SI 1158 **תקן ישראלי ת"י 1158**

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DIN 15018 part 1 November 1984
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כללי תכן של מתקני הרמה

Rules for the design of hoisting appliances

מכון התקנים הישראלי
The Standards Institution of Israel

רח' חיים לבנון 42, תל-אביב 69977, טל' 03-6465154, פקס' 03-6412762, www.sii.org.il

תקן זה הוכן על ידי ועדת המומחים 47907 – כללי תכן של מתקני הרמה, בהרכב זה:
רם טלמור (יו"ר), מיכה סויסה, דן קרונפלד, אורי שחר, חיים שנקר

תקן זה אושר על ידי הוועדה הטכנית 479 – מתקני הרמה, בהרכב זה:

אגף הפיקוח על העבודה	-	חיים שנקר
איגוד התעשייה הקיבוצית	-	נמרוד כהן (יו"ר)
איגוד חברות הביטוח בישראל	-	שלמה גור
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התאחדות התעשיינים בישראל	-	רמי השמשוני, דן קרונפלד, אורי שחר
לשכת המהנדסים והאדריכלים	-	יוסף פסח
מכון התקנים הישראלי – אגף התעשייה	-	מיכה סויסה
צבא ההגנה לישראל – חיל החימוש	-	זיו גולדפרב
רשות ההסתדרות לצרכנות	-	גדעון כץ

אלון שמש ולימור ארגמן ריכזו את עבודת הכנת התקן.

הודעה על מידת התאמת התקן הישראלי לתקנים או למסמכים זרים

תקן זה זהה למסמך של האיגוד האירופי לשינוע חומרים

F.E.M. 1.001 3rd EDITION REVISED 1998.10.01

(וראו הערה בהקדמה לתקן הישראלי)

או

לתקנים הלאומיים:

DIN 15018 part 1 November 1984

DIN 15018 part 2 November 1984

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הודעה על רוויזיה

תקן זה בא במקום

התקן הישראלי ת"י 1158 חלק 1 מפברואר 1982

התקן הישראלי ת"י 1158 חלק 2 מאוקטובר 1991

(וראו להלן הערה לאומית בסוף החלק העברי של התקן)

מילות מפתח:

מתקני הרמה, ציוד הרמה, התקנים המופעלים בחשמל, עגורנים, כננות, בטיחות ציוד.

Descriptors:

hoists, lifting equipment, electrically-operated devices, cranes, winches, equipment safety.

עדכניות התקן

התקנים הישראליים עומדים לבדיקה מזמן לזמן, ולפחות אחת לחמש שנים, כדי להתאימם להתפתחות המדע והטכנולוגיה.

המשתמשים בתקנים יוודאו שבידיהם המהדורה המעודכנת של התקן על גיליונות התיקון שלו.

מסמך המתפרסם ברשומות כגיליון תיקון, יכול להיות גיליון תיקון נפרד או תיקון המשולב בתקן.

תוקף התקן

תקן ישראלי על עדכוניו נכנס לתוקף החל ממועד פרסומו ברשומות.

יש לבדוק אם המסמך רשמי או אם חלקים ממנו רשמיים. תקן רשמי או גיליון תיקון רשמי (במלואם או בחלקם) נכנסים לתוקף 60 יום מפרסום ההודעה ברשומות, אלא אם בהודעה נקבע מועד מאוחר יותר לכניסה לתוקף.

סימון בתו תקן

כל המייצר מוצר, המתאים לדרישות התקנים הישראליים החלים עליו, רשאי, לפי היתר ממכון התקנים הישראלי, לסמנו בתו תקן:

הקדמה לתקן הישראלי

תקן ישראלי זה דן בכללי תכן של מתקני הרמה.

מטרת כללים אלו היא לקבוע את העומסים ואת שילוב העומסים שיש להביא בחשבון כאשר מתכננים מתקני הרמה, וכן לקבוע את תנאי החוזק והיציבות הבסיסיים שיש לשמור בשילובי עומס שונים.

תקן ישראלי זה הוא

המסמך של האיגוד האירופי לשינוע חומרים F.E.M. 1.001 (מהדורה שלישית) מאוקטובר 1998 (להלן: "המסמך האירופי"), שאושר כלשונו כתקן ישראלי.

הערה:

במסמך זה ניתן לעיין בספריית מכון התקנים הישראלי,

או

תקן ישראלי זה הוא

התקנים הלאומיים DIN 15018 חלקים 1 ו-2 מנובמבר 1984, DIN 15019 חלק 1 מספטמבר 1979, DIN 15019 חלק 2 מיוני 1979, DIN 15020 חלק 1 מפברואר 1974 ו-DIN 15020 חלק 2 מאפריל 1974 (להלן: "התקנים הלאומיים"), שאושרו כלשונם כתקן ישראלי.

תקן זה מאפשר בחירה בין עמידה בדרישות המסמך האירופי לבין עמידה בדרישות התקנים הלאומיים (DIN).

