_w -value, gusts of wind, wind speed, wind load or roughness class will be discussed in the following.

What do these mean for crane operation in wind?

New calculation of the max. permissible wind speed

When planning activities, in particular in cases with large projected surfaces or high c_w -values, it is necessary to reduce the maximum permissible wind speed quoted in the load charts.

The person responsible for the crane operation must have basic knowledge **in the field of wind influence on crane operations. Likewise, this person must** be able to calculate the necessary reduction in permissible wind speeds for special load cases with large surface area loads.

The maximum permissible wind speed (v_{max}) and the maximum permissible wind speed in accordance with the load chart (v_{max_TAB}) relate at all times to the 3-second gust speed prevalent at maximum hoist height.



Influence of wind on crane operation

1. 2 Exercises

Exercise 1

What types of wind can have an effect on the boom? (Multiple answers possible)

- Wind load
- Wind energy
- Evaporation
- Wind from the rear
- Wind from the front
- Wind from the side



Exercise 2

Which types of wind have an effect on the LMB?

(Answer)

The LMB shut-off actuates at a load that is less than the maximum permissible load capacity according to the load chart.

(Answer)

Shut-off actuates only after a load that is greater than the maximum permissible load capacity.

(Answer)

There is no LMB shut-off.

Exercise 3

What effect does the wind have on the crane load? (Multiple answers possible)

- None
- The load can swing
- The load turns on the cable
- The radius of the load can increase



How does wind arise?

2. Wind basics

In this chapter you will learn the basics of how wind arises and you will obtain initial explanations for wind-specific terminology.

Wind is moving air. The movement arises through equalising flows resulting from different air temperatures and the pressure differences caused by this between high and low pressure areas.

The driving force of winds is solar radiation. It strikes the earth and its atmosphere with different intensities: Perpendicular at the equator and only tangentially at the poles. The earth and air masses at the equator heat up, the air becomes lighter and rises. Hot over the tropics, cold at the polar regions: It cannot remain like this as nature always seeks equilibrium. So the warm air - at the upper edge of the troposphere - flows to wherever it is colder.

On the way north the air loses so much of its heat that it eventually becomes heavy and drops to the ground cold. A circuit is completed: In the upper atmosphere warm air pushes towards the polar region. On the ground cold air flows back to the tropics as through drawn from a vacuum cleaner. The air transportation from the equator never reaches the pole: The rotation of the earth diverts it far to the side. It also causes the high and low pressure areas to rotate.

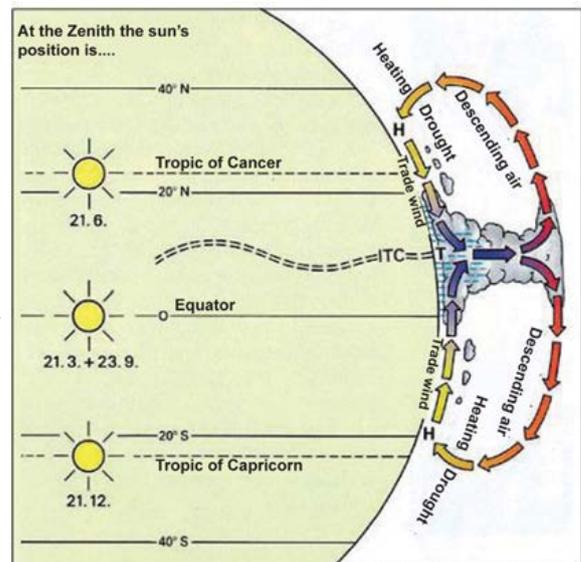


Fig. 6: The formation of wind

The highest wind speed measured in Germany to date was 335 km/h recorded on the 12th June 1985 on Zugspitze. This represents a computed Beaufort value of 23.1.

Beaufort (bft) is an "arbitrary" unit. It expresses the discerned effects of the wind. Beaufort (bft) however is directly related to the physically measurable wind speed. The following diagram shows the interdependency of wind speed and wind strengths.

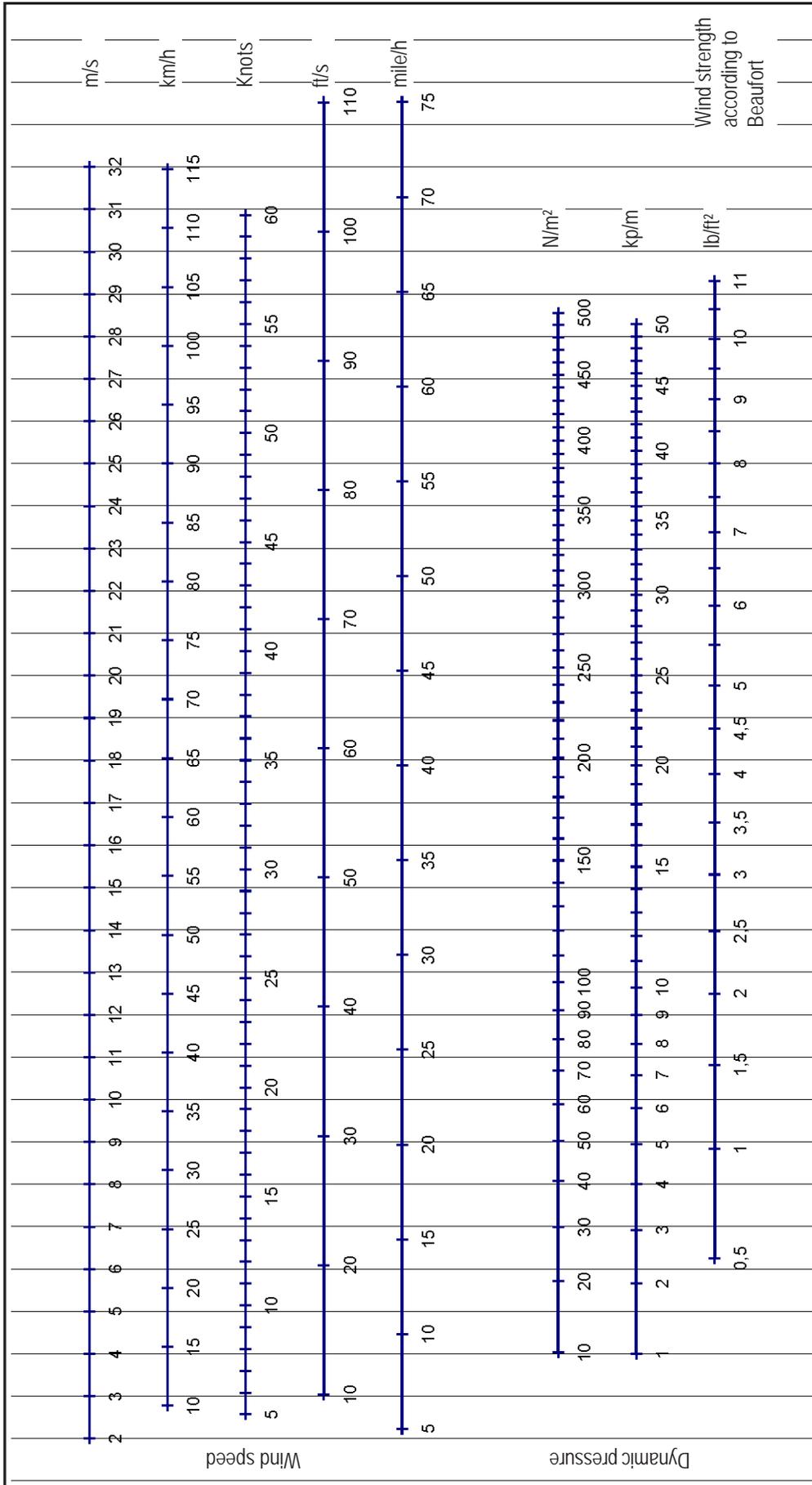


Fig. 7: Comparison of wind strength and wind speed

Wind strength diagram



What is a gust?

2. 1 Gusts and roughness

A strong flurry of wind that is active within a wind or storm system is known as a **gust**. People are surprised time and again when the weather reports speak of a wind of 33 km/h for example, as one has the impression that the wind is much stronger.

In reality with gusts we are dealing with a **flurry of wind** that is more powerful and independent of the average speed of the wind. So a gust of wind can reach 60 km/h or more whilst the average value lies significantly below this.

Gusts can therefore also be **very dangerous** as they occur suddenly and do not last long. Here the duration is not the problem but rather the sudden appearance of a much stronger air movement than the rest of the wind leads one to expect.

Thus gusts can lead to dangerous situations not only in road traffic.



Fig. 8: Bus turned over after a gust

Definition of a gust in accordance with EN 13000

The speed of a gust is the average value of the wind speed measured for a duration of **3 seconds**. The gust speed is higher than the average wind speed, which is measured over a period of 10 minutes.

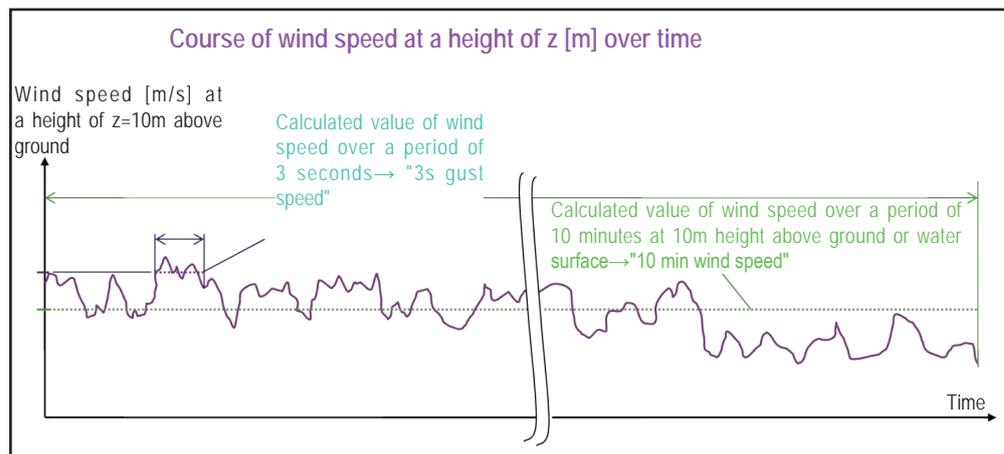


Fig. 9: Diagram showing wind gust determination

There are external factors, which can increase or decrease the wind gust speed:

- Buildings
- Narrow valleys and gullies
- Smooth water surfaces
- Height above ground

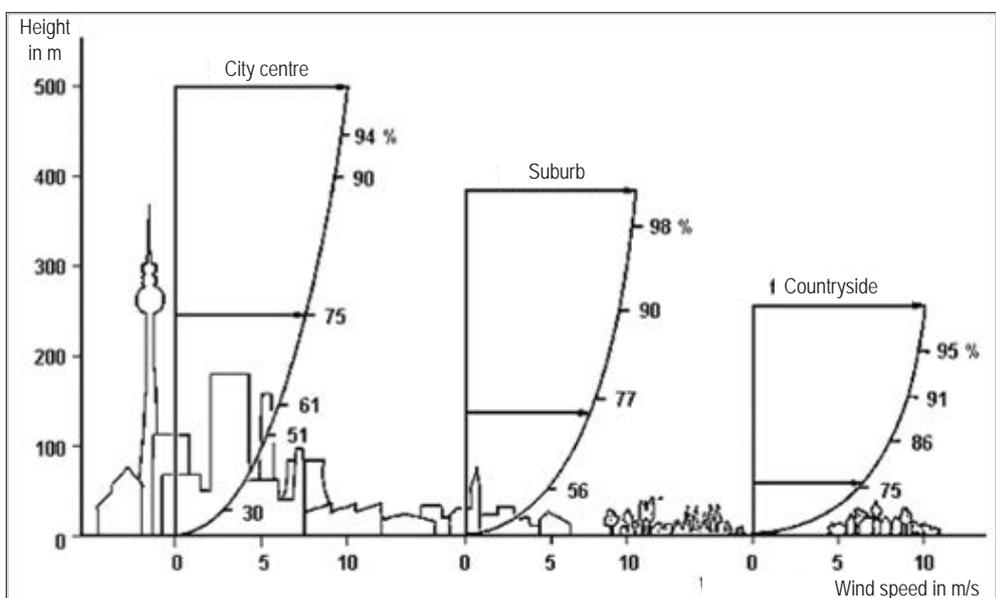


Influence of wind on crane operation

High above the ground, at an altitude of approx. 1 kilometre, the wind is hardly affected by the surface characteristics of the ground any more. The wind speeds in the lower atmospheric layers are reduced by ground friction. One differentiates between the **roughness of the terrain**, the influence of obstacles and the influence of the contours of the landscape, which is also known as the "orography" of the land.

The more pronounced the roughness of the terrain, the greater the reduction in the wind speed. Forests and cities naturally slow the wind appreciably, whereas across the concrete runways at airport the wind is only fractionally slowed. Smoother still are water surfaces, they have therefore an even lesser influence on the wind, whereas long grass, shrubs and bushes slow the wind considerably.

Behaviour of the wind at high altitudes



Wind speeds with different roughness classes

Fig. 10: Diagram of the various roughness classes

In the wind industry the technicians often speak of roughness classes when they are dealing with the evaluation of the wind characteristics of a landscape. A high roughness class of 3 to 4 is characterised by many trees and buildings, whereas the surface of a lake falls into roughness class 0. Concrete runways at airports fall into roughness class 0.5.



Influence of wind on crane operation

Roughness classes in over-view

Roughness class	Type of terrain surface
0	Water surfaces
0.5	Open terrain, smooth surfaces e.g. runways
1	Open terrain without fences and hedges, possibly with sparsely spread buildings and very gentle rolling hills
1.5	Terrain with a few houses and 8 m high hedges with at least 1 km clearance
2	Terrain with a few houses and 8 m high hedges with approx. 500 m clearance
2.5	Terrain with a few houses, bushes and plants, or 8 m high hedges with approx. 250 m clearance
3	Villages, small towns, terrain with many or high hedges, forests and very rugged and uneven terrain
3.5	Larger towns with high buildings
4	Cities with very high buildings

Table 1: Roughness class



The "nozzle effect" phenomenon

In cities with high buildings the roughness lies around 4 (see table 2). This creates the impression that the wind is not so strong there. However in large cities with high buildings there are also large urban canyons present. The air is compressed on the wind side of the houses and its speed rises considerably whilst it blows through the urban canyons. This phenomenon is known as the "nozzle effect".
If the normal wind speed in open terrain is 6 m/s for example, then in an urban canyon it can certainly reach 9 m/s.



