SPECIAL WIRE ROPES

Analysis of the bending cycle distribution of 1- to 8-part electric hoists

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by Dipl.-Ing. Roland Verreet

1. Introduction

During the hoisting operation of a crane, not all sections of the hoist rope are subjected to the same number of bending cycles. Instead, the distribution of the bending cycles depends on the geometry of the reeving system and on the mode of operation of the crane.

The author has written a program which calculates and displays the distribution of the bending cycles along the rope length and the maximum number of bending cycles depending on the lifting height.

As an example of the possibilities of such software, the distribution of bending cycles of 1- to 8-part electric hoists, according to figure 1, will be analyzed in the following paper.

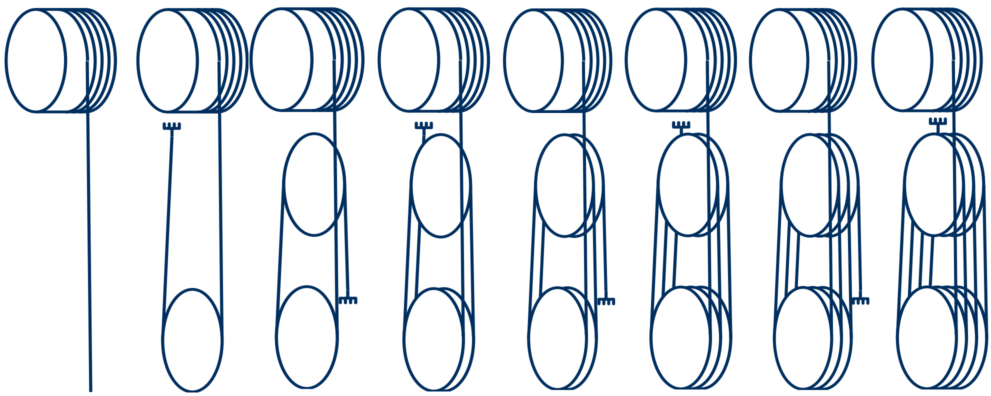

Fig. 1: Schematic arrangements of the 1- to 8-part hoists

For all hoists, the distribution will be analyzed for lifting heights of 25%, 50%, 75% and 100% of the maximum possible lifting height. In addition, the distribution of bending cycles will be analyzed under the assumption that these four lifting heights will occur with the same frequency.

At the end, a proposal for an estimation of the maximum number of bending cycles for different lifting heights will be presented.

Figure 2 shows the data of the 8 electric hoists. The rope diameter has been set to d = 16 mm, the sheave and drum diameters to D = 320 mm (= 20 x d). The maximum distances between the sheaves have been set to 16 m for all hoists, and the maximum lifting height to 15m. In addition, a reserve rope length on the drum (the "dead turns") has been allowed for on all hoists.

	No. of parts [-]	No. of sheaves [-]	Rope length [mm]
Hoist 1	1	0	19000
Hoist 2	2	1	35503
Hoist 3	3	2	52005
Hoist 4	4	3	68508
Hoist 5	5	4	85011
Hoist 7	6	5	101513
Hoist 7	7	6	118016
Hoist 8	8	7	134519

Fig. 2: Data of the analyzed hoists

In the following, the results of every one of the 8 hoists will be presented on two pages each. The results are shown as a function of the rope length, displayed as a percentage of the total rope length according to figure 2.

In the final chapter some general conclusions are drawn.

2. The single-part hoist

Figure 3 shows the <u>maximum</u> number of bending cycles for one full hoisting cycle (=1x lifting, 1 x lowering) as a function of the lifting height. Figure 5 (next page) shows the distribution of bending cycles as a function of the rope length (expressed in % of the total rope length) for one full hoisting cycle (=1 x lifting, 1 x lowering) for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height. Figure 4 shows the <u>average</u> number of bending cycles for a hoist which lifts the block to these four heights with the same frequency.

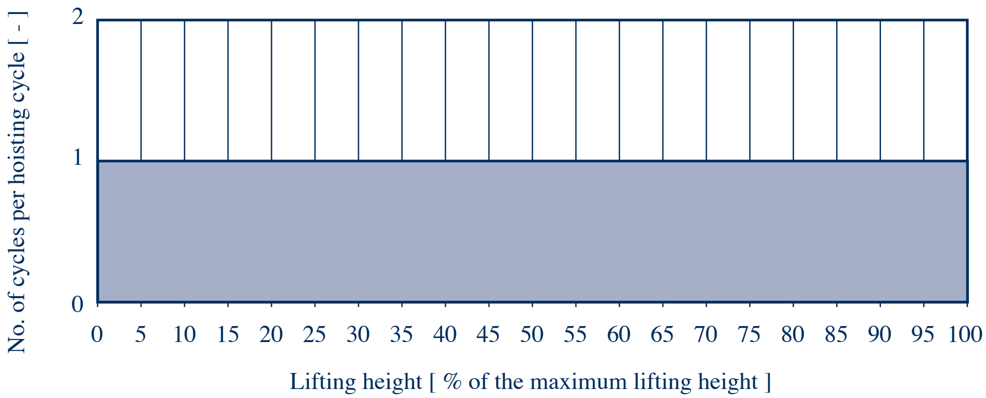

Fig. 3: Maximum number of cycles depending on the lifting height

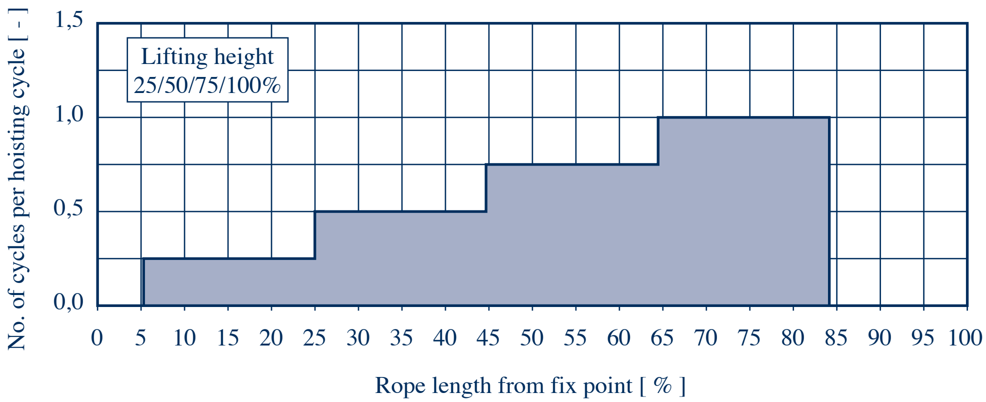

Figure 4: Distribution of bending cycles per hoisting cycle if lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height occur with the same frequency