תקן זה כולל, בסדר המפורט להלן, רכיבים אלה:

- תרגום סעיף חלות המסמך האירופי (בעברית)
- תרגום תחומי היישום או החלות של התקנים הלאומיים (DIN) (בעברית)
- סעיף התאמה לתקן (בעברית)
- הערה לאומית (בעברית)
- התקנים הלאומיים (כלשונם)

חלות המסמך האירופי (תרגום סעיף 1.4 של המסמך האירופי)

הכללים דנים בתכן של מתקני הרמה או של חלקים של מתקני הרמה שמופיעים ברשימת המונחים לעגורנים ולמתקני הרמה שב-.F.E.M, Section I.

.F.E.M, Section I, אינו חל על מתקני הרמה אלה:

1) מתקני הרמה הנכללים ב-.F.E.M, Section V, לדוגמה:
- עגורני זרוע ניידים, הנעים על צמיגי גומי פנימטיים או צמיגי גומי מלאים (solid), או על זחלים (crawler tracks), או על משאיות, או על גרורים (המילה brackets הושמטה).

2) ציוד הרמה שבהתאם לתקנות פנימיות של .F.E.M נכלל ב-.F.E.M, Section IX, כלומר:
- פריטים שונים של ציוד הרמה סדרתי (series lifting equipment),
- גלגלות הרמה חשמליות (electric hoists),
- גלגלות הרמה פנימטיות (pneumatic hoists),
- אמצעי עזר להרמה (accessories for lifting),
- גלגלות שרשרת המופעלות ידנית (hand operated chain blocks),
- במות הרמה (elevating platforms), במות עבודה (work platforms), משטחים משווי-גובה לרציפי פריקה (dock levellers),
- כננות (winches),

- מגבהים, חצובות, התקן משולב למשיכה ולהרמה,
- עגורני מחסן (stacker cranes).

עבור ציוד הרמה סדרתי (series lifting equipment), רצוי להשתמש בפרקים של כללי התכן של Section I שהתקבלו על ידי .F.E.M, Section IX.

כללים אלה כוללים שמונה חוברות (booklets). נוסף על כך, חלק מהחוברות מכילות נספחים המספקים מידע נוסף על שיטת היישום.

תחומי היישום או החלות של התקנים הלאומיים

תחום היישום של התקן הלאומי DIN 15018 חלק 1 (תרגום סעיף 1 של התקן הלאומי)

תקן זה חל על מבני פלדה של עגורנים וציוד לעגורנים מכל טיפוס, וכן על מבני פלדה ניידים עבור מסועים רציפים.

תקן זה אינו חל על מסילות לעגורנים (craneways), מחפרים, רכבלים, מתקנים להיפוך קרונות (wagon tipplers) ומכונות כרייה.

תחום היישום של התקן הלאומי DIN 15018 חלק 2 (תרגום סעיף 1 של התקן הלאומי)

תקן זה חל על מבני פלדה של עגורנים מכל הטיפוסים, וכן על מבני פלדה ניידים עבור מסועים, למעט מסועים רוטטים.

תקן זה אינו חל על מסילות לעגורנים (craneways), מחפרים, רכבלים ומתקנים להיפוך קרונות (wagon tipplers).

תחום היישום והמטרה של התקן הלאומי DIN 15019 חלק 1 (תרגום סעיף 1 של התקן הלאומי)

1.1 תקן זה חל על כל העגורנים שהתקן הלאומי DIN 15018 חלק 1 חל עליהם ושהתנגדות שלהם להתהפכות (toppling over) ולסחיפה (drifting) כתוצאה מרוח צריכה להיות מוכחת. כמו כן, התקן חל על כל חלקי העגורן שאינם מקובעים למבנה התומך.
תקן זה חל גם על עגורנים ניידים שאינם מותקנים על מסילה עם מגדל קבוע.

1.2 תקן זה אינו חל על עגורנים ניידים אחרים שאינם מותקנים על מסילה או על עגורנים צפים או על עגורנים המקובעים ליסודות או לבניינים.

תחום החלות של התקן הלאומי DIN 15019 חלק 2 (תרגום סעיף 1 של התקן הלאומי)

תקן זה חל על עגורנים ניידים שאינם מותקנים על מסילה, המופעלים על ידי מנוע באופן מלא או באופן חלקי.

עגורנים ניידים מוגדרים ומתוארים בתקן הלאומי DIN 15001 חלק 1.

תחום החלות של התקן הלאומי DIN 15020 חלק 1 (תרגום סעיף 1 של התקן הלאומי)
תקן זה חל על מערכות כבלים של עגורנים (ראו DIN 15001) ועל ציוד הרמה סדרתי (ראו DIN 15100) מכל טיפוס.
תקן זה אינו חל על מערכות כבלים עם גלגלת מונעת בחיכוך, מערכות כבלים למחפרים, מעליות, רכבלים ומנועי ליפוף (winding engines), ואף לא על מערכות כבלים על סיפון אוניות למעט עגורני סיפון.
תקן זה אינו חל גם על מערכות כבלים שאינן נעות על תופי כבל או/וגם על גלגלות כבל (כבלי נשיאה וכבלי מתיחה) וכבלי מענבים.

תחום החלות של התקן הלאומי DIN 15020 חלק 2 (תרגום סעיף 1 של התקן הלאומי)
תקן זה חל על הפיקוח בזמן פעולה של מערכות הכבלים, שהחישובים והמבנה שלהן מתוארים בתקן DIN 15020 חלק 1.