Influence of wind on crane operation

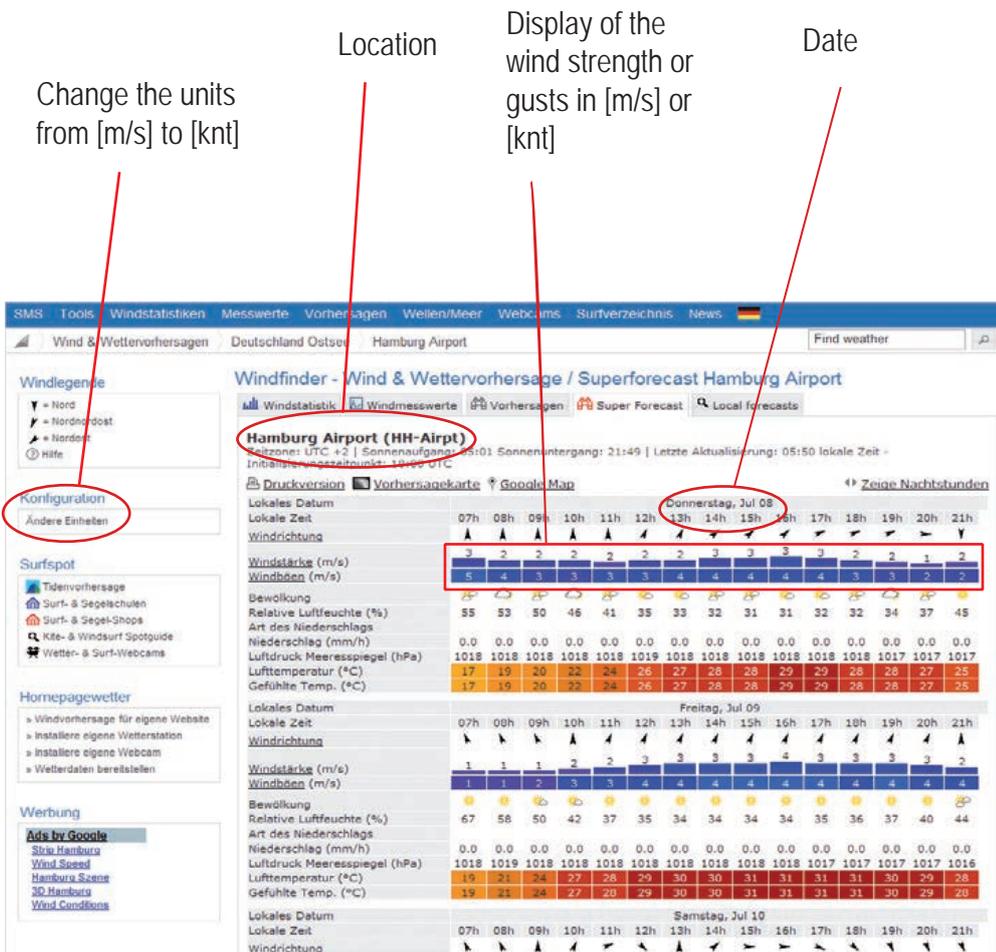
2. 2 Wind and weather information

With crane operation and especially when lifting loads with large surface areas the influence of the wind must certainly be observed.

Before starting work, the crane operator must determine the expected maximum wind speed at site by contacting the appropriate weather office. If impermissible wind speeds are expected, the load must not be lifted and the crane may not be erected.



Current weather data can be found on the internet (e.g. www.windfinder.com under the heading "Super Forecast"). Note with this that the gust speed, as in this example, is based on a height of 10 metres above ground.



Wind values from the internet

Fig. 11: Screenshot from www.windfinder.com

If the crane cannot be taken down at the job site when interrupting work, the occurring wind speeds must be obtained for the entire period of operation. The occurring wind speeds may not exceed the permissible wind speeds from the wind charts.





Influence of wind on crane operation

Height dependent
wind speed

2. 2. 1 Height dependant wind gust speed

The weather office normally provides the average wind speed for a period of 10 minutes and / or the corresponding wind gust speed, in each case in reference to a height of 10 m. Depending on which information is available, also other factors must be considered when determining the height-dependent wind gust speed. These are shown in the following chart.

If the weather office provides wind gust speeds for a height of 10 m, the factors in the blue column must be used to calculate the wind gust speed for the corresponding working height.

If however only wind speeds averaged over a period of 10 minutes are provided, use the yellow column. These factors can be used to calculate the wind gust speed at the available working height.

Working height	Factors for available wind speed determined over a period of 10 minutes at a height of 10 m	Factors for available wind gust speed determined at a height of 10 m
10	1,400	1,000
20	1,502	1,073
30	1,566	1,119
40	1,614	1,153
50	1,653	1,181
60	1,685	1,204
70	1,713	1,224
80	1,738	1,241
90	1,760	1,257
100	1,780	1,272
110	1,799	1,285
120	1,816	1,297
130	1,832	1,309
140	1,847	1,319
150	1,861	1,329
160	1,874	1,339
170	1,887	1,348
180	1,899	1,356
190	1,910	1,364
200	1,921	1,372

Table 2: Factors for determining the height-dependent wind gust speed on the basis of the wind / gust speed at a height of 10 m

Example

$$6.2 \text{ m/s} \times 1.272 = 7.89 \text{ m/s}$$

The weather office indicates a gust speed of 6.2 m/s at a height of 10 metres above the ground.

You have, for example, a max. working height of 100 metres. According to the calculation (see left) the wind gust speed at a height of 100 m is 7.89 m/s. With a maximum permissible gust speed of 9 m/s, the load hoist can be performed according to the load chart.

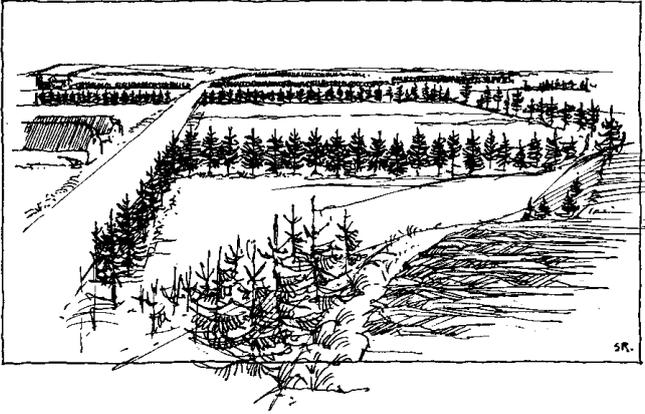


Influence of wind on crane operation

2. 3 Exercises

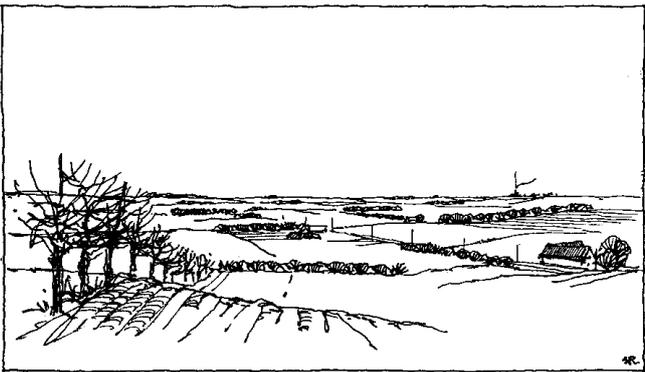
Exercise 4

Determine, with the help of table 1: Roughness classes that correspond to the roughness in the two pictures below!



Answer:

Fig. 12: Determine the roughness class!



Answer:

Fig. 13: Determine the roughness class!

Exercise 5

What do we understand by a "gust", per EN 13000?

- Weak wind caused by a difference in air pressure
- Short severe flurry of wind**
- Severe flurry of wind higher than the average wind speed, over a period of 3 seconds**

Exercise 6

Use "figure 11" (page 17) and "chart 2" (page 18) to determine what the wind gust speed is at the Hamburg Airport on July 9 at 3 pm at a height of 140 metres.

Answer:

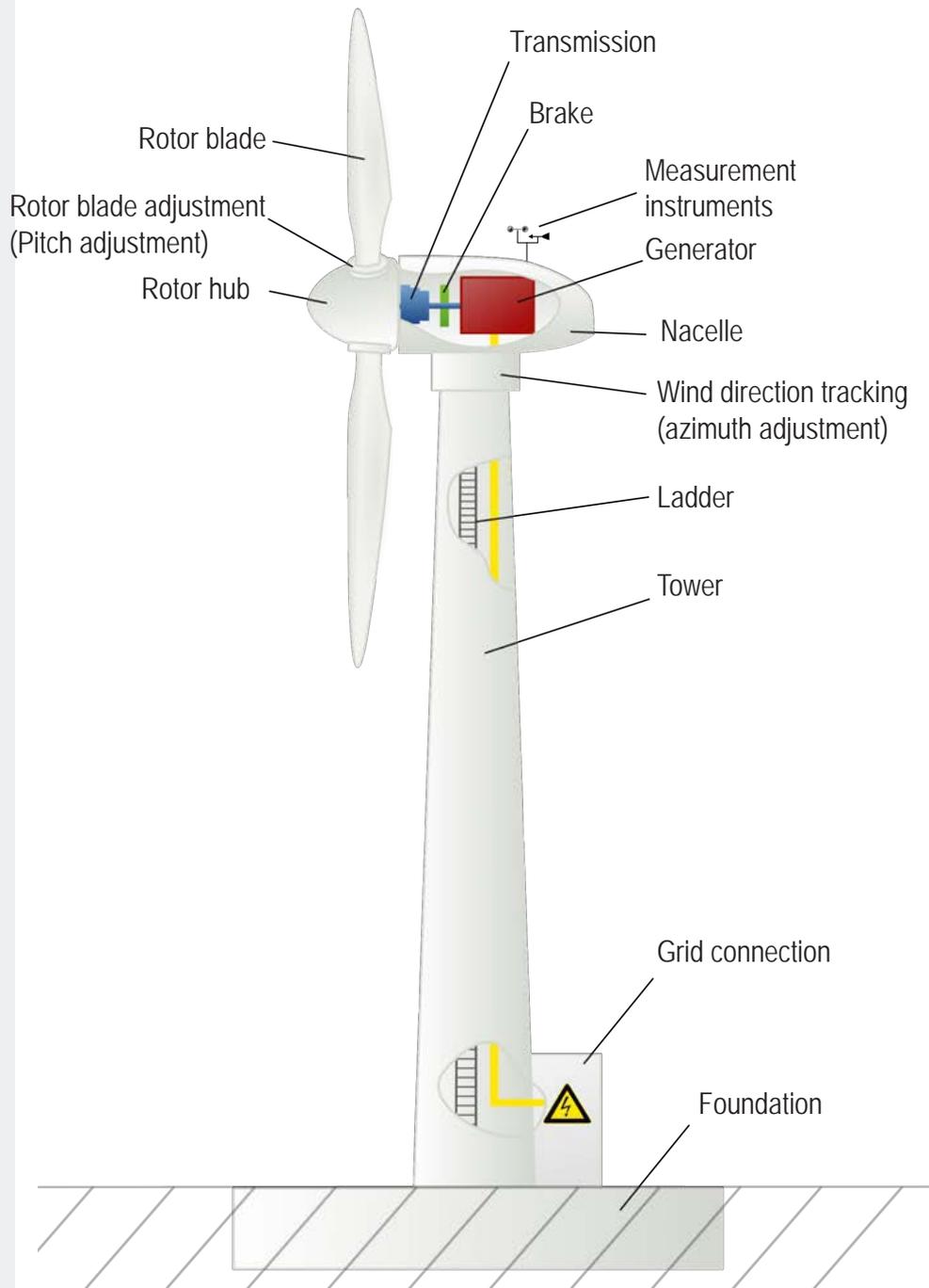


3. Digression – Wind power turbine schematic

In this chapter you will learn about the schematic construction of a wind power turbine. Likewise we will show you how wind speeds behave at various different heights above ground.

The use of wind energy has been known for centuries. The development of increasingly powerful **wind power turbines** is being encouraged. The height of the towers upon which the turbine are being driven, is growing. New systems are breathtaking in their size. With a hub height of up to 135 metres the rotors turn with a diameter of 126 metres. By comparison: The wingspan of an Airbus A380 is just under 80 metres.

Component parts
of a wind power
plant





Influence of wind on crane operation

Whether individual wind power plants or complete wind farms are erected, these are usually installed where the wind blows strongest. Every extra meter higher into the atmosphere that they can push is rewarded with better output. When considering the vertical **subdivision of the atmosphere** only its lower layer is suitable for exploitation of wind energy. This is due to the composition of the lowest air layers. With rising height the roughness of the ground has less influence on the wind speed. Therefore the wind blows more smoothly at high altitudes and is beset with significantly less turbulence. This fact is of great use to the manufacturers of wind power plants.

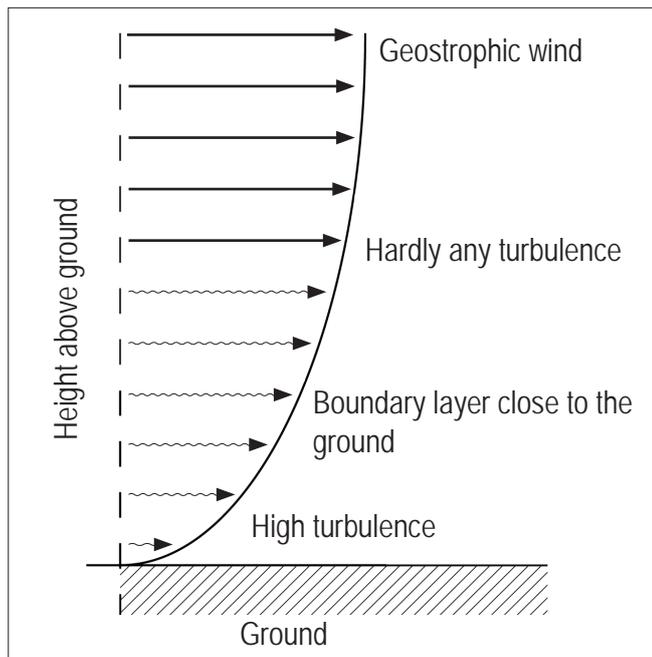


Fig. 14: Turbulence at various different altitudes

A further fact states that the wind speed drops the closer you get to the ground. Consider a system with a hub height of 40 metres and a rotor diameter of 40 metres, where the tips of the rotor blades are subjected to a flow of 9.3 m/s for example, when it is in the **highest position**. The wind speed in the **lowest position** on the rotor blade amounts to just 7.7 m/s. This means that the forces on the rotor blade (bearing load) are significantly higher in the highest position than in the lowest position.