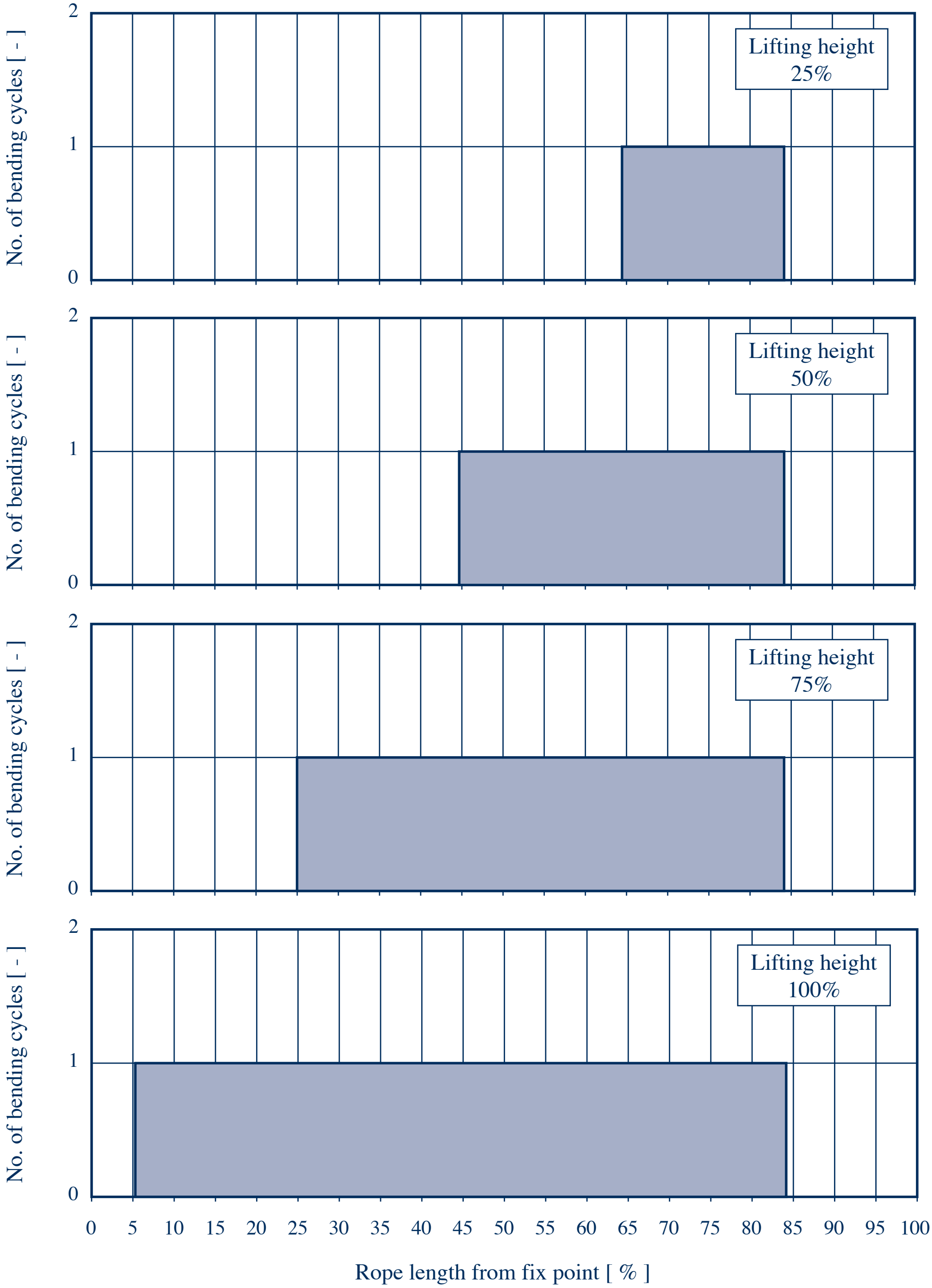

Figure 5: Number of bending cycles depending on the rope length for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height (single-part hoist)

3. The 2-part hoist

Figure 6 shows the maximum number of bending cycles for one full hoisting cycle (=1 x lifting, 1 x lowering) as a function of the lifting height. Figure 8 (next page) shows the distribution of bending cycles as a function of the rope length (expressed in % of the total rope length) for one full hoisting cycle (=1 x lifting, 1 x lowering) for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height. Figure 7 shows the average number of bending cycles for a hoist which lifts the block to these four heights with the same frequency.

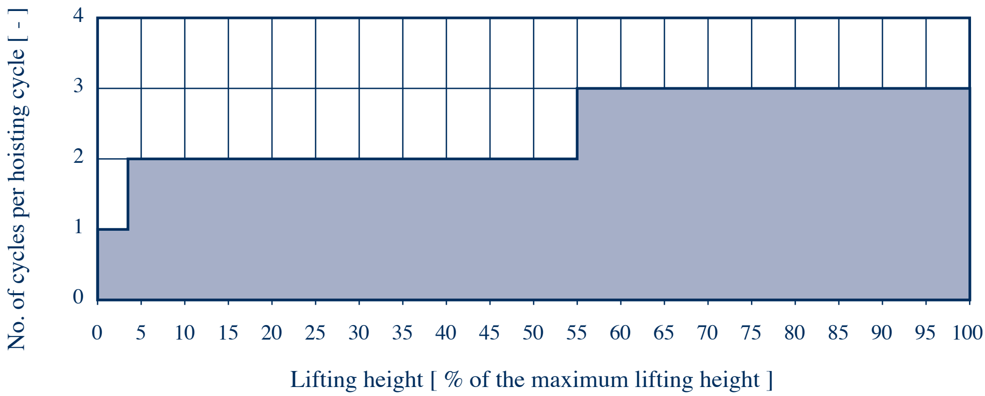

Fig. 6: Maximum number of cycles depending on the lifting height

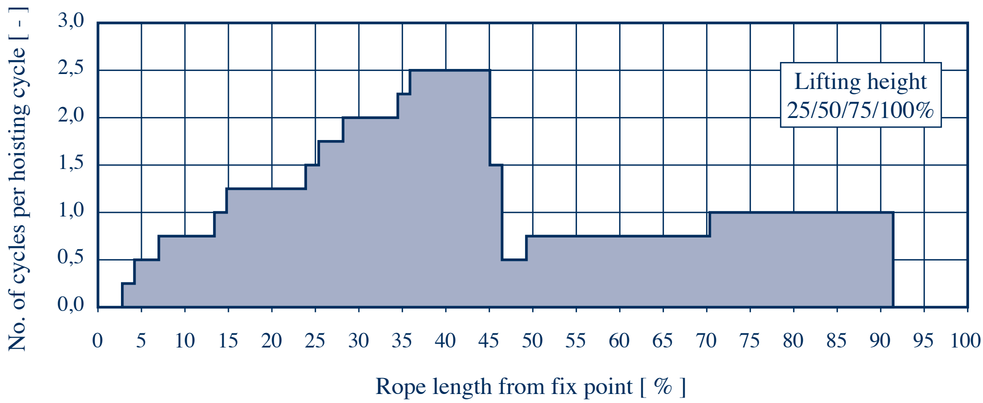

Figure 7: Distribution of bending cycles per hoisting cycle if lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height occur with the same frequency

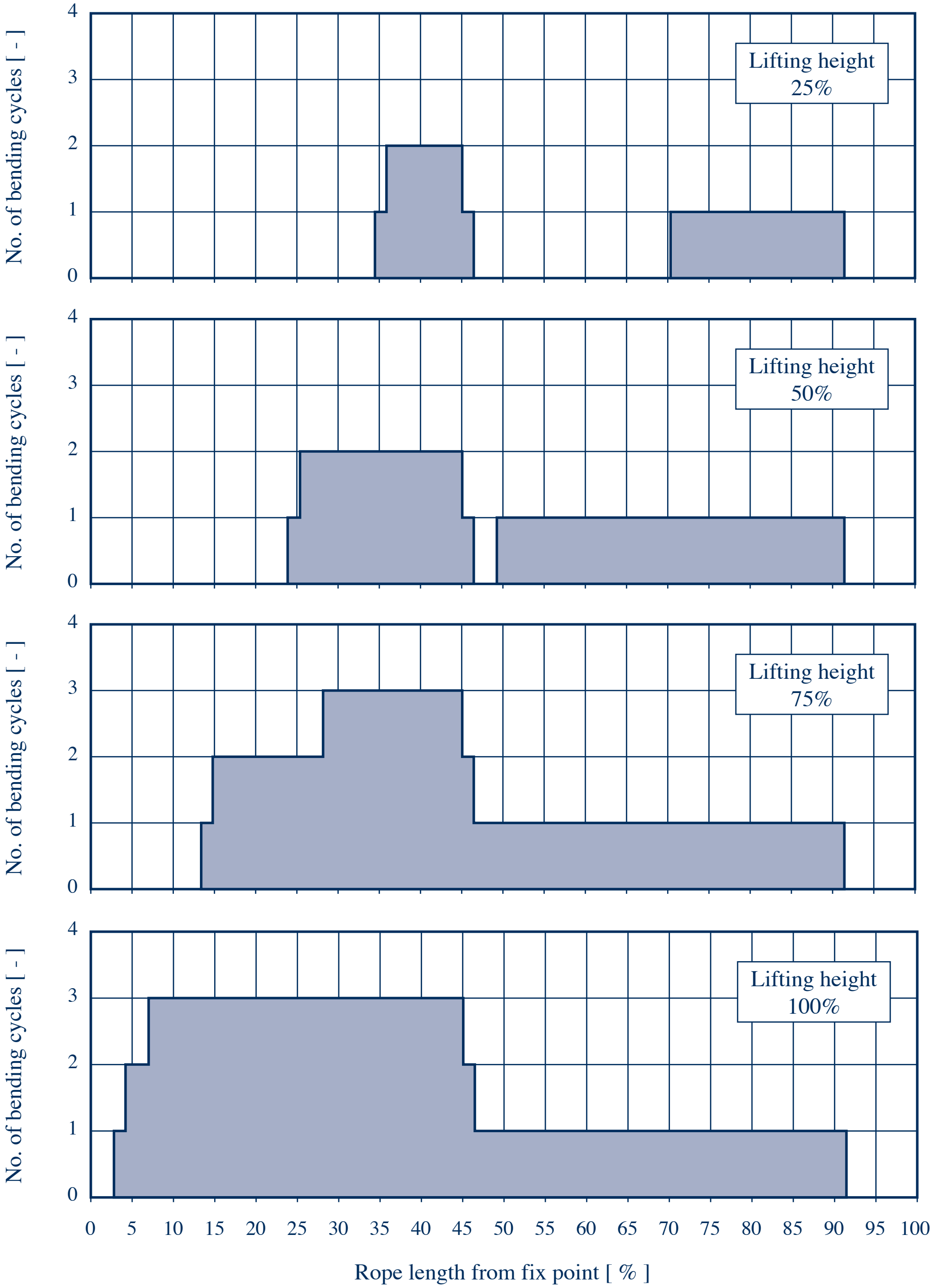

Figure 8: Number of bending cycles depending on the rope length for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height (2-part hoist)

4. The 3-part hoist

Figure 9 shows the maximum number of bending cycles for one full hoisting cycle (=1 x lifting, 1 x lowering) as a function of the lifting height. Figure 11 (next page) shows the distribution of bending cycles as a function of the rope length (expressed in % of the total rope length) for one full hoisting cycle (=1 x lifting, 1 x lowering) for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height. Figure 10 shows the average number of bending cycles for a hoist which lifts the block to these four heights with the same frequency.