בסוף המסמך האירופי ובסוף התקנים הלאומיים יוסף סעיף התאמה לתקן והערה לאומית כמפורט להלן:

התאמה לתקן
מתקני הרמה מתאימים לתקן ישראלי זה, ת"י 1158, אם עמדו בכל דרישות המסמך של האיגוד האירופי לשינוע חומרים F.E.M. 1.001 (מהדורה שלישית) מאוקטובר 1998,
או
עמדו בכל דרישות התקנים הלאומיים DIN 15018 חלקים 1 ו-2 מנובמבר 1984, DIN 15019 חלק 1 מספטמבר 1979, DIN 15019 חלק 2 מיוני 1979, DIN 15020 חלק 1 מפברואר 1974 ו-DIN 15020 חלק 2 מאפריל 1974.

הערה לאומית:
תקן זה ייכנס לתוקף חצי שנה לאחר פרסומו ב"רשומות".

with DIN 15 020 Part 1. The reference to the original wire rope was deliberately made because in some cases wire ropes have to be renewed very promptly and if need be in a makeshift fashion, and it was, therefore, considered that a reference to the discarded wire rope was not sufficient.

Re Section 3.3

Wire ropes are usually re-lubricated in order to prolong their service life. In the final paragraph, mention is made of the fact that re-lubrication of the wire rope has to be dispensed with in some cases. This applies in particular in cases where the material conveyed, or other goods in process of manufacture and lying beneath the crane might be adversely affected by drips of lubricant. Of course, the service life of the wire rope is reduced in such cases.

Re Section 3.4.2

The criteria relating to the readiness for discarding of ropes specified in this Section are applicable to pure hoisting duties, i.e. to the vertical or almost vertical lifting of loads. However, winches for horizontal traction also from part of the lifting appliances. In the case of such winches, and in particular in the case of winches mounted on motor vehicles, the ropes are used in some cases until complete fracture occurs.

The prerequisite for this type of operation is that accidents are prevented by taking suitable safety precautions.

Re Section 3.4.2 a

Wire breaks, apart from those caused by improper laying of the rope, occur only after a given period of operation of the wire rope has elapsed, and thereafter they occur at increasingly frequent intervals; naturally the higher the loading, the more frequently the wire breaks occur. The number of wire breaks which justifies the discarding of the rope must be specified in such a way that the inspections of the wire rope can remain within economically accetable time intervals, without incurring the risk of dangerous conditions arising as a result of the unintentional overstepping of the number of wire breaks which may possibly have occurred. For this reason, lower numbers of visible wire breaks have been specified as justifying readiness for discarding, in the case of the drive groups 1 E_m to 1 A_m in accordance with DIN 15 020 Part 1, than have been specified for the drive groups 2_m to 5_m. There is little risk of practical difficulties in this respect, because the group into which the relevant lifting appliance has been graded is almost always known.

In addition, the rope design (type of rope making) also influences the number of permissible wire breaks. The supervision of the internal strands and of the steel cores presents the greatest difficulties. In order to take these relationships into consideration and to be able to group all the relevant data in o n e table as simply as possible, the permissible number of wire breaks has been specified in function of the load-bearing wires in the outer strands of the wire rope.

For practical applications, this table can be simplified: Because the rope design is known, only the appropriate line of the table applies in each case. It is also useful for the operator to ask the rope manufacturer to indicate the number of load-bearing wires in the outer strands of the wire rope, e.g. in the works certificate supplied with the wire rope.

Re Section 3.4.2 d

In the case of wire ropes with a steel core, the rope diameter can become smaller over lengthy segment of the rope, due to wear of the core. This phenomenon is a sure indication of wear of the rope and is, therefore, included among the factors determining the readiness for discarding the rope. The specified percentage is related to the nominal diameter, in order to avoid the necessity of having to measure the actual diameter of every newly laid rope and of having to record this measurement.

The specified percentage presupposes that the tolerance zones specified in the Standards DIN 3055 to DIN 3070 are complied with. In the case of non-standardized ropes, which have different tolerances, suitable investigations must be carried out in each case, and the permissible values determined accordingly.

Re Section 4

Rope suspensions and rope attachments represent components of lifting appliances which are exposed in the same way as load hooks are; the fracture of the rope or of components of the rope suspensions result in the crash of the load. For this reason, similar yardsticks to those which apply to load hooks and to other load lifting devices must apply here.

Particular attention is drawn to the fact that wire breaks at the rope suspensions and at the rope attachments are often hard to detect. For this reason, it is necessary to carry out particularly thorough inspections.

5 Rope drums, rope pulleys and compensating pulleys

Rope drums, rope pulleys and compensating pulleys must be inspected as required, but at least once a year, and also on every occasion when a new wire rope is laid. In this connection, make sure that all the elements are able to rotate easily in their bearings. Rope pulleys which either stick fast or only rotate with difficulty result in increased wear of the pulleys and wear of the wire rope, whilst compensating pulleys which stick fast cause the rope plies to be loaded unevenly.

Rope pulleys and compensating pulleys which only rotate with difficulty must be repaired or replaced by new ones if the faulty operation cannot be cured by re-lubrication.