Composition
of air layers

Where
different types
of turbulence
occur



4. Factors of wind force calculation

In this chapter you will learn the terms and basis of calculation required for determining the wind influence upon crane operations. Likewise you will learn to read the permissible wind speed from a diagram.

The following factors are of central importance to the calculation of the wind loads:

- Weight of the load
- Maximum projected surface area
- c_w -value
- Maximum wind speed
- Surface area exposed to wind
- Dynamic pressure

4. 1 Request available values

The following values must be requested in advance of the crane operation:

- The **weight of the hoist load** (m_H) (see chapter 4.1.1)
- The **maximum projected surface area** (A_p) of the load (see chapter 4.1.2)
- The **coefficient of resistance** (c_w -value), (see chapter 4.1.3)
- The current **wind speed** (v_{act}) (see chapter 4.1.4)

4. 1. 1 Weight of the hoist load (m_H)

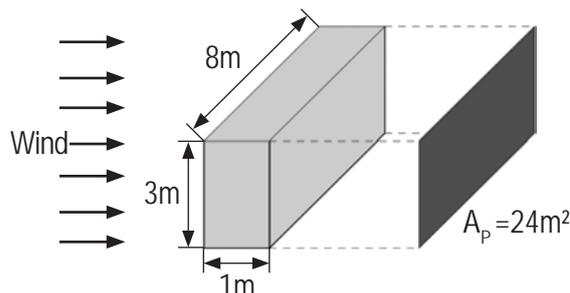
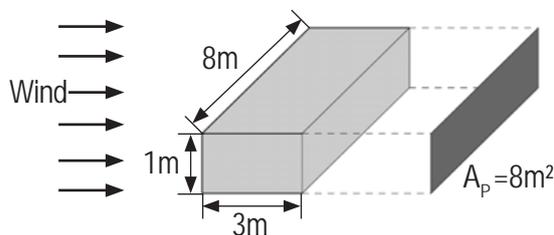
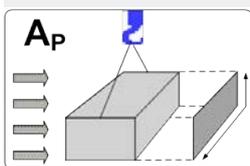
The **weight** of the hoist load (load and hook) to be lifted is measured in kilograms (kg) or tons (t). The crane driver can read the weight of the load from the delivery note or directly on the load or ask the manufacturer. A load for which the weight, the c_w -value and the projected surface area are not all known must not be lifted.

Definition of weight of the hoist load

4. 1. 2 Maximum projected surface area (A_p)

If a body is subjected to a light source then the body casts a shadow. This shadow is the **projected surface area** A_p of the body. If the body is subjected to a wind instead of light then the same shadow arises (projected surface). Depending on wind direction the shadow can be larger or smaller. The manufacturer of the load can supply you with the maximum projected surface area.

Definition of the projected surface area



The example on the left side should make clear that an object can have different projected surface areas. For this reason the maximum projected surface area of a load or body must be assumed.

The larger the projected surface are the larger the area that can be exposed to the wind.



Influence of wind on crane operation

4. 1. 3 c_w -value

If a body is subjected to an air flow, either striking it or flowing through/past it, the air speed will be reduced by this. The body presents an obstacle for the air (flow resistance). The flow resistance changes depending on the shape of the body. In order to describe the shape of the body the **coefficient of resistance** is defined.

The coefficient of resistance (c_w -value) of a body specifies how great the obstruction to the air flow the body presents. The manufacturer of the load can supply you with the coefficient of resistance c_w -value).

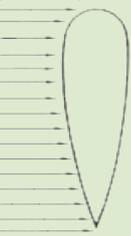
Body	Coefficient of resistance c_w
Plate / cube 	1.1 to 2.0
Cylinders 	0.6 to 1.0
Ball 	0.3 to 0.4
Hemisphere (front) 	0.2 to 0.3
Hemisphere (rear) 	0.8 to 1.2
Wind power plant rotor 	Approximately 1.6

Table 3: c_w -values of common bodies

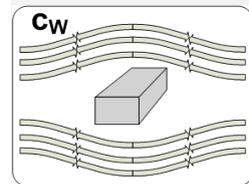
4. 1. 4 Current wind speed (v_{act})

The current wind speed is given in [m/s] or [km/h]. Before starting work you must find out what wind speed is expected, from the weather office or the internet (e.g. www.wetterfinder.com). Lifting is prohibited if the expected wind speeds are impermissibly high!

Likewise, you can read out the current wind speed with the help of the **wind sensor** on the LICCON computer system.

The current value from the wind sensor on the crane must not be used as the sole basis for calculating the load hoist. Before starting the load hoist, contact the appropriate weather office or go online to find the expected / current wind gust / wind speed for the period of time of the load hoist.

Definition of coefficient of resistance



Where do I find the current wind speed?





Wind sensor (air speed indicator)

Up to **two wind sensors** can be installed on the crane. The wind warning appears on the operating screen of the LICCON computer system. If the current wind speed value exceeds the displayed maximum value, the "wind warning" icon starts to flash, and the acoustic alarm >>SHORT HORN<< sounds. But the crane movements do not shut off. The load hoist must be ended as quickly as possible and the boom must be taken down if necessary. When doing so, observe the permissible wind speeds in the wind chart and the erection and take-down chart.

The **top value** in the "wind warning" symbol on the operating screen shows the value from the wind sensor on the fixed jib.

The **bottom value** in the "wind warning" symbol on the operating screen shows the value from the wind sensor on the main boom.

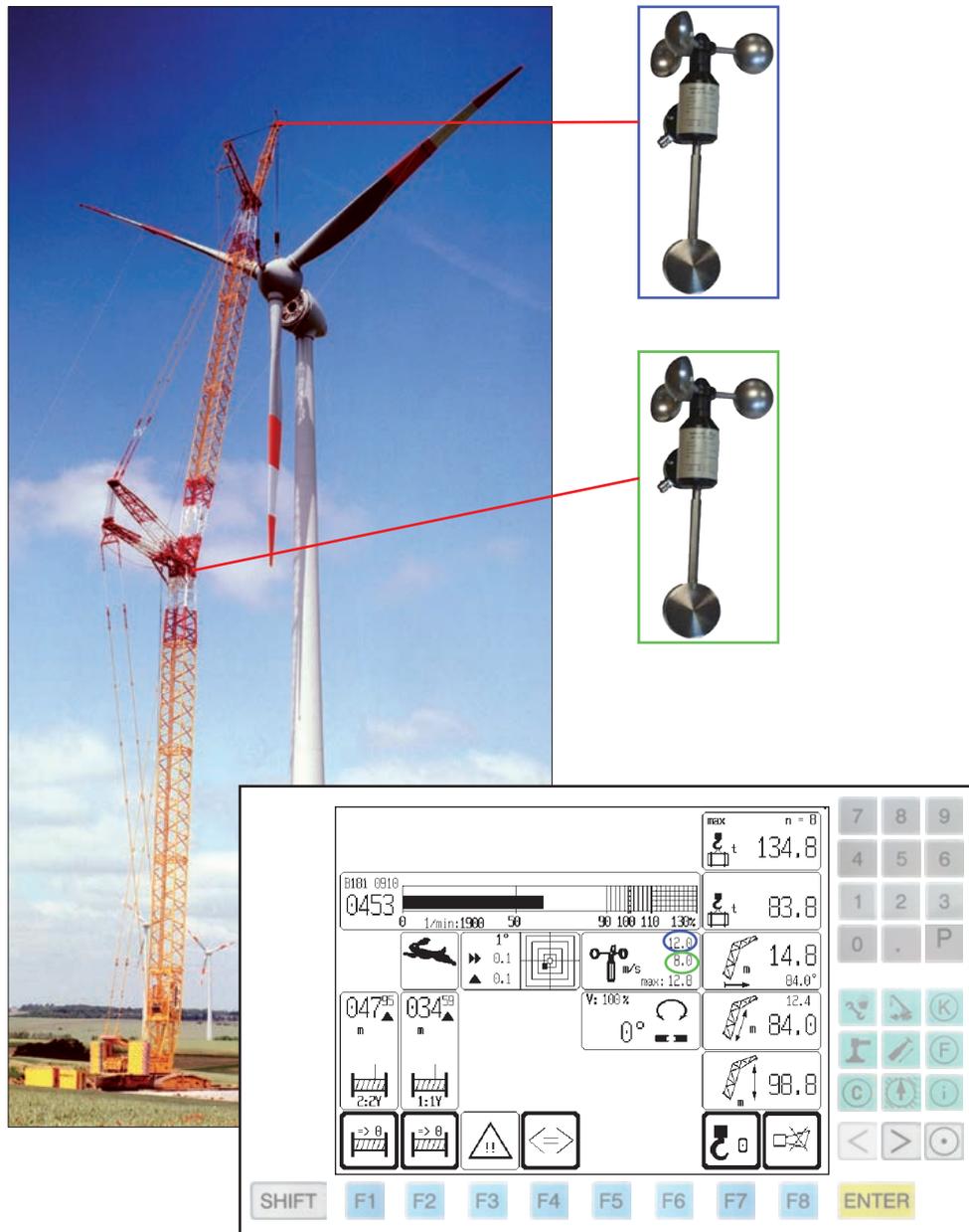


Fig. 15: Installation position of the wind sensor and LICCON operating screen



Influence of wind on crane operation

4. 2 Determine or calculate missing values

If possible, the following values should be determined or calculated with the known factors:

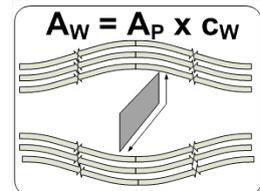
- The surface area exposed to wind (see chapter 4.2.1)
- The permissible wind speed from the load chart book (see chapter 4.2.2)
- The dynamic pressure (see chapter 4.2.3)
- The wind load (see chapter 4.2.4)

4. 2. 1 Surface area exposed to wind (A_w)

The surface area exposed to wind A_w specifies the surface area exposed to wind with consideration to the resistance presented by the body. It is composed of the projected surface area A_p and the c_w -value.

Surface area exposed to wind (A_w):

$$A_w = A_p \cdot c_w$$



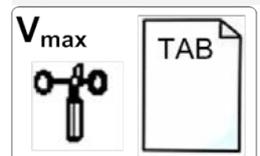
4. 2. 2 Permissible wind speed from the load chart book

A calculated maximum permissible wind speed is given for every crane load chart in the **load chart book**. However, this is dependent on the length of the boom and the crane configuration. Standard values from EN 13000 have been used for the calculation (load reference value of 1.2 m² per ton).

Permissible wind speed from the load chart book

If the **current wind speed** exceeds the **permissible wind speed** from the load chart then the crane operation must be halted and the boom set down if the permissible wind speed in accordance with the crane wind speed table is exceeded.

	1	92 -	0 +	0 +	0 +	0 +	0 +	0 +	0 -	46 -	92 -
	2	46 +	0 +	0 +	0 +	0 +	0 -	46 -	46 +	46 +	46 +
	3	46 +	0 +	0 +	0 -	46 -	46 +	46 +	46 +	46 +	46 +
	4	0 +	0 -	46 -	46 +	46 +	46 +	46 +	46 +	46 +	46 +
	5	0 +	0 +	0 +	0 +	0 +	0 +	0 +	0 +	0 +	0 +
		11,1	14,3	14,3	14,3	12,8	12,8	12,8	12,8	11,1	11,1



	T	--			
			12,8 t	9,30 x 5,40 m	360°

Fig. 16: Extract from the load chart with the permissible wind speeds for each telescope configuration/Lattice mast configuration



Influence of wind on crane operation

Definition of dynamic pressure

4. 2. 3 Dynamic pressure (p)

If wind strikes a spring supported plate (see diagram on the right) then the air flows around this. At the same time a portion of the wind is backed up against the surface of the plate. This backing up results in an increase in pressure which presses the plate against the spring. This pressure is known as **dynamic pressure**.

If the wind speed (v) doubles then the dynamic pressure increases four-fold.

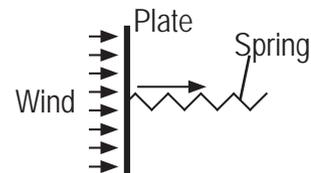
Formula for the dynamic pressure (p):

Air density:
 $\rho = 1.25 \text{ kg/m}^3$

$$p = F_w : A_w$$

or

$$p = 0.5 \cdot \rho \cdot v^2$$



Definition of force

4. 2. 4 Wind load (F_w)

Strong wind is required to start up a propeller. That means that the **dynamic pressure** of the wind must be so large that the rotor starts to rotate. The larger the rotor's surface area exposed to wind the less the dynamic pressure needs to be in order to start it turning.

Formula Wind load (F_w):

$$F_w = A_w \cdot p$$

4. 3 Exercises



Exercise 7

You must replace a window pane in a glass facade with your crane. The window pane has a projected surface area of 2.6 m² and a c_w-value of 1.2. Calculate the surface area exposed to wind.

Answer:

$$A_w = \quad \text{m}^2$$

Exercise 8 (Fill in the missing words!)

If the wind speed exceeds the wind speed from the load chart then the crane operation must be and the boom..... if the permissible wind speed in accordance with the crane wind speed table is.....

Exercise 9

Use "figure 16" (page 25) to determine which wind speed is permissible with a teleconfiguration of 92-/46+/46+/46+/0.