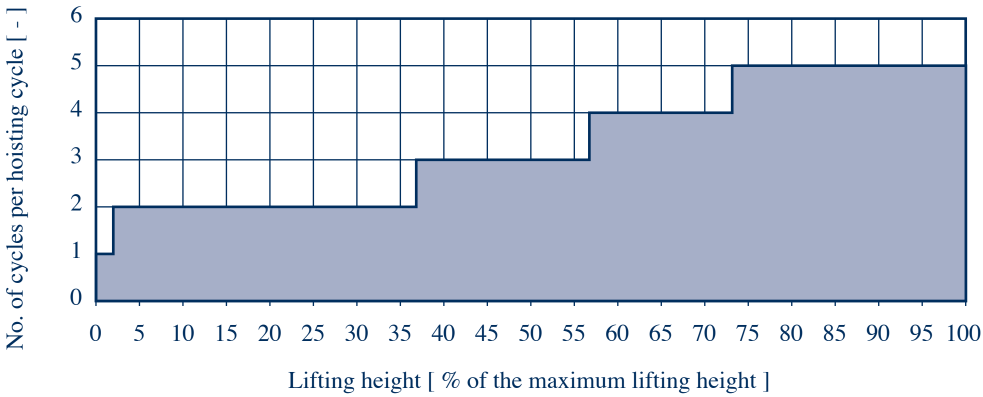

Fig. 9: Maximum number of cycles depending on the lifting height

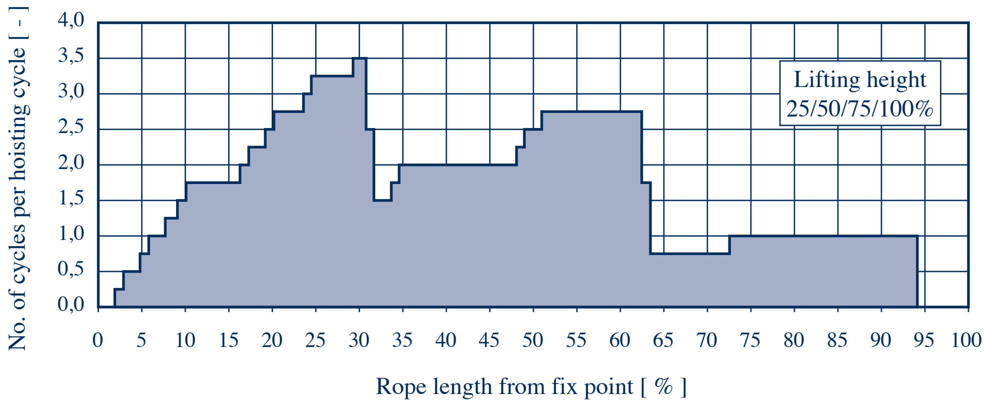

Figure 10: Distribution of bending cycles per hoisting cycle if lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height occur with the same frequency

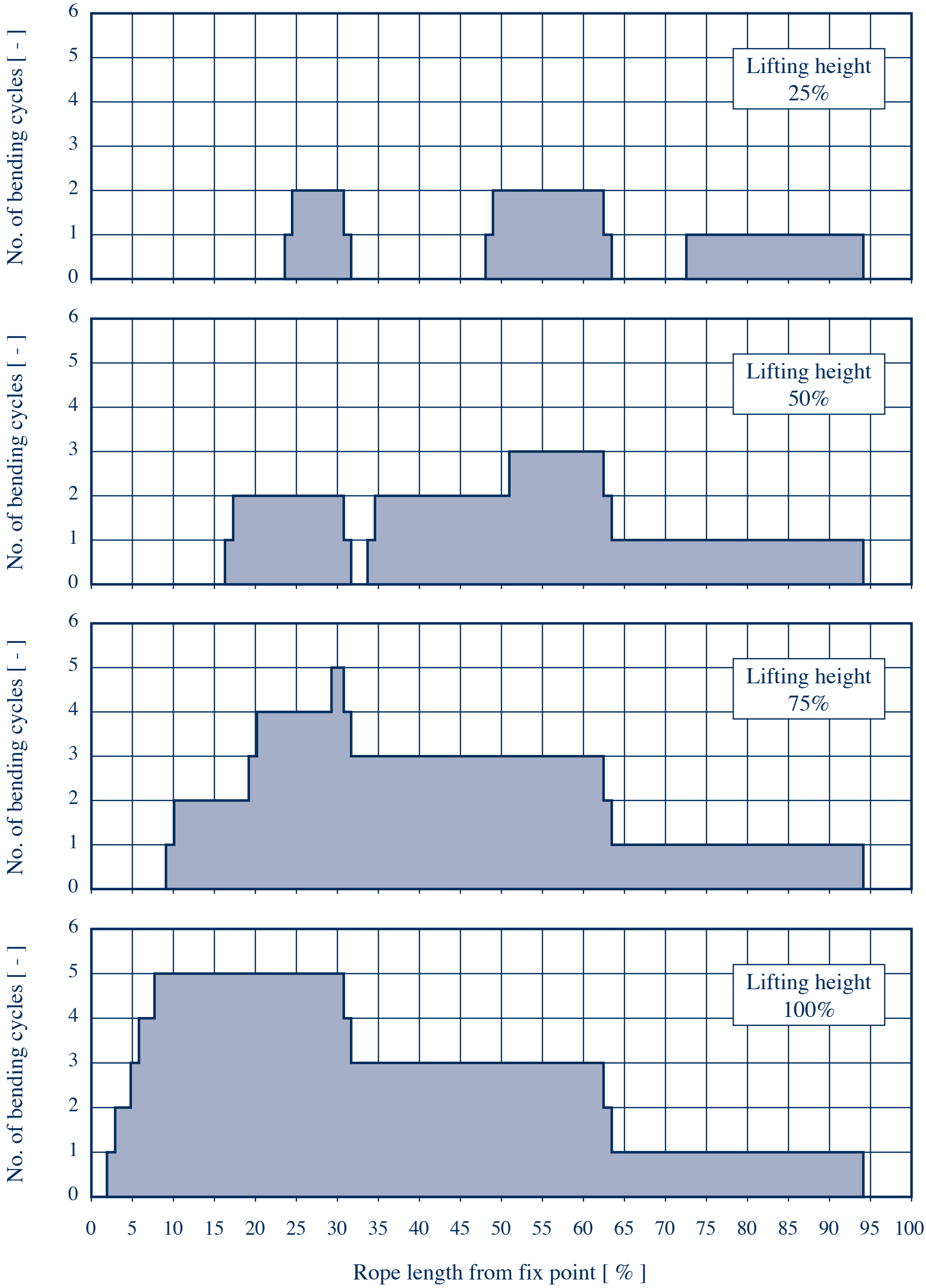

Figure 11: Number of bending cycles depending on the rope length for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height (3-part hoist)

5. The 4-part hoist

Figure 12 shows the maximum number of bending cycles for one full hoisting cycle (=1 x lifting, 1 x lowering) as a function of the lifting height. Figure 14 (next page) shows the distribution of bending cycles as a function of the rope length (expressed in % of the total rope length) for one full hoisting cycle (= 1 x lifting, 1 x lowering) for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height. Figure 13 shows the average number of bending cycles for a hoist which lifts the block to these four heights with the same frequency.