In addition, it must be checked whether the groove radius still matches the nominal rope diameter. If the groove radius has become too large in the course of the operating life, then the grooves must be touched up by machining. If the groove radius has become too small, then the grooves must be touched up in view of the service life of the rope. Touching up will also be required if sharp edges have been formed on the groove by wear, as these sharp edges may lead to local overstressing of the wire rope.

Weld seams on rope drums, rope pulleys and compensating pulleys must be checked in respect of freedom from surface cracks. If surface cracks are detected in weld seams, the components concerned must be either repaired or replaced by new ones.

Explanations

Wire ropes in the rope drives of lifting appliances cannot be dimensioned in such a way that they exhibit an unlimited fatigue strength for all time, and in addition they are subjected to a wide variety of wear phenomena. For these reasons, the careful supervision during operation of the wire ropes is of essential importance to guarantee an accident-free operation of the lifting appliances. The entire contents of this standard must, therefore, be regarded in the light of a technical safety stipulation in accordance with the Law on Technical Equipment.

The factual contents of this standard are in accordance with the current deliberation results of an ISO Working Group.

In DIN 15020 Part 2, November 1954 edition, "Cranes, electric hoists and winches; rope drives; condition of wire ropes which necessitates the discarding thereof" – the condition necessitating the discarding of wire ropes was limited in the main to the occurrence of wire breaks. Practical experience has shown that other criteria are also of importance in determining the readiness for discarding of a wire rope, and that they must consequently be taken into account in the standard. The VDI Technical Group Materialfluss und Fördertechnik (Materials Handling and Conveying Technology) have been aware of the deficiency of the previous version of the standard in this respect for a long time already, and they have drawn attention to the various types of rope damage and to their influence on the readiness for the discarding of the ropes in VDI Guideline 2358 (12.67 edition). This preliminary study has been carried out with such meticulous care that it has been possible to adopt the terminology of the types of rope damage and of the criteria relating to the readiness for discarding of the ropes in this standard with practically no factual alteration from the VDI Guideline. We should, therefore, like to express our thanks to the VDI Technical Group Materialfluss und Fördertechnik for this preliminary study and for the photographs of types of damage to wire ropes which they so kindly put at our disposal.

At the request of the crane operators, for whom this standard is especially intended, the contents of the standard have now been enlarged to such an extent that they not only cover all types of rope damage which are liable to occur, but also the necessary supervision work in respect of a l l the components of the rope drive. In this way, a complete document has now been drawn up, which can, if necessary, be handed over to the maintenance personnel in its present form, and which makes it unnecessary to compile any particular operational instructions.

Inasmuch as is necessary, the following explanations relating to individual sections of this standard are reproduced below:

Re Section 2

The rope drives of lifting appliances cannot be sized in a way which ensures that the ropes exhibit a fatigue strength; in addition, both the ropes and the other components of the rope drive are subjected to wear. The correct and proper performance of maintenance and supervision work on rope drives has a decisive effect on the accident-free, and consequently on the reliable operation of the lifting appliances.

Re Section 3.1

Wire ropes coated or sheathed with plastics are specifically barred from use in lifting appliances in this Section, because they must be regarded as particularly accident-prone. In addition to the complications they cause in respect of supervision, which are mentioned in the standard, it should also be mentioned that wire ropes of this type are particularly susceptible to corrosion, because any water which penetrates under the sheathing is drawn further into the interior of the rope by capillary action, and is unable to evaporate there. This destructive process starts already during the storage period of the rope, and is completely invisible from outside. Serious accidents caused by such wire ropes have come to light: the rope break occurred only hours after the wire rope had been laid, and was of course totally unexpected.

Re Section 3.2

In the first paragraph, attention is drawn to the fact that the rope drive must be reeved in the same way as it was originally reeved, when fitting a new rope, i.e. in the way in which it was supplied by the manufacturer with the lifting appliance. Any change must be verified in accordance

Kinks (see Fig. 9) are deformations of the wire rope caused by a violent outside action.

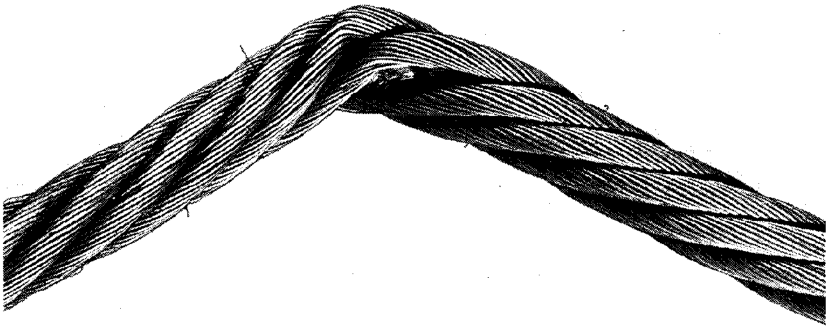

Figure 9. Wire rope with kink

Wire ropes with kinks must be discarded.

h) Effect of heat

Wire ropes which have been subjected to an excessive exposure to heat (ascertainable by the presence of temperature discoloration of the outside of the rope) must be discarded.

i) Service life

If adequately extensive operational experience details are available, the moment in time for the renewal of the wire rope can be estimated in advance, within the framework of a preventive maintenance programme, providing that the operating conditions do not change, and that the type of rope remains the same. The determining factors for discarding remain however the criteria a) to h) specified above.