Answer:



5. Determination of permissible wind speed

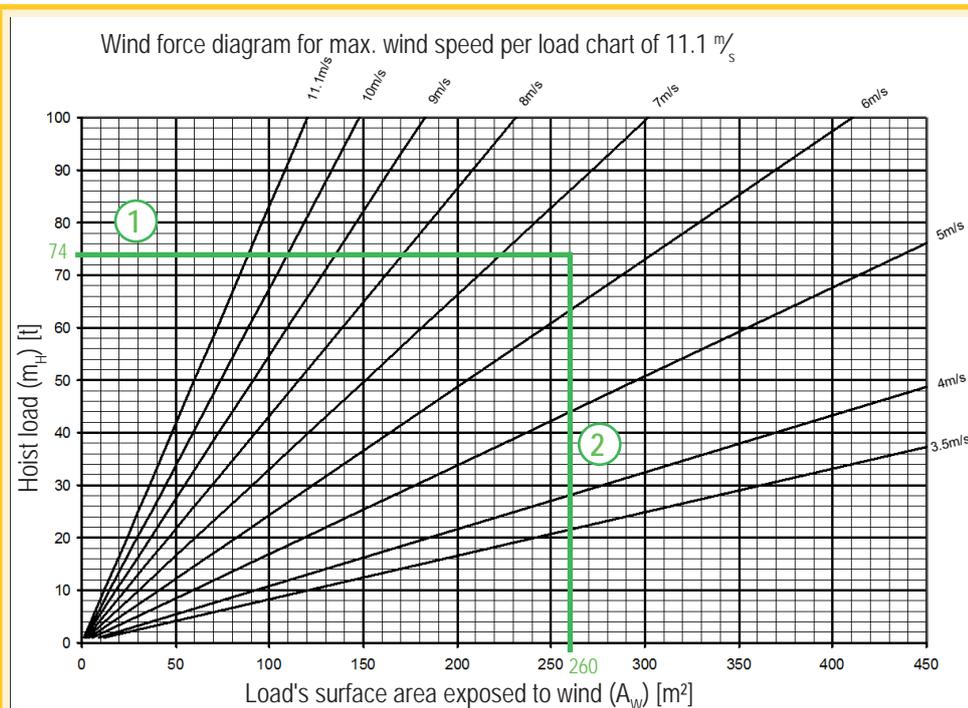
The following methods facilitate the determination of the maximum permissible wind speed:

- Method (1): Wind force diagram (see chapter 5.1)
- Method (2): Formula (see chapter 5.2)
- Method (3): The determination of the maximum permissible wind speed of the older load chart books (Diagram 1 and 2) is no longer used.

5. 1 Method (1): Wind force diagram

This form of determining the permissible wind speed is an inherent part of the load chart book. In this chapter we would like to inform you about this method.

If the surface area exposed to wind of the load is greater than 1.2 m² per t load then the maximum permissible wind speeds per the load table are **no** longer valid. In this case, compare the maximum permissible wind speed from the load chart with the wind speed in the **wind force diagram**. The two values must match with one another as otherwise you will read an incorrect wind speed from the wrong wind force diagram. This could cause an accident.



To determine the maximum permissible wind speed with the aid of a wind force diagram, the hoist load m_H (load + fastening equipment) must first be drawn in horizontally (see line 1).

In a further step, the wind-exposed surface A_W (projection surface x c_w value) must be drawn in vertically (see line 2).

The maximum permissible wind speed can be read at the point in which the lines cross.





Example 1

280 m² / 65 t =
4.31 m²/t



5. 1. 1 Example for determining the maximum permissible wind speed for a special load case

The load to be lifted weighs 65 t, has a c_w -value of 1.4 and a surface area exposed to wind of 280 m² with a projected surface area of 200 m². If we divide the surface area exposed to wind by the load then we have a value of 4.31 m² per t. This value exceeds the permissible value for the load's surface area exposed to wind of 1.2 m² per t. According to the load chart a maximum wind speed of 11.1 m/s is permissible for the crane configuration required. Now the maximum permissible wind speed must be determined by means of the wind force diagram 11.1 m/s (see illustration 22 on page 32).

The maximum permissible wind speed for the load amounts to 5.9 m/s.

The determined maximum permissible wind speed of 5.9 m/s is not accepted into the LICCON computer system. There is no warning if the determined maximum permissible wind speed of 5.9 m/s is exceeded. For that reason, the crane operator himself must monitor the wind speed value in the LICCON computer system. If the determined maximum permissible wind speed is reached, the load lift must be discontinued.

5. 1. 2 Example for determining the maximum permissible wind speed for a standard load case

Example 2

Surface area exposed to wind:
1.2 · 50 m² =
60 m²

A load weighs 85 t, has a c_w -value of 1.2 and a projected surface area of 50 m². A c_w -value of 1.2 and a projected surface area of 50 m² results in a surface area exposed to wind of 60 m². If you divide the surface area exposed to wind by the load then we have a value of 0.71 m² per t. In this example the load chart has a maximum wind speed of 9 m/s. For this reason the wind force diagram with 9 m/s must be used.

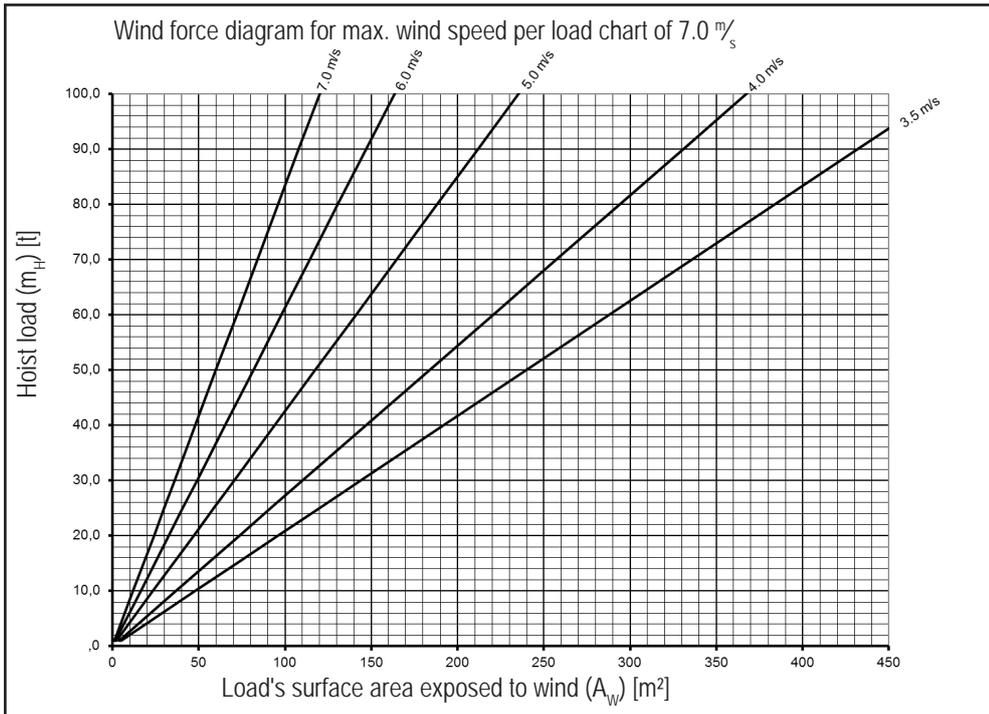
This means that the load can be lifted up to a maximum wind speed of 9 m/s, as given in the load chart.

Exercise 10

Plot the values from example 5.1.1 on the corresponding wind force diagram on the following pages to determine the maximum permissible wind speed.

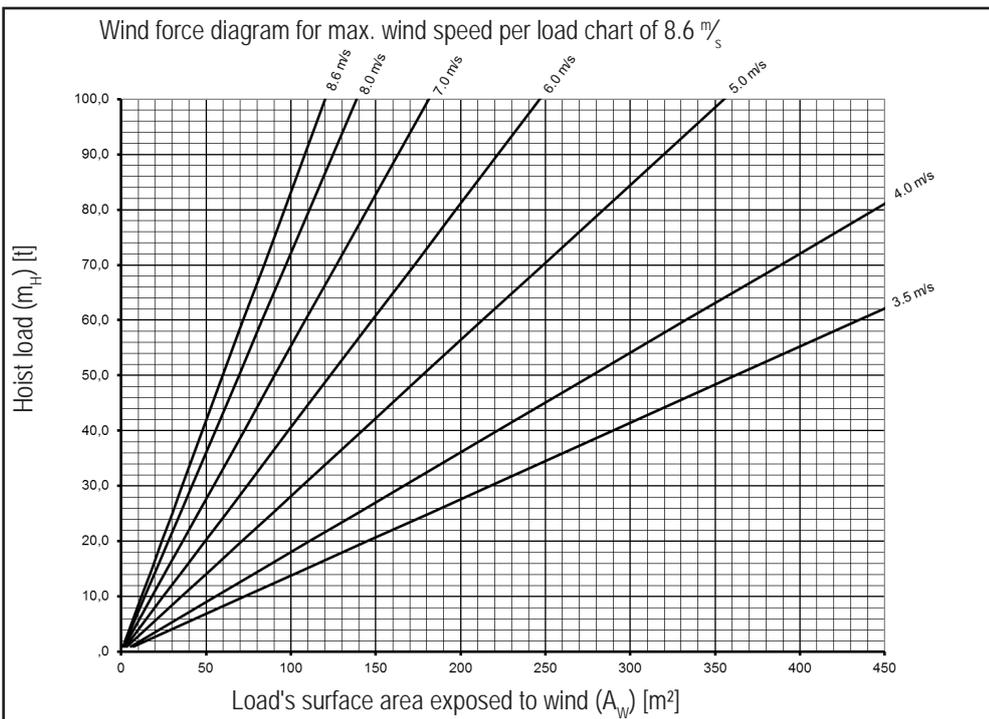
Exercise 11

Plot the values from example 5.1.2 on the corresponding wind force diagram on the following pages to determine the maximum permissible wind speed.



Wind force diagram 7.0 m/s

Fig. 17: Wind force diagram 7.0 m/s (only valid for tables with max. wind speed of 7.0 m/s)



Wind force diagram 8.6 m/s

Fig. 18: Wind force diagram 8.6 m/s (only valid for tables with max. wind speed of 8.6 m/s)



Wind force diagram
9.0 m/s

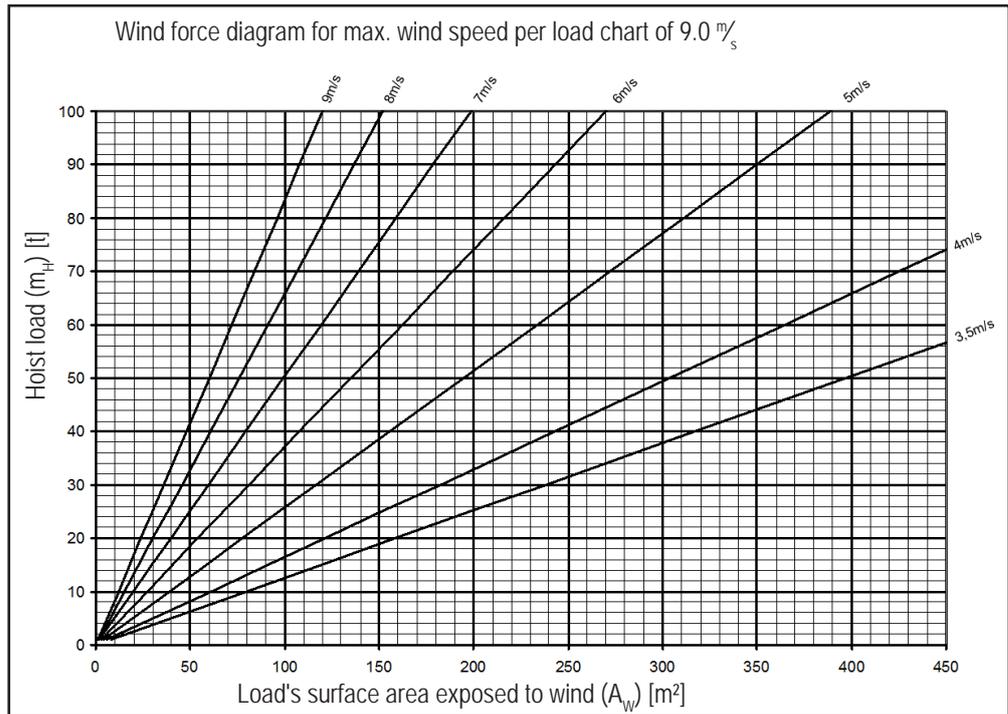


Fig. 19: Wind force diagram 9.0 m/s (only valid for tables with max. wind speed of 9.0 m/s)