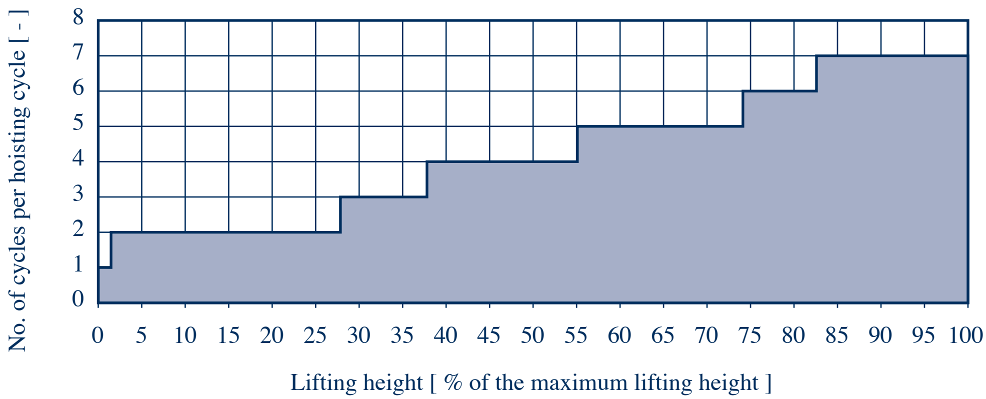

Fig. 12: Maximum number of cycles depending on the lifting height

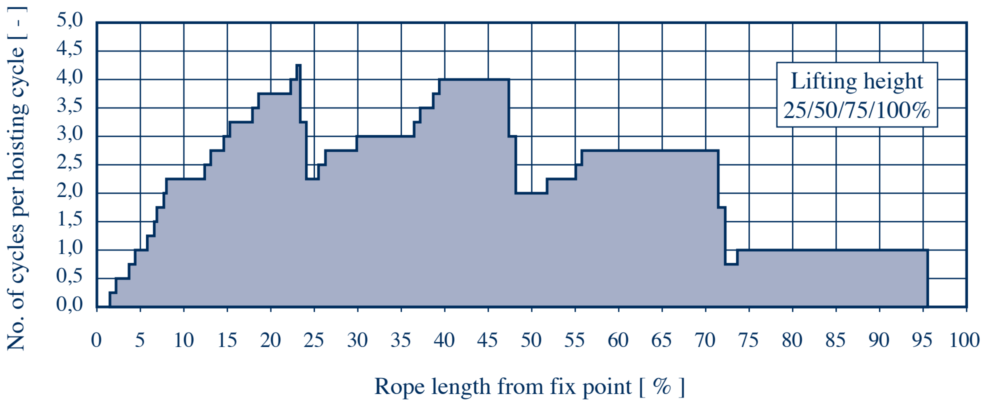

Figure 13: Distribution of bending cycles per hoisting cycle if lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height occur with the same frequency

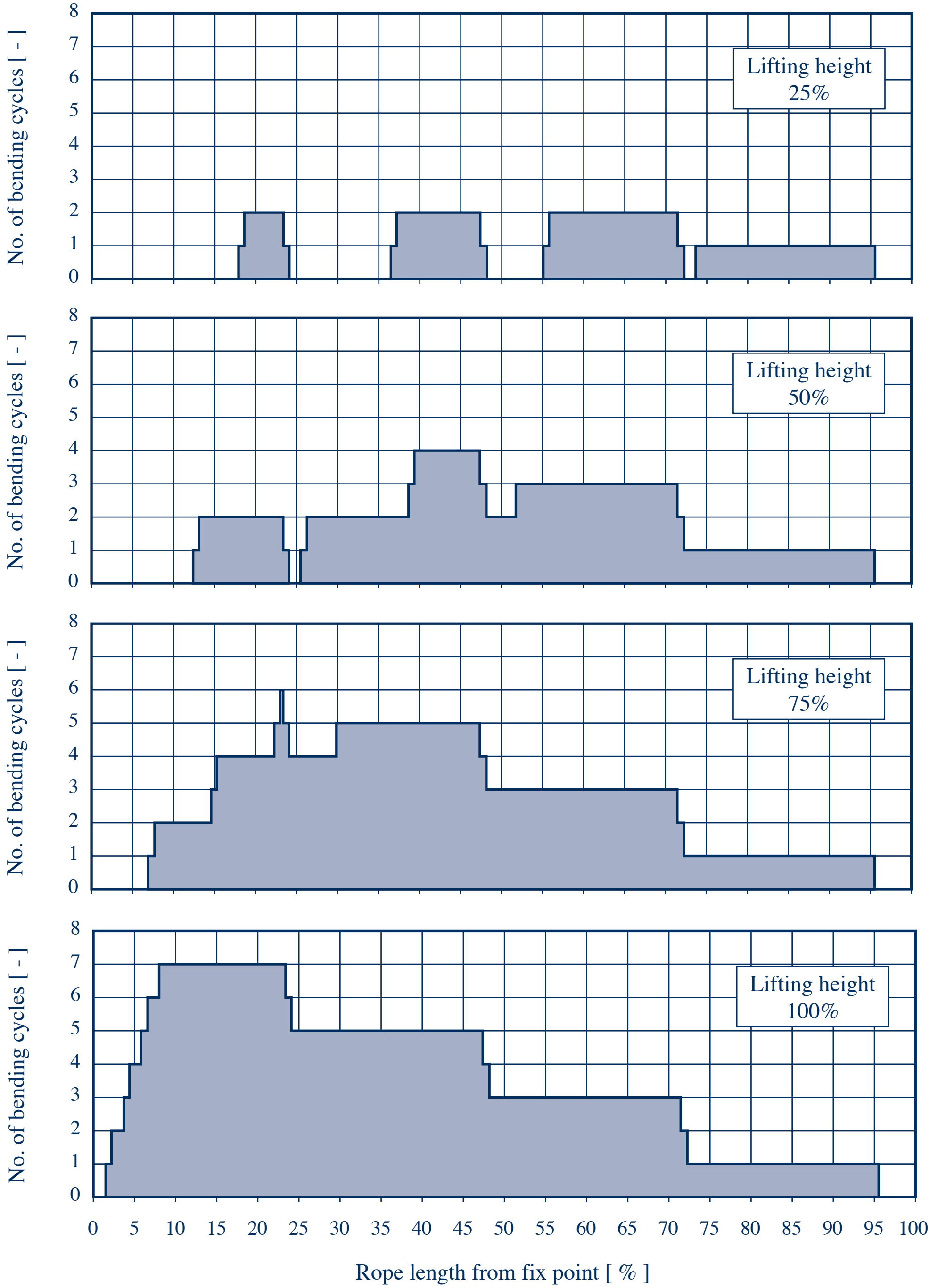

Figure 14: Number of bending cycles depending on the rope length for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height (4-part hoist)

6. The 5-part hoist

Figure 15 shows the maximum number of bending cycles for one full hoisting cycle (=1 x lifting, 1 x lowering) as a function of the lifting height. Figure 17 (next page) shows the distribution of bending cycles as a function of the rope length (expressed in % of the total rope length) for one full hoisting cycle (=1 x lifting, 1 x lowering) for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height. Figure 16 shows the average number of bending cycles for a hoist which lifts the block to these four heights with the same frequency.

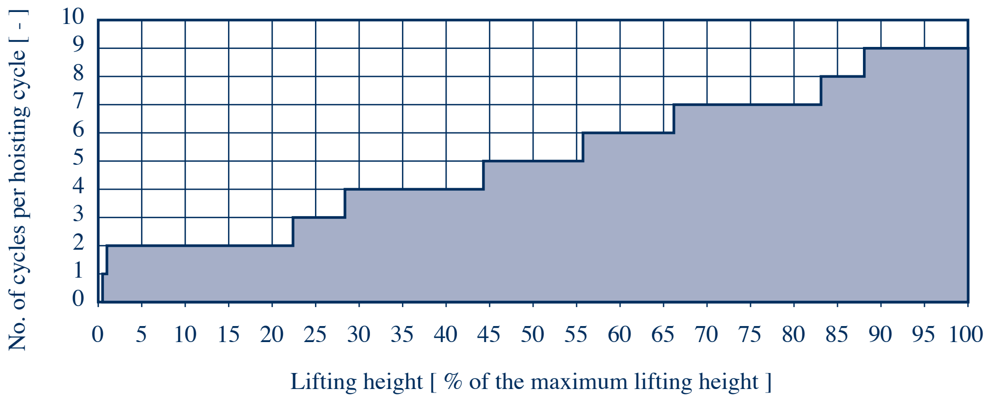

Figure 15: Maximum number of cycles depending on the lifting height

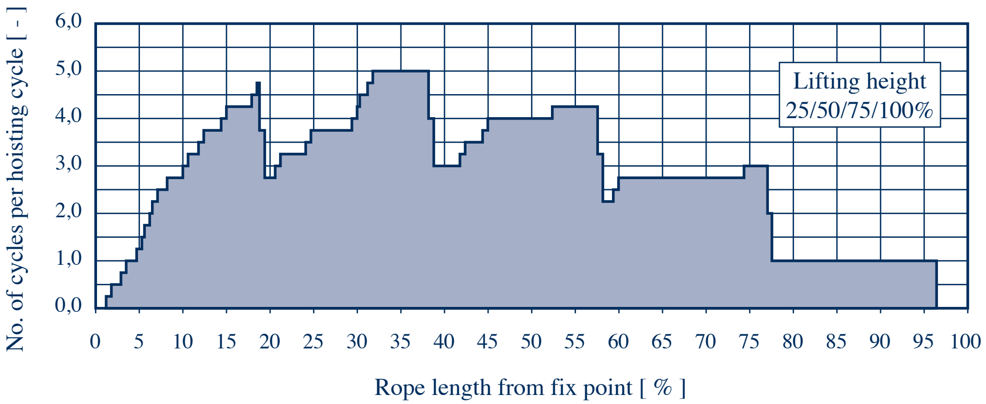

Figure 16: Distribution of bending cycles per hoisting cycle if lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height occur with the same frequency