4 Rope suspensions and rope attachments

The end of the wire rope to be laid anew must be of such a condition that a durable guarantee exists that the rope structure will not become slack in time (e.g. by flash butt welding or by serving with wire), in so far as the rope formation itself is not unravelled by the nature of the rope attachment (e.g. in the case of splicing or sweating).

When a new wire rope is laid, no alterations and/or additions must be made to the rope suspensions and rope attachments [5], i.e. the rope end must be inserted in the same way as the original wire rope end was inserted.

After a new wire rope has been laid, the rope suspensions must be checked at regular intervals. This inspection includes checking the correct seating of the wire rope in the attachment and the correct attachment to the adjoining support structure, in particular in the case of screwed connections to the support structure.

DIN 15405 Part 1 must be followed as appropriate, in respect of the supervision of forged components of rope suspensions. As regards cranes for dangerous transport applications (e.g. foundry cranes), it is recommended to carry out a visual inspection at three-monthly intervals, and an inspection in respect of absence of surface cracks and of internal fissures at least once a year.

Sweated rope ends must be inspected at regular intervals for wire breaks and corrosion in the immediate vicinity of the exit of the wire rope out of the cast sealing metal. The seizing prescribed at this spot by DIN 83315 must be removed for inspection. If any damage has occurred, the rope end must be cut off and the rope sweated afresh.

Rope suspensions using compression clips must be checked in respect of wire breaks next to the clip, cracks in the material of the clip and slippage of the wire rope. If any such damage has occurred, the wire rope must be shortened and the joint renewed.

Detachable rope suspensions (rope sockets, rope clamps for drums and the like) must be checked in respect of wire breaks and corrosion in the wire rope, slippage of the wire rope and slackening of the fastening bolts. If wire breaks or corrosion have occurred, the wire rope must be shortened and fastened afresh, and in the event of slippage and slackening of the clamping bolts, the connection must be tightened.

Spliced rope suspensions must be carefully inspected in respect of wire breaks and slippage of the inserted strands. For this reason, the entire zone of the splice must not be wrapped around with seizing or lined.

If any slackening, slippage or other displacement has been ascertained at the splice, the splice must be renewed.

If a rope socket is used as rope suspension, the free rope end must be secured against pull through. The device used for securing the rope end must not connect the free rope end to the load carrying rope ply by means of a force-transmitting connection.

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5) If any modifications to rope suspensions or rope attachments become necessary, then the new shape must satisfy the requirements of DIN 15020 Part 1.

Contractions (see Fig. 6) are reductions in the diameter of the wire rope over short stretches.
Rope segments immediately next to the end attachments must be examined in respect of contractions with particular care, because contractions are often difficult to pinpoint at such locations.

Figure 6. Wire rope with contraction

Wire ropes which exhibit marked contractions must be discarded.

Flattenings (see Fig. 7) are permanent deformations of the wire rope, caused by squeezing.

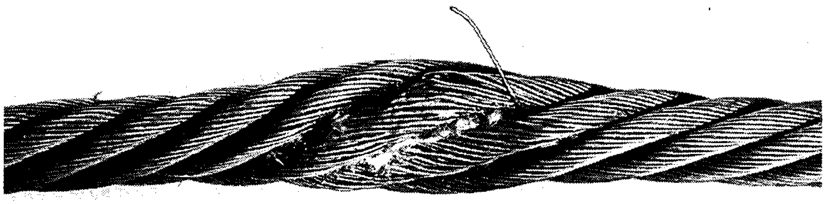

Figure 7. Wire rope with flattening caused by driving over the rope

Flattenings result in increasing wire breaks.

Curly deformation occurs when a loaded wire rope is pulled over a sharp edge.
Wire ropes with curly deformation must be discarded.

Knots (see Fig. 8) are deformations of the wire rope which arise when an eye-shaped rope loop is pulled straight without giving the wire rope the chance of compensating the deformation by twisting about its axis.

Figure 8. Wire rope with knot

Wire ropes with one or more knots must be discarded.

Figure 3. Wire rope with loop formation of wires

If the rope formation has suffered an extensive alteration as a result of the loop formation of wires, the wire rope must be discarded.

In the case of slackening of individual wires or strands, the outer wires of the loaded wire rope or individual strands thereof are capable of shifting. Therefore they are no longer able to absorb that portion of the traction force for which they were designed, and consequently the remainder of the wires or strands are overstressed. This in turn may give rise to excessive bending stresses when the rope runs over rope pulleys, and premature wire breaks will ensue.