Wind force diagram
9.9 m/s

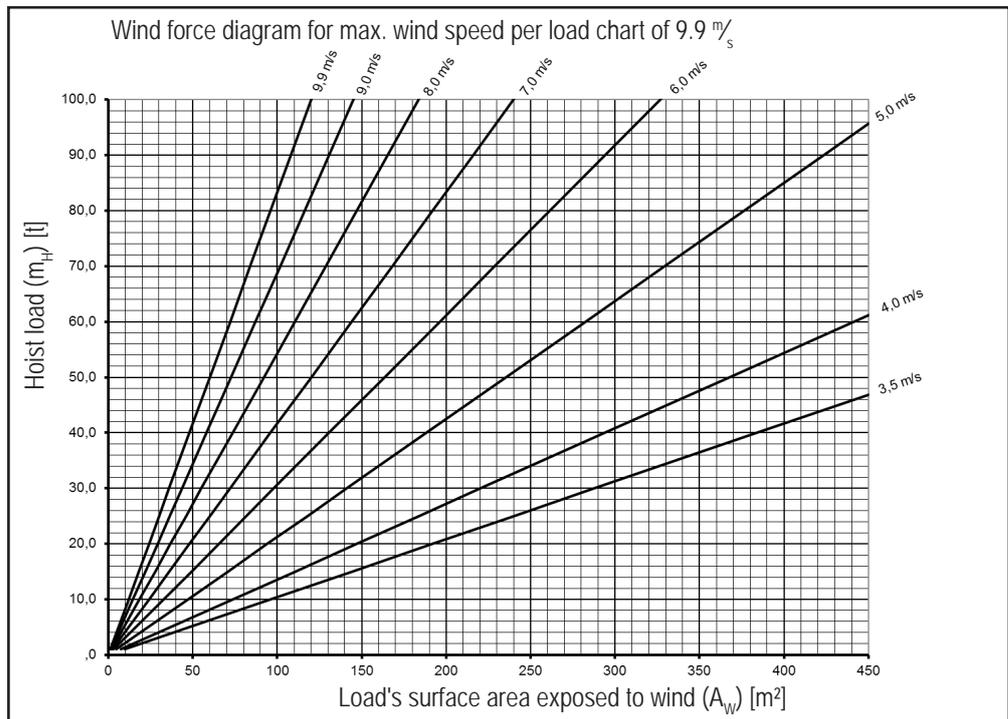
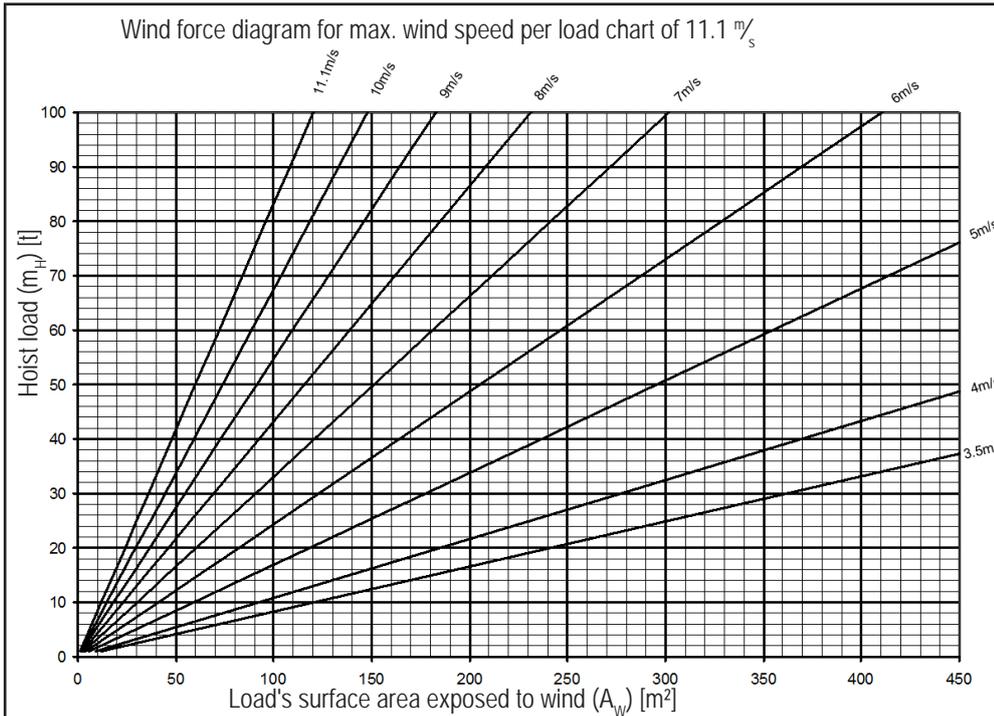


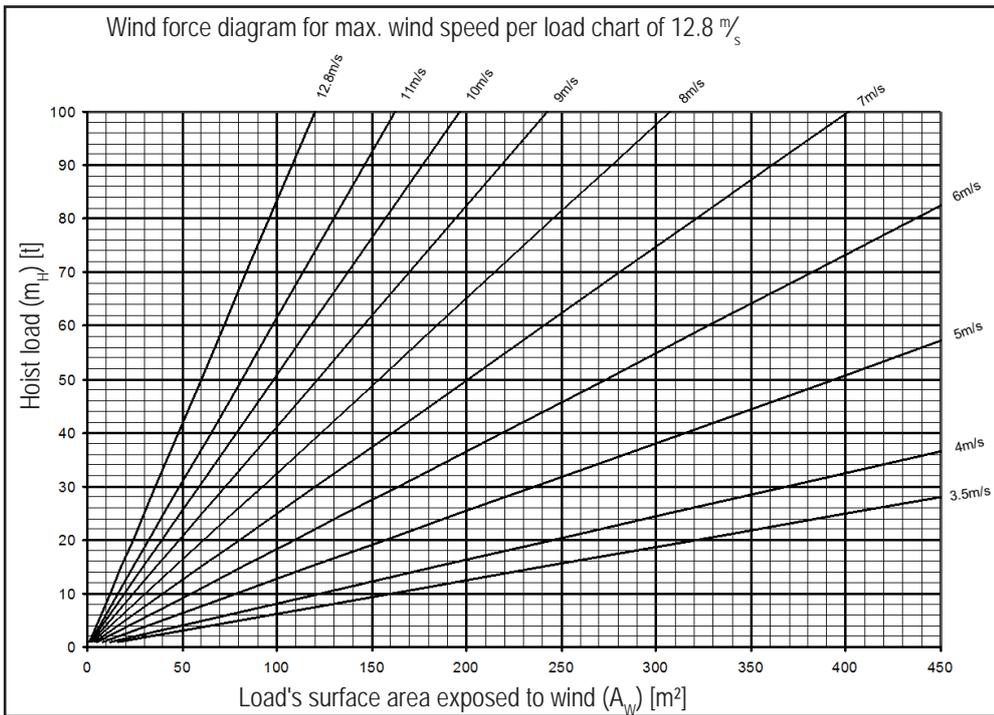
Fig. 20: Wind force diagram 9.9 m/s (only valid for tables with max. wind speed of 9.9 m/s)

Influence of wind on crane operation



Wind force diagram 11.1 m/s

Fig. 21: Wind force diagram 11.1 m/s (only valid for tables with max. wind speed of 11.1 m/s)



Wind force diagram 12.8 m/s

Fig. 22: Wind force diagram 12.8 m/s (only valid for tables with max. wind speed of 12.8 m/s)



Wind force
diagram
14.3 m/s

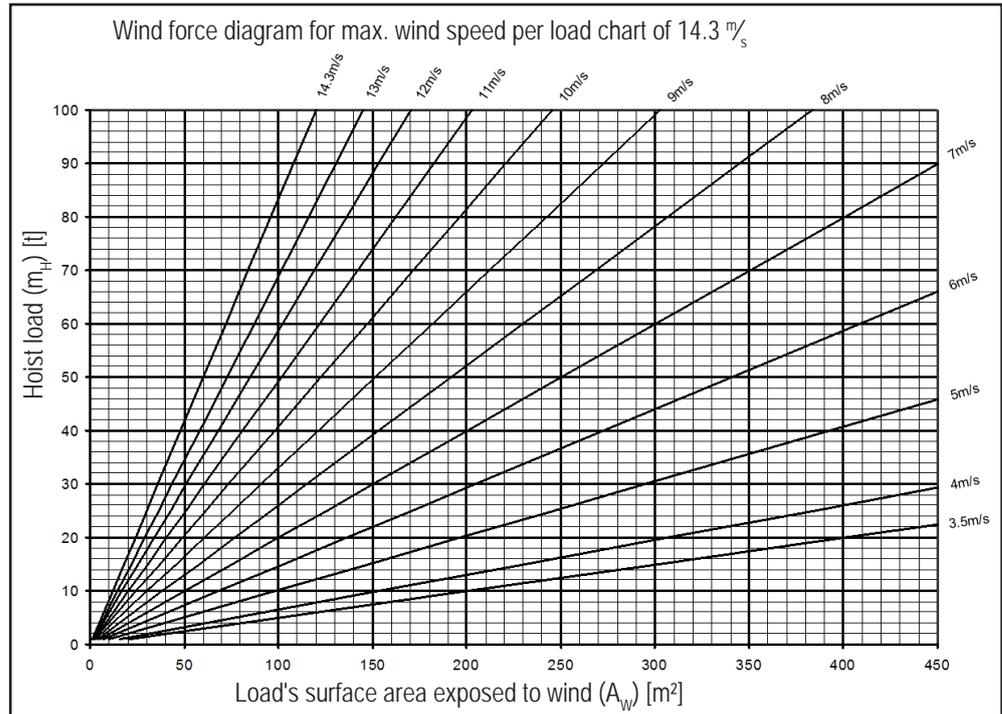


Fig. 23: Wind force diagram 14.3 m/s (only valid for tables with max. wind speed of 14.3 m/s)



Influence of wind on crane operation

5. 2 Method (2): Formula

The permissible wind speed can be calculated with a single formula.
For this the following data must first be collected:

- The hoist load (m_H) (incl. lifting accessories and hook block and any relevant portion of hoisting cable)
- The surface area exposed to wind (A_W)
- The maximum wind speed per the load chart

Formula for calculating the permissible wind speed:

$$V_{\max} = V_{\max_TAB} \cdot \sqrt{\frac{1,2 \frac{m^2}{t} \cdot m_H}{A_W}}$$

The value $1,2 \frac{m^2}{t}$ below the root corresponds to the constant according to EN 13000 and **not** the c_w value! This value may **not** be changed!

5. 2. 1 Example for calculating the maximum permissible wind speed for a special load case

The load to be lifted weighs **65 t**, has a c_w -value of **1.4** and a surface area exposed to wind of **280 m²** with a projected surface area of **200 m²**. A maximum wind speed of **11.1 m/s** is permissible for the crane configuration required according to the load chart.

$$V_{\max} = 11,1 \frac{m}{s} \cdot \sqrt{\frac{1,2 \frac{m^2}{t} \cdot 65 t}{280 m^2}}$$

$$V_{\max} = 5,86 \frac{m}{s}$$

Example 1

Surface area exposed to wind:
 $1,4 \cdot 200 m^2 =$
280 m²

The wind speed from the load chart drops from **11.1 m/s** to **5.86 m/s**.
The load may be lifted up to a maximum wind speed of **5.86 m/s**.

The determined maximum permissible wind speed of **5.86 m/s** is not accepted into the LICCON computer system. There is no warning if the determined maximum permissible wind speed of **5.86 m/s** is exceeded. For that reason, the crane operator himself must monitor the wind speed value in the LICCON computer system. If the determined maximum permissible wind speed is reached, the load lift must be discontinued.



5. 2. 2 Example for calculating the maximum permissible wind speed for a standard load case

A load weighs **85 t**, has a c_w -value of **1.2** and a projected surface area of **50 m²**. With a c_w -value of **1.2** and a projected surface area of **50 m²** we have a surface area exposed to wind of **60 m²**. The maximum permissible wind speed from the load chart amounts to **9 m/s** in this example.

$$V_{\max} = 9 \frac{m}{s} \cdot \sqrt{\frac{1,2 \frac{m^2}{t} \cdot 85 t}{60 m^2}}$$

$$V_{\max} = 11,73 \frac{m}{s}$$

Example 2

Surface area exposed to wind:
 $1,2 \cdot 50 m^2 =$
60 m²

If the result of the v_{\max} is **larger** than v_{\max_TAB} , the load can be lifted up to the maximum wind speed specified in the load chart, here **9 m/s**.





5. 3 Exercises

Exercise 12

You must lift a load of 47 t and a surface area exposed to wind of 235 m² to a height of 21 m with a boom projection of 6m, using an LTM 1150-6.1 (CODE 0050). The crane is supported with a support base of 9.30 m x 8.30 m. The counterweight amounts to 46.8 t.

Determine the correct tele-configuration from this extract from the load chart book (see below). In addition determine the permissible wind speed for this lift by means of the applicable wind force diagram (see chapter 5.1).

m	CODE > 0050 < T186.00301x(x)													
	13,7	18,5	18,5	18,5	23,3	23,3	23,3	23,3	28,1	28,1	28,1	28,1	28,1	32,9
3,0	96,4	81,8	61,6	57,5	71,6	61,2	58,4	41,2						
3,5	92,3	82,1	62,2	56,0	71,0	61,6	58,6	39,5	54,0	56,1	53,9	40,1		
4,0	85,6	82,5	62,7	54,6	70,0	62,0	58,3	37,8	53,5	55,6	53,4	38,3	37,2	
4,5	79,6	79,7	63,2	52,7	68,6	62,5	56,1	36,0	53,1	55,0	52,8	36,4	35,5	41,0
5,0	74,2	74,3	63,8	50,5	67,1	62,9	54,0	34,1	52,5	54,3	52,3	34,5	33,8	40,3
6,0	64,9	65,1	64,0	45,9	63,1	63,5	49,6	30,6	50,4	52,1	49,9	31,5	31,0	38,9
7,0	57,1	57,4	57,8	42,3	56,9	57,7	46,1	28,1	48,1	49,8	47,1	28,7	28,4	37,5
8,0	51,0	51,1	51,5	39,3	51,0	51,7	42,6	25,7	45,9	47,6	44,2	26,2	26,0	36,1
9,0	45,6	45,7	46,2	36,3	45,7	46,4	39,4	23,7	43,6	45,5	41,2	24,4	24,2	34,7
10,0	41,1	41,2	41,7	34,0	41,2	41,9	36,8	22,2	40,6	41,7	38,2	22,5	22,5	33,0
11,0	35,9	37,4	37,9	32,0	37,3	38,1	34,2	20,6	36,9	37,9	35,4	20,8	20,8	31,0
12,0		34,0	34,6	30,2	33,9	34,7	31,6	19,1	33,5	34,5	33,5	19,6	19,7	29,0
14,0		28,0	28,6	27,3	27,9	28,8	28,0	17,0	27,4	28,6	29,5	17,3	17,5	25,4
16,0		21,1	21,6	22,0	23,4	24,3	24,9	15,2	22,9	24,1	25,1	15,3	15,6	22,3
18,0					19,9	20,8	21,6	13,8	19,4	20,6	21,6	13,8	14,1	18,9
20,0					17,1	18,0	18,8	12,7	16,6	17,8	18,8	12,5	12,8	16,1
22,0									14,4	15,5	16,5	11,5	11,8	13,8
24,0									12,5	13,7	14,7	10,6	11,0	12,0
26,0														10,4
28,0														9,1
30,0														7,6
32,0														
34,0														
36,0														
38,0														
40,0														
42,0														
44,0														
46,0														
48,0														
50,0														
52,0														
54,0														
56,0														
* n *	12!	10	8	7	9	8	7	5	7	7	7	5	5	5
1	0+	0+	0+	0+	0+	0+	0+	0+	46+	0+	0+	0+	0+	92+
2	0+	0+	0+	0+	46+	0+	0+	0+	46+	46+	0+	0+	0+	46+
3	0+	46+	0+	0+	46+	46+	0+	0+	46+	46+	46+	0+	0+	46+
4	0+	0+	46+	0+	0+	46+	46+	0+	0+	46+	46+	92+	46+	0+
5	0+	0+	0+	46+	0+	0+	46+	92+	0+	0+	46+	46+	92+	0+
%														
m/s	14,3	14,3	14,3	14,3	12,8	12,8	12,8	12,8	12,8	12,8	12,8	12,8	12,8	11,1



Fig. 24: Extract from the load chart book for the LTM 1150-6.1



Influence of wind on crane operation

Exercise 13

You must lift a load of 45 t and a surface area exposed to wind of 112 m² to a height of 42 m with a boom projection of 18 m, using an LTM 11200-9.1 (CODE 0016). The crane is supported with a support base of 13 m x 13 m. The counterweight amounts to 22 t.