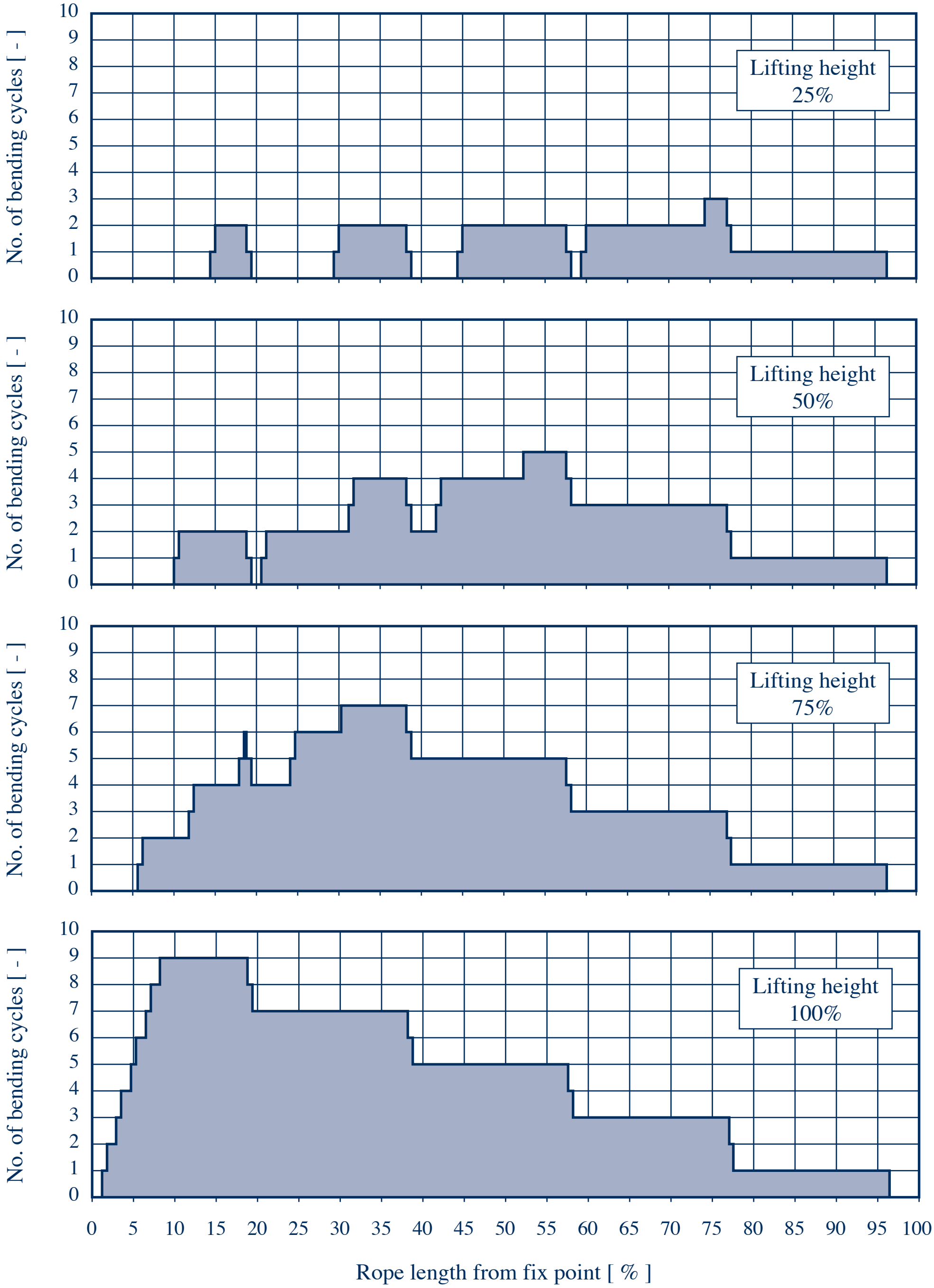

Figure 17: Number of bending cycles depending on the rope length for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height (5-part hoist)

7. The 6-part hoist

Figure 18 shows the maximum number of bending cycles for one full hoisting cycle (=1 x lifting, 1 x lowering) as a function of the lifting height. Figure 20 (next page) shows the distribution of bending cycles as a function of the rope length (expressed in % of the total rope length) for one full hoisting cycle (=1 x lifting, 1 x lowering) for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height. Figure 19 shows the average number of bending cycles for a hoist which lifts the block to these four heights with the same frequency.

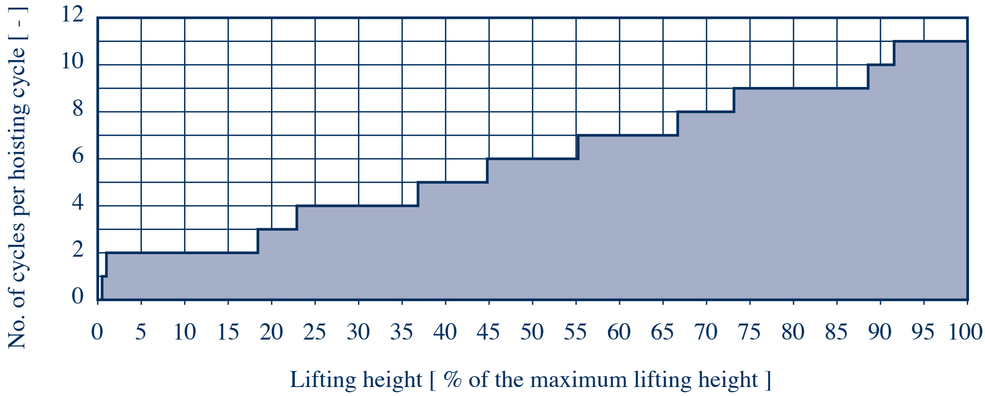

Figure 18: Maximum number of cycles depending on the lifting height

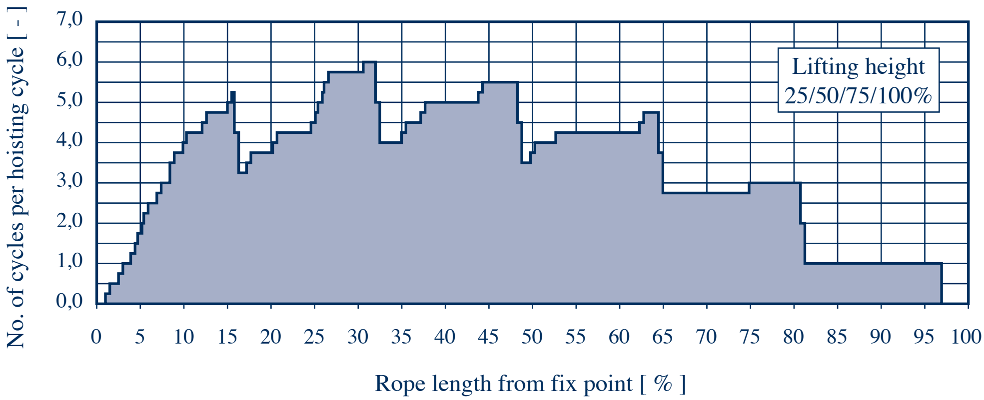

Figure 19: Distribution of bending cycles per hoisting cycle if lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height occur with the same frequency