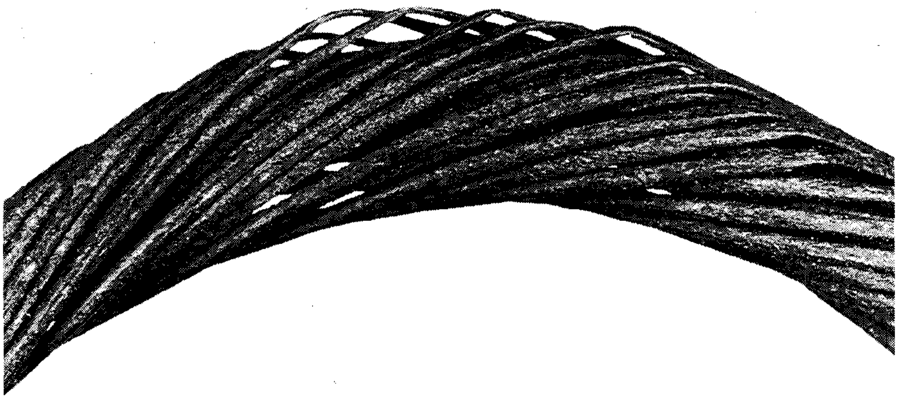

Figure 4. Wire rope with slackened wires due to corrosion and abrasive wear

If the wire slackening has been caused by corrosion or abrasive wear, the wire rope must be discarded. If the slackening is due to other causes, the wire breaks arising as a consequential damage are the determining factor in deciding that the rope is ready for discarding.

Nodes (see Fig. 5) are rope bulges occurring at repeated intervals over fairly long segments of the rope. At the bulges, the core often protrudes out of the rope. At the more slender portions of the rope, the strands support one another mutually in arch formation, and this may result in wire breaks.

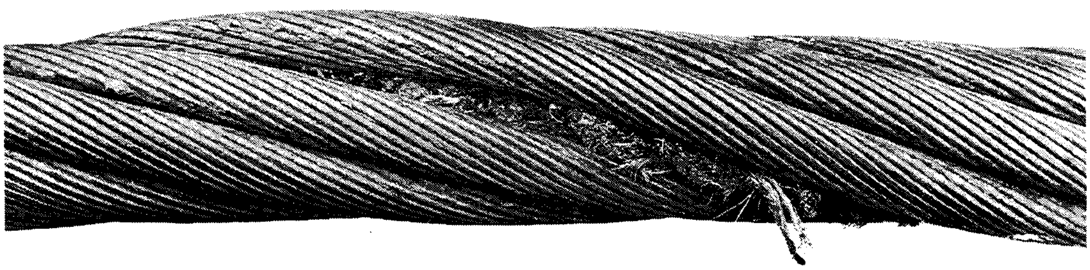

Figure 5. Wire rope with nodes

If nodes are present in the rope, it will perform additional movements.
Wire ropes with a pronounced node formation must be discarded.

up and braking), or caused by dragging of the wire rope on the floor or on the material conveyed. Abrasive wear is fostered by inadequate lubrication or by lack of lubrication, and by the action of dust.

Abrasive wear can reduce the static breaking force of the wire rope because of the reduction in the metallic cross-section of the rope, and also the operational strength as a result of the formation of wear grooves.

If the rope diameter has decreased by 10 % or more in comparison with the nominal dimension, the wire rope must be discarded, even if no wire breaks have been ascertained.

g) Rope deformations

Deformations of the wire rope are visible alterations in the rope formation. Depending on their appearance, the most prevalent deformations are:

corkscrew-shaped deformation,	contraction,
basket formation,	flattening,
loop formation of wires,	curly deformation,
slackening of individual wires or strands,	knots and
nodes,	kinks.

Deformations as a general rule also cause a slackening of the rope structure, at least in the vicinity of the location of the deformation.

In the case of the corkscrew-shaped deformation (see Fig. 1), the axis of the unloaded wire rope is twisted into a helix.

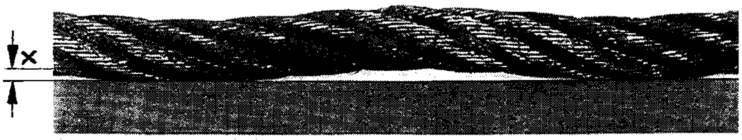

Figure 1. Wire rope with corkscrew-shaped deformation

The corkscrew-shaped deformation does not at first lead to any weakening of the wire rope, but the rope drive may run unsteadily because of the deformation of the wire rope.

Subsequent damage after a relatively long period of service may take the form of increased abrasive wear and wire breaks. The wire rope must be discarded, if the deformation x according to Fig. 1 is $1/3 \cdot d$ at the most unfavourable spot (d = nominal rope diameter). The deformation must be measured without load, but with the weight of the carrying device, if the latter is less than 30 % of the lifting capacity.

Basket formation (see Fig. 2) can occur on wires ropes with a steel core, if the outer layer of the wires becomes slack, or if the outer strands are longer than the inner strands. Due to the displacement of the outer wire or strand layers in relation to the inner layers, the excess length portion is shifted at one spot. Simultaneously, an excess length of the core in relation to the outer strands may arise as a result, at another spot on the wire rope, and this causes the core to buckle or to protrude outside the wire rope.

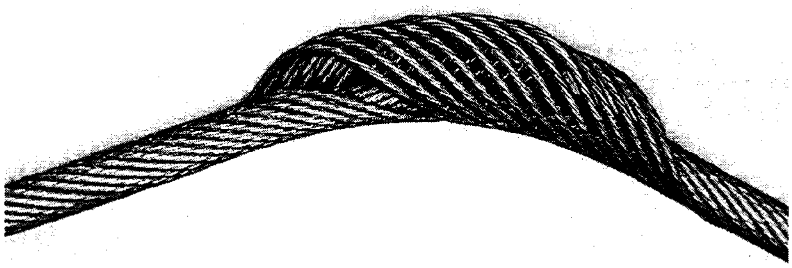

Figure 2. Wire rope with basket formation

In the event of basket formation, the wire rope must be discarded.