Determine the correct tele-configuration from this extract from the load chart book (see below). In addition determine the permissible wind speed for this lift by means of the applicable wind force diagram (see chapter 5.1).



m	CODE > 0016 < V178 0F00 .x(x)													
	18,3	24,1	24,1	30,0	30,0	30,0	35,8	35,8	41,6	41,6	41,6	47,5	47,5	47,5
3,0	213,0	213,0	213,0	213,0	213,0	213,0	213,0	213,0						
3,5	213,0	213,0	213,0	213,0	213,0	213,0	213,0	190,0						
4,0	213,0	213,0	213,0	213,0	213,0	213,0	213,0	183,0	213,0	213,0	92,0			
4,5	213,0	213,0	213,0	213,0	213,0	213,0	213,0	176,0	213,0	213,0	88,0			
5,0	213,0	213,0	213,0	213,0	213,0	213,0	213,0	170,0	213,0	213,0	84,0	213,0	161,0	110,0
6,0	213,0	213,0	213,0	213,0	213,0	213,0	213,0	158,0	213,0	213,0	78,0	213,0	150,0	101,0
7,0	213,0	213,0	213,0	213,0	213,0	209,0	213,0	148,0	213,0	213,0	72,0	207,0	140,0	94,0
8,0	213,0	213,0	213,0	213,0	213,0	189,0	213,0	139,0	213,0	198,0	67,0	194,0	131,0	87,0
9,0	213,0	213,0	213,0	211,0	213,0	174,0	194,0	130,0	181,0	186,0	63,0	171,0	123,0	81,0
10,0	211,0	192,0	196,0	171,0	184,0	158,0	160,0	121,0	151,0	159,0	59,0	144,0	116,0	76,0
12,0	143,0	134,0	137,0	120,0	131,0	135,0	114,0	105,0	109,0	117,0	52,0	106,0	103,0	67,0
14,0	100,0	98,0	100,0	89,0	99,0	104,0	85,0	92,0	83,0	90,0	46,0	82,0	93,0	60,0
16,0	73,0	72,0	74,0	68,0	78,0	81,0	65,0	81,0	64,0	71,0	41,0	64,0	77,0	54,0
18,0		55,0	57,0	53,0	60,0	63,0	51,0	70,0	51,0	57,0	37,0	51,0	64,0	48,0
20,0		42,0	44,5	40,0	47,5	51,0	39,5	57,0	40,0	46,5	33,5	41,0	54,0	44,0
22,0		32,0	34,5	29,7	38,0	41,0	30,5	47,5	31,5	37,5	31,0	32,5	45,0	40,0
24,0				21,8	29,9	33,5	23,6	40,0	24,6	30,5	28,4	26,0	38,0	36,0
26,0				15,5	23,4	26,8	17,2	33,5	19,0	24,9	26,0	20,6	32,5	33,5
28,0					18,2	21,6	12,1	28,3	14,4	19,8	24,4	16,0	27,6	28,8
30,0							7,8	23,8	10,3	15,4	22,7	12,2	23,1	24,2
32,0								20,1	6,0	11,8	21,1	9,0	19,3	20,4
34,0								17,1		8,7	20,0	5,3	16,1	17,1
36,0										5,8	17,5		13,4	14,4
38,0										3,0	15,0		11,0	11,9
40,0											13,0		8,9	9,8
42,0													7,1	8,0
44,0														
46,0														
48,0														
50,0														
52,0														
54,0														
56,0														
58,0														
* n *	14	14	14	14	14	14	14	13	14	14	6	14	11	7
1	0+	0+	0+	50+	0+	0+	50+	0+	50+	0+	50+	0+	50+	0+
2	0+	50+	0+	50+	0+	0+	50+	0+	50+	50+	0+	50+	0+	0+
3	0+	0+	50+	0+	50+	0+	50+	0+	50+	50+	0+	50+	50+	0+
4	0+	0+	0+	0+	50+	50+	0+	0+	50+	50+	0+	50+	50+	100+
5	0+	0+	0+	0+	0+	50+	0+	50+	0+	50+	0+	50+	50+	50+
6	0+	0+	0+	0+	0+	0+	0+	50+	0+	0+	100+	0+	50+	50+
7	0+	0+	0+	0+	0+	0+	0+	50+	0+	0+	100+	0+	50+	50+
%														
m/s	14,3	14,3	14,3	12,8	12,8	12,8	12,8	12,8	11,1	11,1	11,1	11,1	11,1	11,1
TAB ***	0019	0019	0019	0019	0019	0019	0019	0019	0019	0019	0019	0019	0019	0019

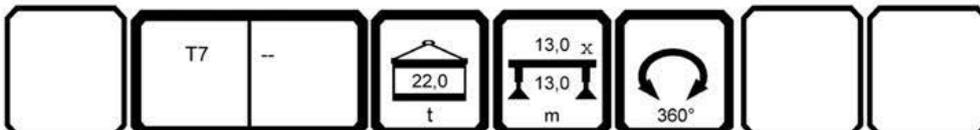


Fig. 25: Extract from the load chart book for the LTM 11200-9.1



6. Wind influences for “Crane out of operation”

In addition to the danger of wind occurring during crane operation, there is also the danger of a crane accident due to the influence of wind on the crane when it is out of operation, or without a load. Mobile and crawler cranes have very large wind-exposed surfaces in spite of their filigree construction, also without a load. Even in the case of lattice booms, wind-exposed surfaces of multiple hundred square meters are possible. Very large boom lengths and a compact support base result in a great potential for danger when the maximum wind speed is exceeded.

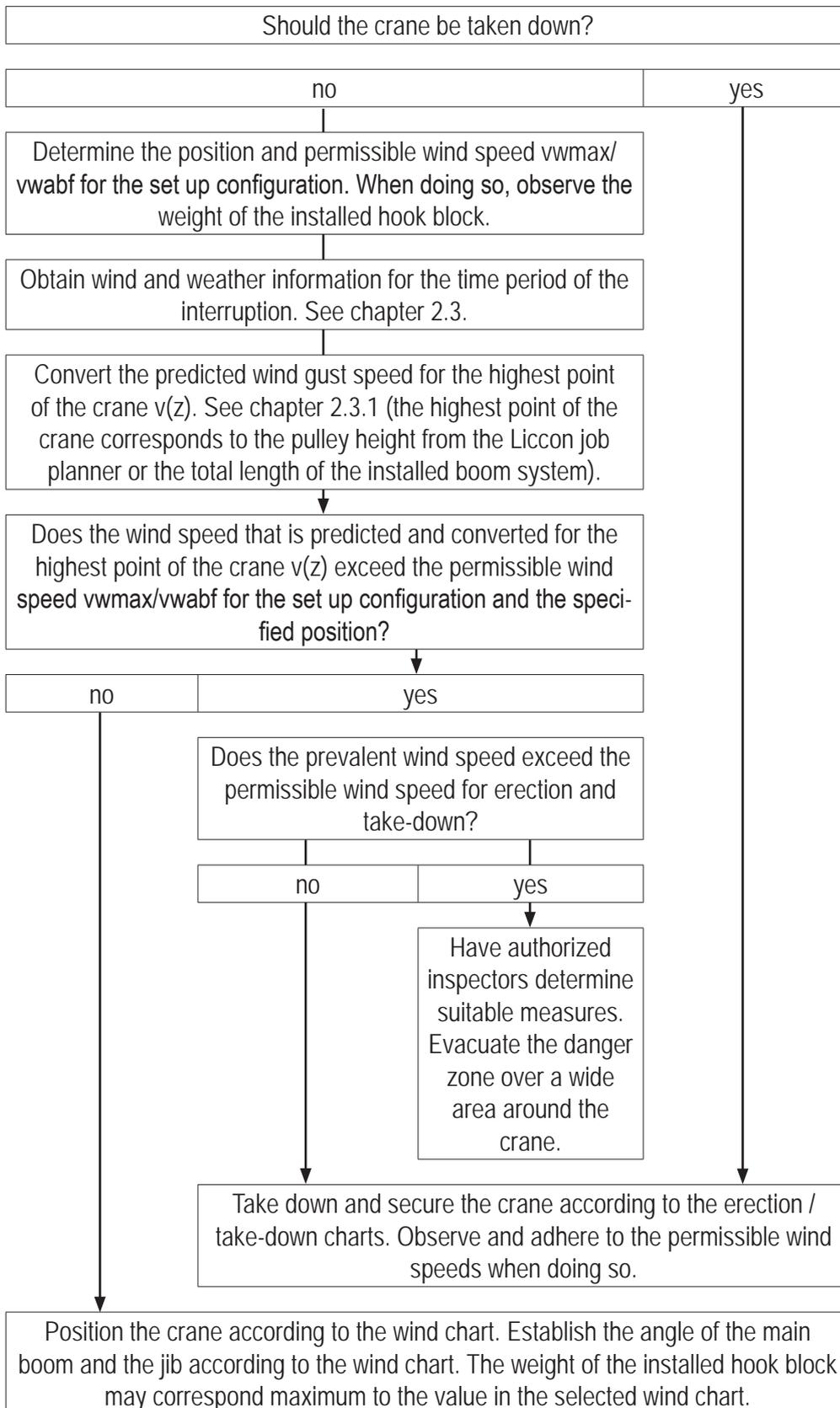
The best image is that the entire crane could tip over. It is also possible, however, that wind from the front can cause the luffing lattice jibs and the main boom to tip over to the rear. Furthermore, a side wind can overload the slewing gear brake, which could cause the crane to turn inadvertently.

As described in the operating instructions from Liebherr-Werk Ehingen GmbH, the crane boom must always be taken down if the crane will not be supervised while the crane work is interrupted. If this is not possible due to limited space at the job site, the crane must be brought to the position specified by the manufacturer. This position is safe however only up to the specified wind speed. In order to determine the respective maximum wind speed, all Liebherr cranes with a lattice mast and all Liebherr telescopic cranes that can be equipped with a luffing lattice jib are equipped with wind charts. This information can be taken from the wind charts. If there are no wind speed charts available for the set up configuration, the value for the maximum permissible wind speed in the load chart must be used.



Influence of wind on crane operation

6. 1 Procedure when interrupting crane work





6. 2 Using the wind charts

6. 2. 1 Example with a telescopic crane:

LTM 1750-9.1 – TYVEN

Support base:	12 m x 12 m
Counterweight:	184 t
Telescopic boom:	T-49.1 (92/92/92)
Luffing lattice jib:	N-59.5
Hook block weight:	1.5 t

Observe the operating mode, counterweight and support base in the chart description!

The hook block weight in the chart may not be exceeded.



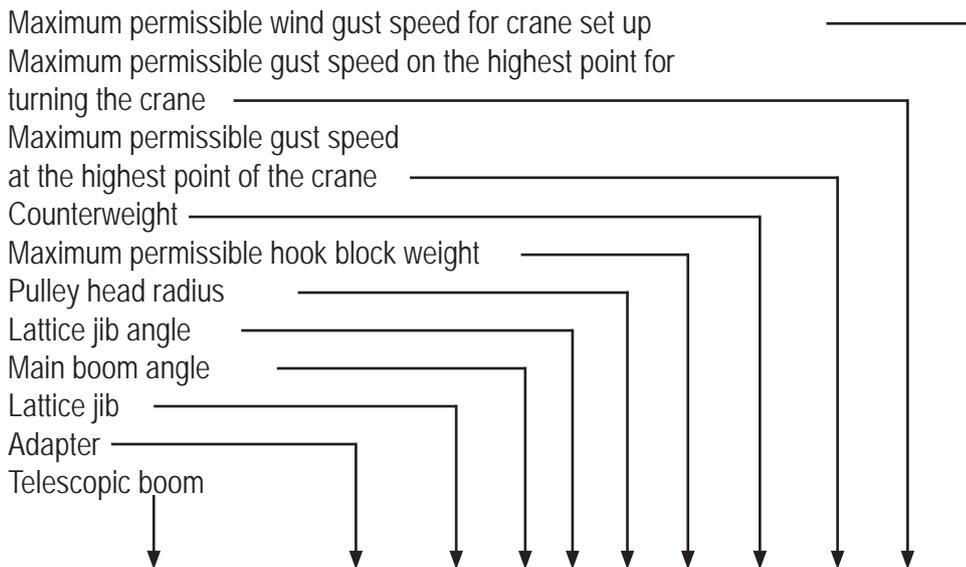
TYVEN - 64.0t to 204.0t counterweight - support base: 12.0m * 12.0m

Note

- ▶ TYVEN - Guyed telescopic boom with TY-guying, lattice extension and luffing lattice jib
- ▶ 5m lattice extension
- ▶ Y-frame position 45°
- ▶ 64.0t to 204.0t counterweight
- ▶ Guy point of telescopic boom guying on eccentric
- ▶ The angle of the Y-frames is to be set according to the load chart
- ▶ The specified wind speeds are valid for the guyed status, if the boom may be guyed
- ▶ Extension conditions for which no load information is available in guyed condition may not be guyed
- ▶ For shortest telescopic boom T-16.3 and NA-frame 3 rods, the maximum angle of the luffing lattice jib is 58°
- ▶ Luffing lattice jibs from a length of 80.5m cannot be telescoped and must be placed down
- ▶ Support base 12.0m * 12.0m