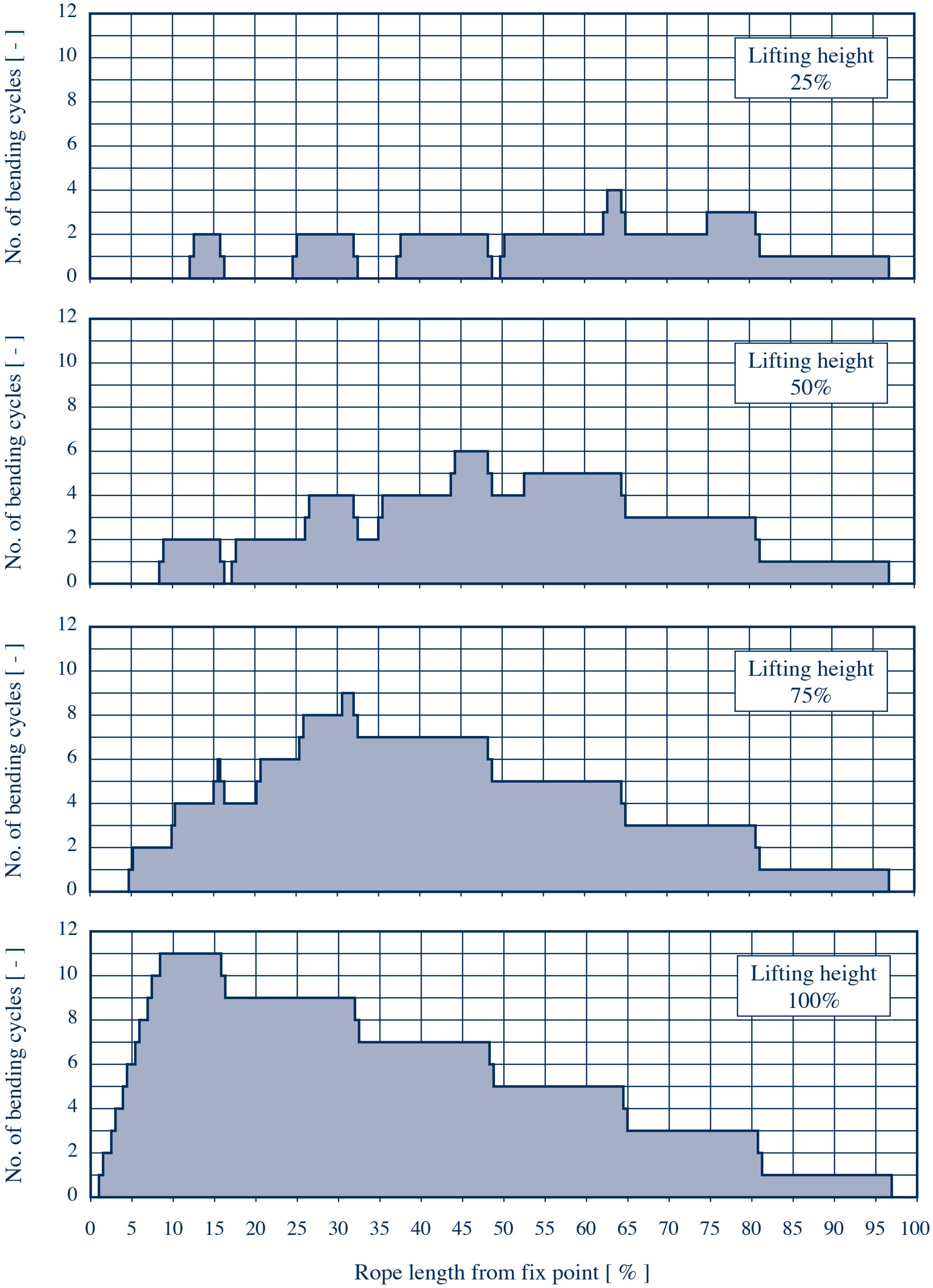

Figure 20: Number of bending cycles depending on the rope length for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height (6-part hoist)

8. The 7-part hoist

Figure 21 shows the maximum number of bending cycles for one full hoisting cycle (=1 x lifting, 1 x lowering) as a function of the lifting height. Figure 23 (next page) shows the distribution of bending cycles as a function of the rope length (expressed in % of the total rope length) for one full hoisting cycle (=1 x lifting, 1 x lowering) for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height. Figure 22 shows the average number of bending cycles for a hoist which lifts the block to these four heights with the same frequency.

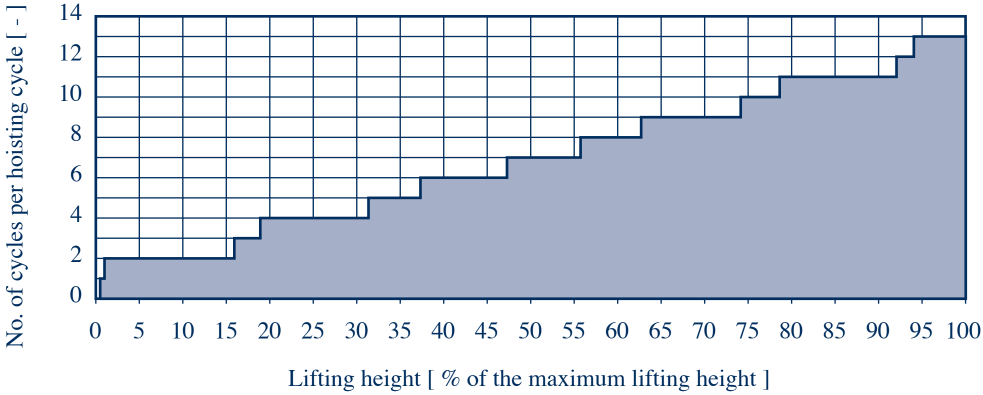

Figure 21: Maximum number of cycles depending on the lifting height

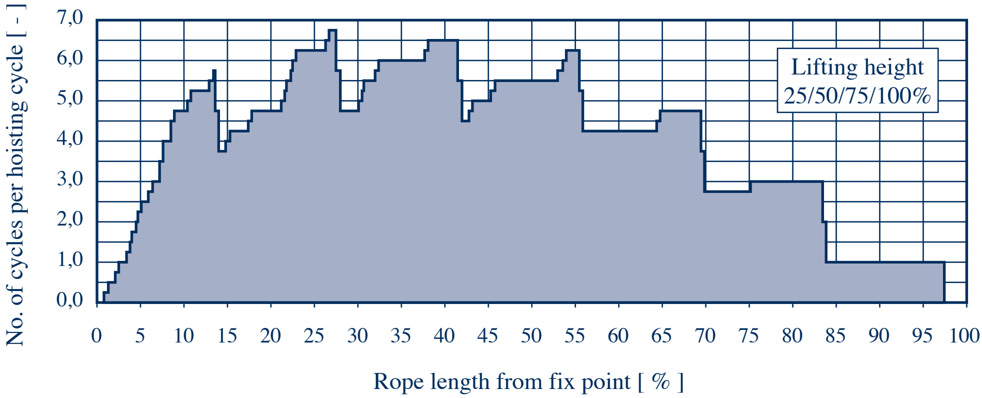

Figure 22: Distribution of bending cycles per hoisting cycle if lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height occur with the same frequency