In the case of loop formation of wires (see Fig. 3), individual wires or groups of wires protrude from the rope formation in hairpin shape, on the side of the rope facing away from the rope groove. In most cases, the loops are situated in several strands one behind the other.

certain period of operation has elapsed, and subsequently occur at increasingly shorter intervals.

d) Diminution of wire rope diameter during the period of operation

If the rope diameter of a wire rope has decreased by 15 % or more of its nominal diameter over long segments of the rope, due to structural changes, then the wire rope must be discarded.

The pre-requisite for the above is that the tolerances on the new wire rope in accordance with DIN 3055 to DIN 3070 are also complied with in cases where the wire rope is not of standardized design.

e) Corrosion

Corrosion is most likely to occur in maritime climates, in operation in corrosive atmospheres and on wire ropes which are used outdoors for long periods.

Corrosion of the external rope wires can be ascertained by visual inspection. Corrosion of wires which are not visible from outside can on the other hand be difficult to detect.

Corrosion may reduce the static breaking force of the wire rope because of the reduction in the metallic cross-section of the rope, and it may also reduce the operational strength as a result of corrosion pitting.

Readiness for discarding of wire ropes on the basis of wire breaks

Number of load bearing wires in the outer strands of the wire rope 3)	Number of visible wire breaks which justifies discarding							
	Drive groups $1\,E_m$, $1\,D_m$, $1\,C_m$, $1\,B_m$, $1\,A_m$				Drive groups 2_m, 3_m, 4_m, 5_m			
	Crosslay		Long-lay		Crosslay		Long-lay	
	on a length of		on a length of		on a length of		on a length of	
n	$6\,d$	$30\,d$	$6\,d$	$30\,d$	$6\,d$	$30\,d$	$6\,d$	$30\,d$
up to 50	2	4	1	2	4	8	2	4
51 to 75	3	6	2	3	6	12	3	6
76 to 100	4	8	2	4	8	16	4	8
101 to 120	5	10	2	5	10	19	5	10
121 to 140	6	11	3	6	11	22	6	11
141 to 160	6	13	3	6	13	26	6	13
161 to 180	7	14	4	7	14	29	7	14
181 to 200	8	16	4	8	16	32	8	16
201 to 220	9	18	4	9	18	35	9	18
221 to 240	10	19	5	10	19	38	10	19
241 to 260	10	21	5	10	21	42	10	21
261 to 280	11	22	6	11	22	45	11	22
281 to 300	12	24	6	12	24	48	12	24
over 300 4)	$0{,}04 \cdot n$	$0{,}08 \cdot n$	$0{,}02 \cdot n$	$0{,}04 \cdot n$	$0{,}08 \cdot n$	$0{,}16 \cdot n$	$0{,}04 \cdot n$	$0{,}08 \cdot n$

In the case of wire rope designs which incorporate exceptionally thick wires in the outer layer of the outer strands, e.g. round strand rope 6 x 19 Seale in accordance with DIN 3058 or round strand rope 8 x 19 Seale in accordance with DIN 3062, the number of visible wire breaks which justifies discarding of the wire rope must be chosen 2 lines lower than that indicated in the table values.

Drive groups in accordance with DIN 15 020 Part 1

d diameter of wire rope

3) Filler wires are not considered to be load bearing.
In the case of wire ropes with several layers of strands, only the strands of the outermost strand layer count as "outer strands".
In the case of wire ropes with a steel core, the core must be regarded as an inner strand.

4) The calculated values must be rounded up.

If the rope diameter has decreased by 10 % or more in comparison with the nominal dimension, the wire rope must be discarded, even if no wire breaks have been ascertained.

f) Abrasive wear

Abrasive wear occurs on the rope wires in the form of "internal abrasive wear", caused by the relative movements of the strands and wires against one another during flexure of the wire rope, and also in the form of "external abrasive wear" caused by movements between the wire rope and rope groove (e.g. when the wire rope slides in the groove during start-

If the wire rope is liable to drag over structural components in the slack condition, then such points where scraping can occur must be covered when the wire rope is first laid and when a new rope is fitted.

Before commissioning, make sure that the newly laid wire rope is correctly reeved and that it seats properly in the grooves of rope drums, rope pulleys and compensating pulleys. Thereafter, a few motions with a light load should be performed (the load must not exceed 10 % of full load).

All the items of equipment which are operationally connected to the rope drive must be checked in respect of correct functioning after the wire rope has been laid. Such items of equipment include e.g rope compensation devices, limit switches, overload protection devices, safety devices, rope winders.

3.3 Maintenance

Wire ropes must receive maintenance at regular intervals, and the maintenance work involved depends on the type of lifting appliance, its use, and on the type of rope. Rope drives which have been graded into a lower drive group, according to DIN 15 020 Part 1 (February 1974 edition), Section 4.1, than the group corresponding to the anticipated operating conditions must be subjected to a particularly careful maintenance. Wire ropes must be re-lubricated at regular intervals, which depend on the operating conditions, particularly in the region of the bending zone. The lubricant used for this purpose must be compatible with existing lubricants already present on the wire rope. In general, oils have the advantage over greases that they can penetrate the interior of the wire rope; but one can also use greases doped with special additives which facilitate penetration into the interior of the rope.