Influence of wind on crane operation



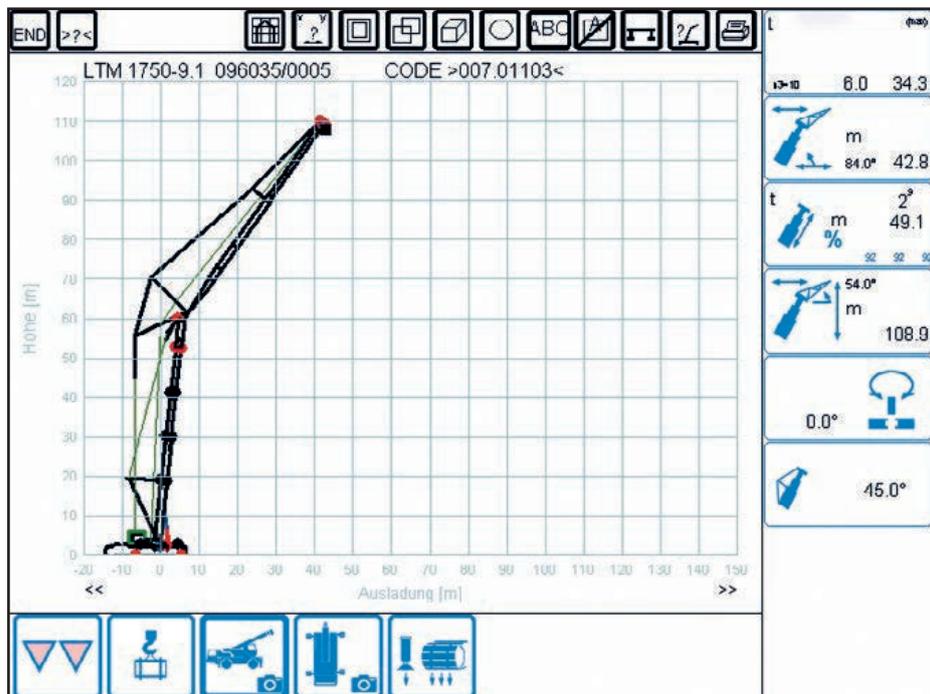
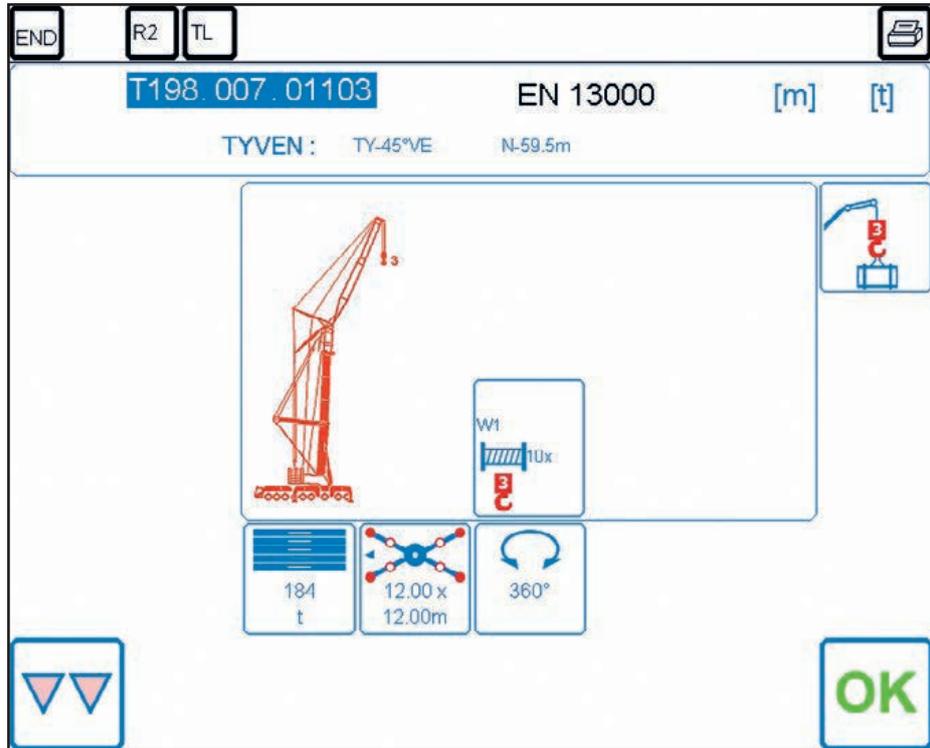
Permissible wind speeds		WAB-TAB198-007-001-00								
H A	A	H I	W H A	W H I	R A D	H K F L	O W B	V W M A X	V W A B F	V W R S T
[m]	[m]	[m]	[°]	[°]	[m]	[t]	[t]	[m/s]	[m/s]	[m/s]
T-16.3 (0/0/0)	A-9.0	N-59.5	84	51	41.8	2.0	var.	16.8	13.3	8.9
T-16.3 (0/0/0)	A-9.0	N-59.5	84	51	41.8	2.0	var.	16.8	13.3	8.9
T-21.8 (0/46/0)	A-9.0	N-59.5	84	52	41.6	2.0	var.	16.6	13.1	8.9
T-21.8 (0/0/46)	A-9.0	N-59.5	84	52	41.6	2.0	var.	16.6	13.1	8.9
T-27.2 (46/46/0)	A-9.0	N-59.5	84	50	43.7	2.0	var.	16.1	12.9	8.9
T-32.7 (92/46/0)	A-9.0	N-59.5	84	51	43.5	2.0	var.	15.8	12.6	8.9
T-38.2 (92/92/0)	A-9.0	N-59.5	84	49	45.6	2.0	var.	15.2	12.4	8.9
T-43.7 (92/92/46)	A-9.0	N-59.5	84	50	45.4	2.0	var.	14.9	12.2	8.9
T-49.1 (92/92/92)	A-9.0	N-59.5	84	48	47.6	2.0	var.	14.3	11.9	8.9

By telescoping in the telescopic boom from T-49.1 (92/92/92) to T-16.3 (0/0/0), the permissible wind speed increases from 14.3 m/s to 16.8 m/s.



Which gust speed is permissible at a height of 10 m for T-49.1 (92/92/92)?

Determining the pulley height using the job planner:





Pulley height: 108.9 m

Determining the height using the total system length: $49.1 + 9 + 59.5 = 117.6$ m

The predicted wind gust speed is 11 m/s at a height of 10 m

By making the conversion using chart 2.3.1, a gust speed of 14.2 m/s at a height of 120 m is determined, which means that the crane can be turned off as it is.

By telescoping in the boom, the permissible wind gust speed increases to 16.8, which represents a clear increase in safety if longer interruptions must always be performed.

6. 2. 2 Example with a lattice crane:

LR 11000 - SDWB

Main boom: S-54 m

Luffing lattice jib: W-114 m

Derrick boom: D-36 m

OW-ballast: 210 t

Central ballast: 50 t

Hook block weight: 14 t

If a chart with derrick ballast is not available, but an operating mode with derrick is set up, charts without derrick ballast should be used. The derrick ballast must be placed on the ground.

Example:

Set up - charts to be used

SDB - SD

SDWB - SDW

SDWB2- SDW - the ballast guide must be removed



SDWB - system

Note

- ▶ Hook block weight 18t
- ▶ Derrick ballast 0t
- ▶ Turntable ballast 210t
- ▶ Central ballast 50t
- ▶ Derrick radius 12m
- ▶ Number of slewing gears: 3

Maximum permissible wind gust speed for crane set up
 Maximum permissible gust speed on the highest point for
 turning the crane

Maximum permissible gust speed
 at the highest point of the crane

Derrick radius

Central ballast

Counterweight

Maximum permissible hook block weight

Pulley head radius

Lattice jib angle

Main boom angle

Lattice jib

Derrick

Main boom

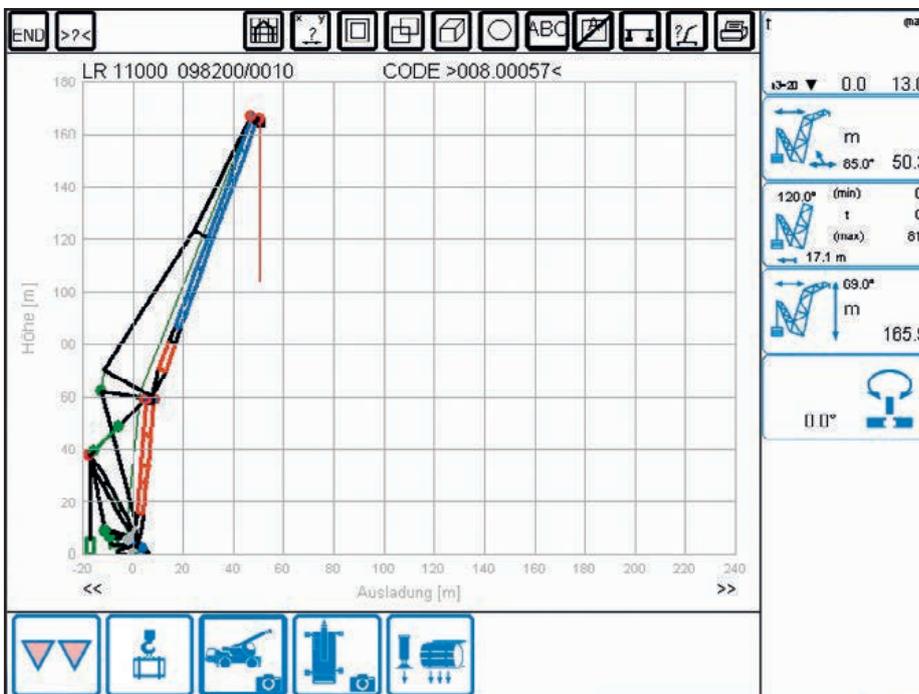
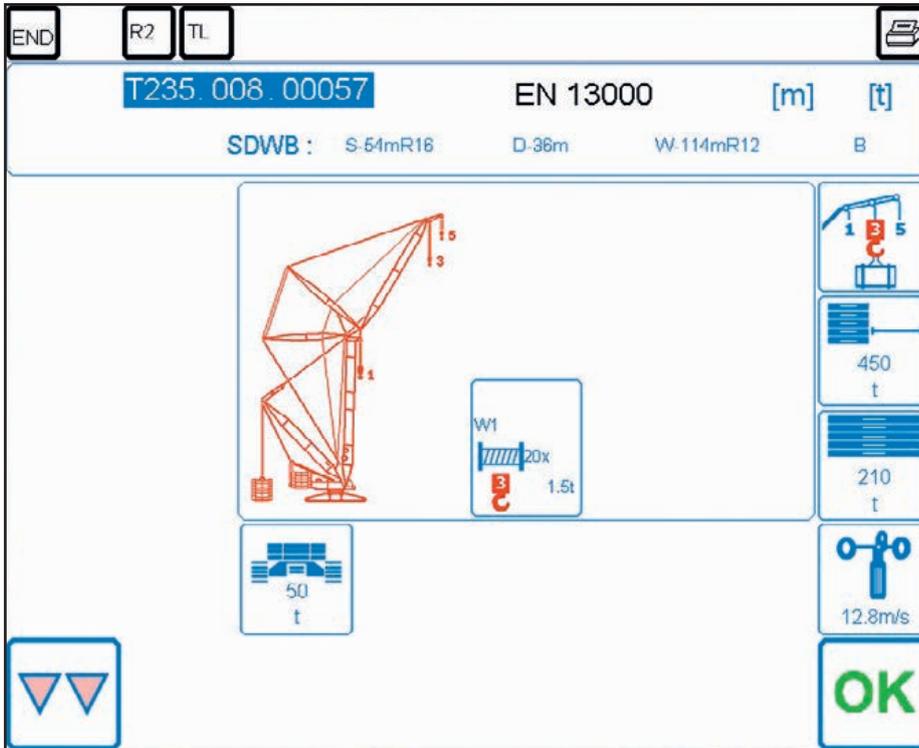
Permissible wind speeds													wab_235_008_00001_00_000		
H A	D	H I	W A	W I	R A D	H K F L	O W B	Z B L	D R A D	V W A B	V W A B F	V W R S T			
[m]	[m]	[m]	[°]	[°]	[m]	[t]	[t]	[t]	[m]	[m/s]	[m/s]	[m/s]			
S-48	D-36	W-108	85	67	51.1	18.0	210	50	12	17.6	14.3	8.9			
S-48	D-36	W-114	85	68	51.6	18.0	210	50	12	17.1	13.5	8.9			
S-54	D-36	W-18	75	0	35.2	18.0	210	50	12	23.4	23.4	8.9			
S-54	D-36	W-24	75	0	41.2	18.0	210	50	12	24.9	24.9	8.9			
S-54	D-36	W-30	75	30	44.1	18.0	210	50	12	24.0	24.0	8.9			
S-54	D-36	W-36	75	45	43.9	18.0	210	50	12	23.6	23.6	8.9			
S-54	D-36	W-42	75	55	42.8	18.0	210	50	12	23.2	23.1	8.9			
S-54	D-36	W-48	75	60	42.8	18.0	210	50	12	22.6	21.8	8.9			
S-54	D-36	W-54	75	65	41.7	18.0	210	50	12	22.1	20.4	8.9			
S-54	D-36	W-60	80	52	50.9	18.0	210	50	12	21.2	21.0	8.9			
S-54	D-36	W-66	80	58	49.0	18.0	210	50	12	20.7	19.7	8.9			
S-54	D-36	W-72	80	62	47.9	18.0	210	50	12	20.2	18.5	8.9			
S-54	D-36	W-78	80	66	45.9	18.0	210	50	12	19.7	17.3	8.9			
S-54	D-36	W-84	80	68	45.7	18.0	210	50	12	19.2	16.4	8.9			
S-54	D-36	W-90	85	61	53.0	18.0	210	50	12	18.5	16.8	8.9			
S-54	D-36	W-96	85	63	52.9	18.0	210	50	12	18.0	15.8	8.9			
S-54	D-36	W-102	85	66	50.9	18.0	210	50	12	17.5	15.0	8.9			
S-54	D-36	W-108	85	68	49.9	18.0	210	50	12	17.2	14.2	8.9			
S-54	D-36	W-114	85	69	50.3	18.0	210	50	12	16.7	13.4	8.9			



Influence of wind on crane operation

Which gust speed is permissible at a height of 10 m?

Determining the pulley height using the job planner



Pulley height: 165.9 m

Determining the height using the total system length: $54 \text{ m} + 114 \text{ m} = 168 \text{ m}$

The predicted wind gust speed is 11 m/s at a height of 10 m

By making the conversion using chart 2.3.1, a wind gust speed of 14.9 m/s at a height of 170 m is determined, which means that the crane can be turned off as it is. 16.7 m/s is permissible.



7. Final comments

The wind power boom of the last few years has given rise to many crane manufacturers' innovations. Never before have so many large machines been commissioned in order to meet the increasing demands of the new wind power plant technology as today.

When erecting a modern wind power plant care must always be taken to ensure that the size of the crane is suitable for the weight of the turbine house and the rotor's surface area exposed to wind in conjunction with the hub height. Likewise these must be considered when carrying out repair work or maintenance work.