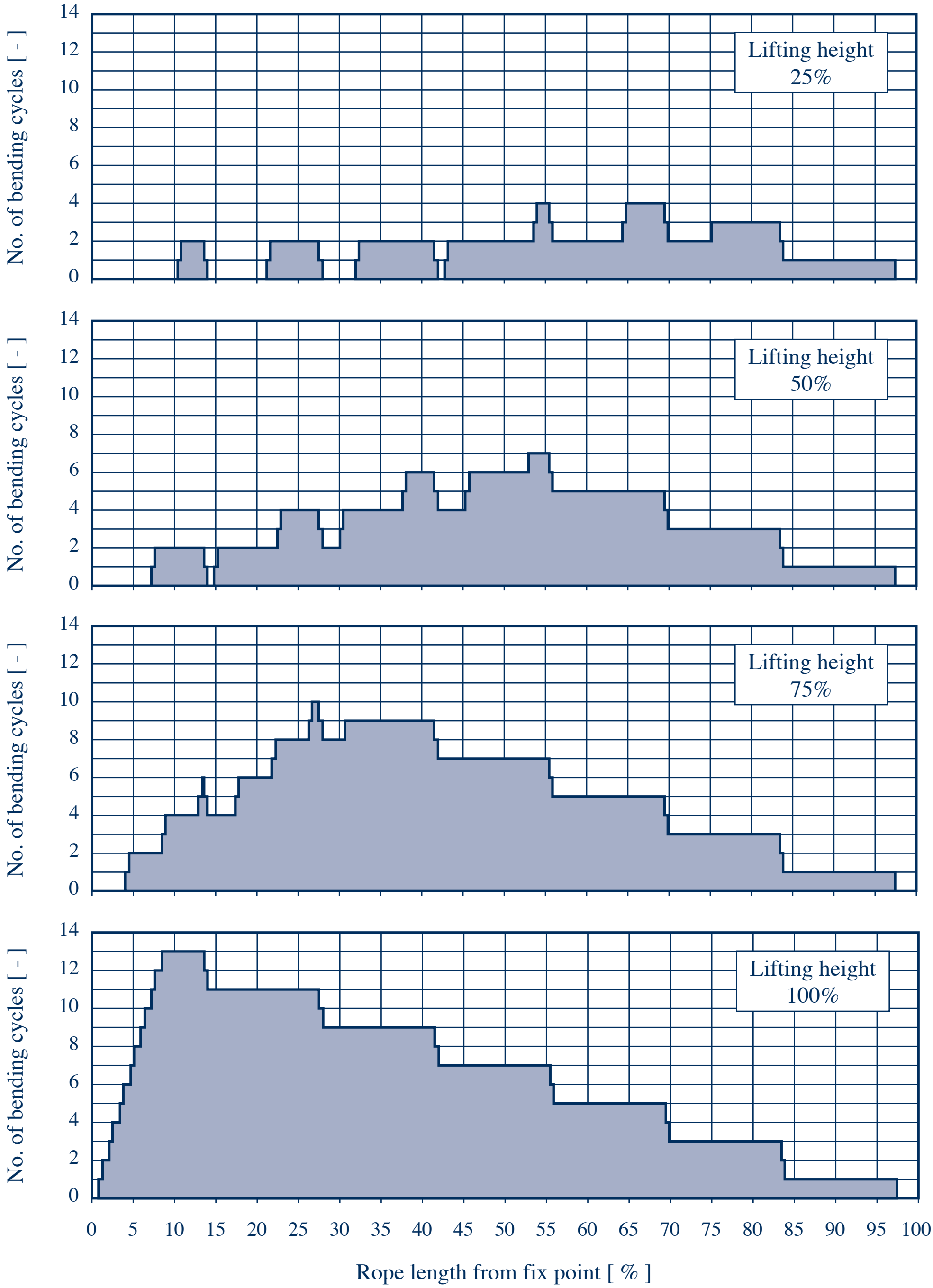

Figure 23: Number of bending cycles depending on the rope length for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height (7-part hoist)

9. The 8-part hoist

Figure 24 shows the maximum number of bending cycles for one full hoisting cycle (=1x lifting, 1x lowering) as a function of the lifting height. Figure 26 (next page) shows the distribution of bending cycles as a function of the rope length (expressed in % of the total rope length) for one full hoisting cycle (=1 x lifting, 1 x lowering) for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height. Figure 25 shows the average number of bending cycles for a hoist which lifts the block to these four heights with the same frequency.

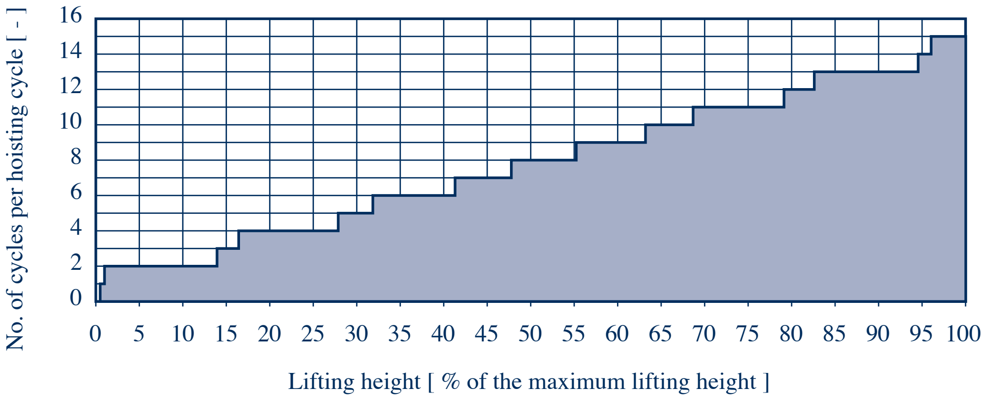

Figure 24: Maximum number of cycles depending on the lifting height

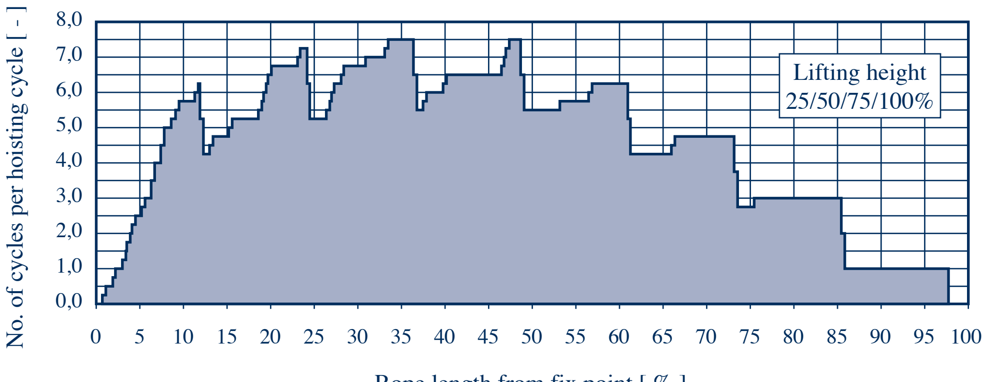

Figure 25: Distribution of bending cycles per hoisting cycle if lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height occur with the same frequency

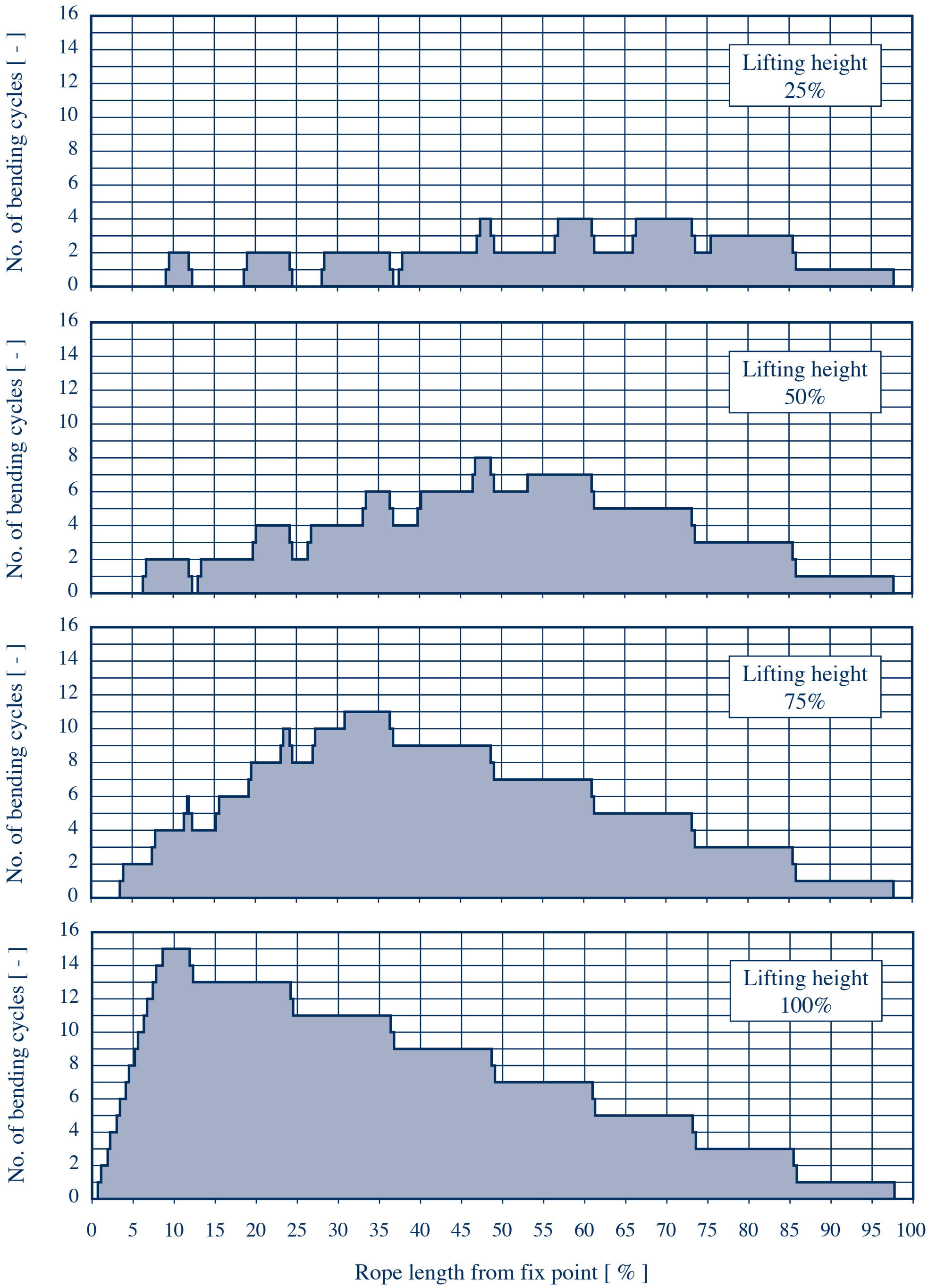

Figure 26: Number of bending cycles depending on the rope length for lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height (8-part hoist)

10. Summary

During every lifting operation, the most stressed rope section can, at most, pass over every sheave once (= 1 bending cycle each) and spool onto the drum (= 1/2 bending cycle). During every lowering operation it can at maximum spool off the drum (= 1/2 bending cycle) and pass over every sheave once (= 1 bending cycle each). In total, the maximum number of bending cycles which can be generated during a full hoisting cycle (= 1 x lifting, 1 x lowering) is therefore equal to twice the number of sheaves plus one.

100% lifting height:
Maximum number of bending cycles per lift
= 2 • number of sheaves + 1.

Figure 27 shows the maximum number of bending cycles which the eight hoists generate with lifting heights of 25%, 50%, 75% and 100% of the maximum possible lifting height. As can been seen, the maximum possible number of bending cycles (= 2 • number of sheaves + 1) is generated by every one of the hoists in hoisting cycles lifting to 100% of the maximum possible lifting height. In hoisting cycles lifting to only 50% of the maximum possible lifting height, the maximum number of bending cycles generated corresponds to the number of rope parts.

Number of parts [-]	Number of sheaves [-]	BC for 25% lift. height [-]	BC for 50% lift. height [-]	BC for 75% lift. height [-]	BC for 100% lift. height [-]
1	0	1	1	1	1
2	1	2	2	3	3
3	2	2	3	5	5
4	3	2	4	6	7
5	4	3	5	7	9
6	5	4	6	9	11
7	6	4	7	10	13
8	7	4	8	11	15

Figure 27: Maximum number of bending cycles (BC) depending on the lifting height

50% lifting height:
Maximum number of bending cycles per lift
= number of rope parts.

Figure 28 shows the average number of bending cycles which are generated when the block is lifted to lifting heights of 25%, 50%, 75% and 100% with the same frequency.

Number of parts [-]	Number of sheaves [-]	Number of bending cycles [-]	Approximation [-]	Error [%]
1	0	1.00	2.00	100
2	1	2.50	2.80	12
3	2	3.50	3.60	2.9
4	3	4.25	4.40	3.5
5	4	5.00	5.20	4.0
6	5	6.00	6.00	0.0
7	6	6.75	6.80	0.7
8	7	7.50	7.60	1.3

Figure 28: Distribution of bending cycles per hoisting cycle if lifting heights of 25%, 50%, 75% and 100% of the maximum lifting height occur with the same frequency

The number of bending cycles per hoisting cycle can be approximated by the following equation:

Random lifting height:
Maximum number of bending cycles per lift
= 1.2 + 0.8 • number of rope parts.

Figure 28 compares the number of bending cycles calculated by this formula with the real number. As can be seen, the approximation is very good for all hoists with sheaves, i.e. for all hoists except the single-part hoist. The formula either predicts the exact figure or calculates a slightly higher figure. The prediction will, therefore, always be on the conservative side.

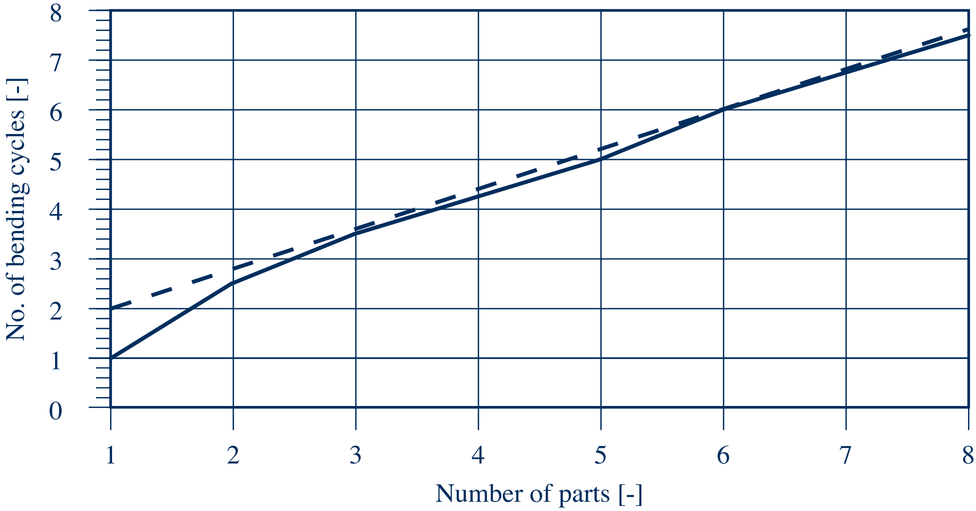

Figure 29: Real number of bending cycles (thick line) and approximation (dotted line)

Figure 29 compares the real number of bending cycles with the number of bending cycles predicted by the formula.

For the analysis presented here, the geometry of the reeving system has deliberately been chosen so that the reeving itself is located close to the drum. With increasing distance from the drum the maximum possible number of bending cycles per hoisting cycle can only decrease. Therefore, the formulas presented here will also be on the conservative side for increasing distances from the drum.

Of course, similar analyzes can also be made for your individual rope drive. The results will be the more accurate, the more details of the mode of operation of the machine are known. Do not hesitate to contact Casar or the author.

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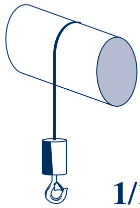
11. The right rope for electric hoists

One-part Operation

When lifting a load with one part, only rotation-resistant ropes must be used. The direction of lay must be chosen contrary to the pitch of the drum.

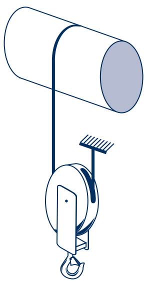


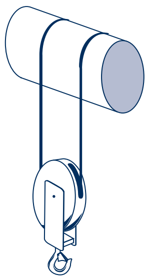
1/1

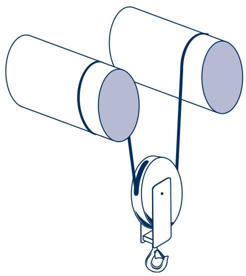
CASAR Starlift
CASAR Eurolift
CASAR Powerlift
CASAR Powerplast

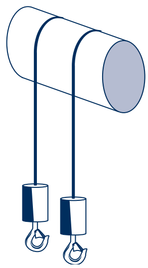
Two-part Operation

Non-rotation-resistant ropes may be used when operating a two-part system with smaller lifting heights. With greater lifting heights, however, rotation-resistant ropes are compulsory. The direction of lay must be chosen contrary to the pitch of the drum. When operating with one left hand grooved drum and one right hand grooved drum, either left hand or right hand lay ropes can be used. As one rope end will always be twisted by one of the drums, a rope with plastic layer between the steel core and the outer strands (Casar Stratoplast or Turboplast) must be used when the lifting heights are small. Casar Quadrolift is recommended for greater lifting heights.









2/1	**1 drum, 2/2**	**2 drums, 2/2**	**2/2 - 2**
Greater lifting heights CASAR Starlift CASAR Eurolift CASAR Powerlift CASAR Powerplast CASAR Quadrolift **Small lifting heights** CASAR Stratoplast CASAR Turboplast CASAR Alphalift CASAR Superplast CASAR Paraplast	Both rope ends winding on two left hand or two right hand grooved drums: cf. 2/1. One rope end winding on a left hand, the other winding on a right hand grooved drum: **Greater lifting heights:** CASAR Quadrolift **Small lifting heights:** CASAR Stratoplast CASAR Turboplast CASAR Superplast	Both rope ends winding on two left hand or two right hand grooved drums: cf. 2/1. One rope end winding on a left hand, the other winding on a right hand grooved drum: **Greater lifting heights:** CASAR Quadrolift **Small lifting heights:** CASAR Stratoplast CASAR Turboplast CASAR Superplast CASAR Paraplast	**Greater lifting heights** CASAR Starlift CASAR Eurolift CASAR Powerlift CASAR Powerplast CASAR Quadrolift **Small lifting heights** CASAR Stratoplast CASAR Turboplast CASAR Alphalift CASAR Superplast CASAR Paraplast

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