The influence of the wind on the crane and load is more heavily emphasised in the mind of the crane operator when installing wind power plant systems as the crane is deployed in locations where high winds must be taken into account.

The rule states that "double the wind speed means 4 times the wind loading on the boom and load".

In order to better evaluate the accident risk and thus to avoid industrial accidents when working with the crane, we have compiled this comprehensive document on the subject of "Wind influence on crane operation". Furthermore, competent colleagues from **LIEBHERR-Werk Ehingen GmbH** are available to answer any further questions that the reader may have.



8. Appendix

8. 1 Liebherr cranes in wind energy

8. 1. 1 Current mobile cranes (2016)



Technical data LTM 1350-6.1	
Maximum load	350 t at 3 m
Telescopic boom	70 m
Max. lifting height	134 m
Driving motor power	Liebherr 8 cylinder turbo-diesel 450 kW
Crane engine power	Liebherr 4 cylinder turbo-diesel 180 kW
Drive, steering	12 x 8 x 12
Driving speed	80 km/h
Weight	72 t (6 x 12 t axle load)
Wind power plant - large	< 1 MW*

LTM 1350-6.1



Technical data LTM 1400-7.1	
Maximum load	400 t at 3 m
Telescopic boom	60 m
Max. lifting height	130 m
Driving motor power	Liebherr 8 cylinder turbo-diesel 450 kW
Crane engine power	Liebherr 6 cylinder turbo-diesel 240 kW
Drive, steering	14 x 8 x 14
Driving speed	80 km/h
Weight	84 t (7 x 12 t axle load)
Wind power plant - large	< 1.5 MW*

LTM 1400-7.1



Technical data LTM 1450-8.1	
Maximum load	450 t at 3 m
Telescopic boom	85 m
Max. lifting height	131 m
Driving motor power	Liebherr 8 cylinder turbo-diesel 505 kW
Crane engine power	Single-Engine-Concept
Drive, steering	16 x 8 x 16
Driving speed	85 km/h
Weight	96 t (8 x 12 t axle load)
Wind power plant - large	< 1.5 MW*

LTM 1450-8.1

* The wind power plant sizes stated are only examples. The correct crane size must be determined through detailed planning of the operation and consideration of the wind loads!

Influence of wind on crane operation



LTM 1500-8.1



Technical data LTM 1500-8.1	
Maximum load	500 t at 3 m
Telescopic boom	50/84 m
Max. lifting height	142 m
Driving motor power	Liebherr 8 cylinder turbo-diesel 500 kW
Crane engine power	Liebherr 6 cylinder turbo-diesel 240 kW
Drive, steering	16 x 8 x 12
Driving speed	80 km/h
Weight	96 t (8 x 12 t axle load)
Wind power plant - large	< 2 MW*

LTM 1750-9.1



Technical data LTM 1750-9.1	
Maximum load	750 t at 3 m
Telescopic boom	52 m
Max. lifting height	154 m
Driving motor power	Liebherr 8 cylinder turbo-diesel 505 kW
Crane engine power	Liebherr 6 cylinder turbo-diesel 300 kW
Drive, steering	18 x 8 x 18
Driving speed	80 km/h
Weight	108 t (9 x 12 t axle load)
Wind power plant - large	2 MW*

LTM 11200-9.1



Technical data LTM 11200-9.1	
Maximum load	1200 t at 2.5 m
Telescopic boom	100 m
Max. lifting height	188 m
Driving motor power	Liebherr 8 cylinder turbo-diesel 500 kW
Crane engine power	Liebherr 6 cylinder turbo-diesel 270 kW
Drive, steering	18 x 8 x 18
Driving speed	75 km/h
Weight	108 t (9 x 12 t axle load)
Wind power plant - large	2 - 3 MW*

* The wind power plant sizes stated are only examples. The correct crane size must be determined through detailed planning of the operation and consideration of the wind loads!



Influence of wind on crane operation

8. 1. 2 Current telescopic crawler cranes (2016)

Technical data LTR 11200	
Maximum load	1200 t at 3 m
Ground pressure	~ 14 t/m ²
Max. lifting height	189 m
Driving motor engine / crane engine power	Liebherr 6 cylinder turbo-diesel 270 kW
Permissible climbing ability	17,6 %
Total weight	~ 380 t
Driving speed	max. 1.8 km/h
Total ballast	202 t
Wind power plant - large	2 - 3 MW*



LTR 11200

8. 1. 3 Current crawler cranes (2016)

Technical data LR 1350	
Maximum load	350 t at 6 m
Max. boom projection	110 m
Max. lifting height	152 m
Driving motor engine / crane engine power	Liebherr 6 cylinder turbo-diesel 270 kW
Track width	8.4 m
Superstructure ballast	max. 125 t
Central ballast	max. 38 t
Derrick ballast	max. 210 t x R 15 m
Wind power plant - large	< 1.5 MW*



LR 1350

Technical data LR 1400/2	
Maximum load	400 t at 4.5 m
Max. boom projection	120 m
Max. lifting height	164 m
Driving motor engine / crane engine power	Liebherr 6 cylinder turbo-diesel 270 kW
Track width	8.7 m
Superstructure ballast	max. 155 t
Central ballast	max. 43 t
Derrick ballast	max. 260 t x R 15 m
Wind power plant - large	< 2 MW*



LR 1400

* The wind power plant sizes stated are only examples. The correct crane size must be determined through detailed planning of the operation and consideration of the wind loads!



LR 1500



Technical data LR 1500	
Maximum load	500 t at 11 m
Max. boom projection	144 m
Max. lifting height	165 m
Driving motor engine / crane engine power	Liebherr 6 cylinder turbo-diesel 350 kW
Track width	9.1 m
Superstructure ballast	max. 170 t
Central ballast	max. 40 t
Derrick ballast	max. 280 t x R 16 m
Wind power plant - large	2 MW*

LR 1600/2



Technical data LR 1600/2	
Maximum load	600 t at 11 m
Max. boom projection	152 m
Max. lifting height	187 m
Driving motor engine / crane engine power	Liebherr 6 cylinder turbo-diesel 400 kW
Track width	9.9 m
Superstructure ballast	max. 190 t
Central ballast	max. 65 t
Derrick ballast	max. 350 t x R 18 m
Wind power plant - large	2 - 3 MW*

LR 1600/2-W



Technical data LR 1600/2-W	
Maximum load	600 t at 11 m
Max. boom projection	144 m
Max. lifting height	166 m
Driving motor engine / crane engine power	Liebherr 6 cylinder turbo-diesel 400 kW
Track width	5.8 m
Superstructure ballast	max. 190 t
Derrick ballast	max. 350 t x R 18 m
Wind power plant - large	2 - 3 MW*

* The wind power plant sizes stated are only examples. The correct crane size must be determined through detailed planning of the operation and consideration of the wind loads!



Technical data LR 1750/2	
Maximum load	750 t at 7 m
Max. boom projection	156 m
Max. lifting height	191 m
Driving motor engine / crane engine power	Liebherr 8 cylinder turbo-diesel 455 kW
Track width	10.3 m
Superstructure ballast	max. 245 t
Central ballast	max. 95 t
Derrick ballast	max. 400 t x R 20 m
Wind power plant - large	3 MW*



LR 1750/2

Technical data LR 11000	
Maximum load	1000 t at 11 m
Max. boom projection	180 m
Max. lifting height	224 m
Driving motor engine / crane engine power	Liebherr 8 cylinder turbo-diesel 500 kW
Track width	11.2 m
Superstructure ballast	max. 250 t
Central ballast	max. 90 t
Derrick ballast	max. 450 t x R 20 m
Wind power plant - large	3 - 5 MW*



LR 11000

Technical data LR 11350	
Maximum load	1350 t at 12 m
Max. boom projection	128 m
Max. lifting height	196 m
Driving motor engine / crane engine power	Liebherr 6 cylinder turbo-diesel 641 kW
Track width	11 m
Superstructure ballast	max. 340 t
Central ballast	max. 30 t
Derrick ballast	max. 600 t x R 25 m
Wind power plant - large	5 - 6 MW*



LR 11350

* The wind power plant sizes stated are only examples. The correct crane size must be determined through detailed planning of the operation and consideration of the wind loads!



LG 1750

8. 1. 4 Current lattice boom cranes (2016)



Technical data LG 1750	
Maximum load	750 t at 7 m
Max. boom projection	136 m
Max. lifting height	193 m
Driving motor power	Liebherr 8 cylinder turbo-diesel 505 kW
Crane engine power	Liebherr 8 cylinder turbo-diesel 455 kW
Drive, steering	16 x 8 x 16
Driving speed	80 km/h
Total ballast	650 t
Wind power plant - large	3 - 5 MW*

* The wind power plant sizes stated are only examples. The correct crane size must be determined through detailed planning of the operation and consideration of the wind loads!



Influence of wind on crane operation

8. 2 Exercise solutions

Solution for exercise 1:

- | | |
|---|--|
| <input checked="" type="checkbox"/> Wind load | <input type="checkbox"/> Wind energy |
| <input type="checkbox"/> Evaporation | <input checked="" type="checkbox"/> Wind from the rear |
| <input checked="" type="checkbox"/> Wind from the front | <input checked="" type="checkbox"/> Wind from the side |

Solution for exercise 2:

Wind from the rear: The LMB shut-off actuates at a load that is less than the maximum permissible load capacity according to the load chart.

Wind from the front: Shut-off actuates only after a load that is greater than the maximum permissible load capacity.

Wind from the side: There is no LMB shut-off.

Solution for exercise 3:

- None
- The load can swing
- The load turns on the cable
- The radius of the load can increase

Solution for exercise 4:

- Forests and uneven land can be seen in picture 12 - this represents roughness class 3.
- A landscape with a few houses and trees and free spaces can be seen in picture 13 - this represents roughness class 2.

Solution for exercise 5:

- Weak wind caused by a difference in air pressure
- Short severe flurry of wind
- Severe flurry of wind higher than the average wind speed, over a period of 3 seconds

Solution for exercise 6:

Determined wind gust speed according to figure 11: **4 m/s**

Factor for a height of 140 m with available wind gust speed: **1.319**

$$4 \text{ m/s} \times 1.319 = \underline{\underline{5.276 \text{ m/s}}}$$



Solution for exercise 7:

$$2.6 \text{ m}^2 \times 1.2 = \underline{3.12 \text{ m}^2}$$

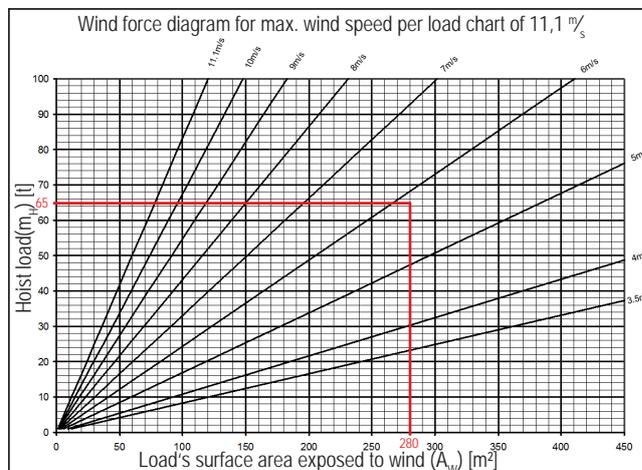
Solution for exercise 8:

If the **current** wind speed exceeds the **permissible** wind speed from the load chart then the crane operation must be **halted** and the boom **set down** if the **permissible** wind speed in accordance with the crane wind speed table is **exceeded**.

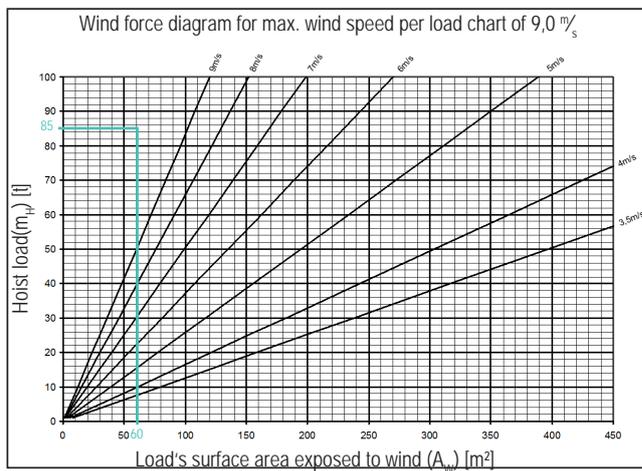
Solution for exercise 9:

11,1 m/s

Solution for exercise 10:



Solution for exercise 11:



Solution for exercise 12:

For the correct tele-configuration telescopic sections 4 and 5 must be pinned at 46 %. The permissible wind speed in accordance with wind force diagram 12.8 m/s amounts to 6.2 m/s.

Solution for exercise 13:

For the correct tele-configuration telescopic section 4 must be pinned at 100 % and telescopic sections 5 - 7 at 50 %. The permissible wind speed in accordance with wind force diagram 11.1 m/s amounts to 7.7 m/s.



Source: @Westermeerwind

Partner of the wind power industry

Liebherr is a strong partner for the wind power industry. Liebherr earthmoving machines, offshore cranes and mobile and crawler cranes are used for the building of wind parks. Single Liebherr

components like drives and engines are installed directly at the facilities and Liebherr gear cutting machines play an ever more important role in the wind power.



Earthmoving equipment and mixing technology

During building of wind parks Liebherr earthmoving machines haven proven their worth. For the foundations of the wind generator units mobile concrete mixer plants and mobile mixers from Liebherr are used, at the building sites of reinforced towers special stationary units.

Offshore Cranes

For the erection of offshore wind power plants Liebherr also offers convincing solutions. All requirements can be met: diesel driven or electric drive units, explosion proved cranes or safety area cranes as well as cranes for operation at ambient temperatures from +40 centigrade to -50 centigrade.

Components

Liebherr is the only manufacturer worldwide who not only can deliver single components but also with large diameter roller bearings, slewing drives, electric motors and hydraulic cylinders can offer the complete system for the electro-mechanic and hydraulic rotor blade and azimuth adjustment in wind power generators.

Machine tools and automation technology

Gear cutting machines from Liebherr contribute significantly to geared parts in e. g. main gearboxes to fulfill the high quality requirements. Automation technology from Liebherr caters for high productivity for the rotor blade fabrication.

www.liebherr.com