Lubrication may also reduce the likelihood of corrosion. Lubricants other than greases or oils may be used. When selecting such lubricants, however, at least the following effects must be taken into consideration:

Alteration of the friction coefficient,

formation of a protective film.

Very badly soiled wire ropes should be cleaned externally from time to time.

If the re-lubrication of a wire rope has to be omitted for operational reasons, its service life diminishes accordingly, and the supervision must be organized accordingly.

3.4 Supervision

In so far as necessary, wire ropes and rope end attachments shall be subjected to a daily visual inspection in respect of possible damage. Any irregularities ascertained in the course of such visual inspections must be reported to the competent person responsible.

Wire ropes must be inspected at regular intervals by technically competent personnel trained for this duty, in respect of their reliability of operation. The time interval between inspections must be fixed in such a way that damage is ascertainable in advance in good time. For this reason the time intervals during the first few weeks after the laying of a new wire rope, and after the occurrence of the first wire breaks, must be selected shorter than the intervals during the remaining service life of the wire rope. After the occurrence of unusually high loadings or of suspected but not visible damage, the time interval must be shortened accordingly (if necessary, to hours). In addition, such an inspection must take place when the rope drive is re-commissioned after a prolonged shutdown, or when the lifting appliances have been dismantled and re-assembled at a new location, before re-commissioning, or after an accident or damage which has involved the rope drive.

During this supervision, particular attention must be paid to the rope segments which run over rope pulleys or which are situated in the vicinity of compensating pulleys, rope suspensions or rope attachments. The results of these inspections must be recorded in writing.[2)]

3.4.1 Supervision work

The operational reliability of wires ropes in service can be assessed according to the following criteria:

a) Nature and number of wire breaks
b) Location of wire breaks
c) Time sequence of occurrence of wire breaks
d) Diminution of wire rope diameter during the period of operation
e) Corrosion
f) Abrasive wear
g) Rope deformations
h) Effect of heat
i) Service life

3.4.2 Condition of wire rope which necessitates the discarding of same

In view of the safety relating to the operation of lifting appliances, the wire rope must be discarded in good time. On the basis of the criteria specified in Section 3.4.1, an indication is given below of the point in time at which a wire rope must be discarded, in relation to the extent of the damage. If the lifting appliance is still in use, its operation may become dangerous.

a) Nature and number of wire breaks

Rope drives are designed in such a way that the wire ropes are not fatigue-resistant. For this reason, wire breaks occur during service.

A wire rope must be discarded at the very latest when one of the number of visible wire breaks specified in the table on page 3 has been ascertained at any one spot.

b) Location of wire breaks

The wire rope must be discarded if clusters of wire breaks occur. The wire rope must be discarded immediately if a strand breaks.

c) Time sequence of occurrence of wire breaks

In important cases, it may be advisable to ascertain the number of wire breaks in function of time. From this, conclusions can be drawn as to the further increase in numbers of wire breaks and as to the anticipated time of discarding. It should be borne in mind in this connection that wire breaks only commence to appear after a

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2) If the Employers' Liability Insurance Associations have stipulated that a log book on the operation of the lifting appliance must be kept, then the inspection results must be entered in said log book.

Lifting Appliances

Principles Relating to Rope Drives

Supervision during Operation

DIN 15 020 Part 2

Translation Fachtechnisches Übersetzungsinstitut Henry G. Freeman, Düsseldorf

Hebezeuge; Grundsätze für Seiltriebe; Überwachung im Gebrauch

As it is current practice in standards published by the International Organization for Standardization (ISO), the comma has been used throughout as a decimal marker.

This standard incorporates technical safety stipulations within the meaning of the Law on Technical Equipment, see Explanations.

This standard has been drawn up in collaboration with the Hauptverband der gewerblichen Berufsgenossenschaften, Zentralstelle für Unfallverhütung (Federation of Industrial Employers' Liability Insurance Associations, Central Office for Accident Prevention), Bonn, and with the Bundesverband der landwirtschaftlichen Berufsgenossenschaften, Hauptstelle für landwirtschaftliche Unfallverhütung (Federation of Agricultural Employers' Liability Insurance Associations, Central Office for Accident Prevention in Agriculture), Kassel.

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1 Scope

This standard applies to the supervision during operation of rope drives, the calculation and construction of which is described in DIN 15 020 Part 1.

2 Purpose

This standard contains recommendations relating to the competent execution of the maintenance and supervision work associated with rope drives in use. This work is intended to safeguard the safety and reliability of the lifting operation, and to prolong the service life of the rope drive components (wire ropes, rope end attachments, rope drums, rope pulleys, compensating pulleys).

3 Wire ropes

3.1 Condition prior to laying

Wire ropes must not exhibit any corrosion, damage or excessive soiling. Wire ropes coated or sheathed with plastic are not admissible, because the supervision described in Section 3.4 cannot be carried out on such ropes.

The data relating to the length tolerance of wire ropes contained in DIN 15 020 Part 1 must be complied with.

3.2 Laying

When renewing a wire rope, make sure that the new wire rope is of the same type and strength as the replaced one in the as-new condition.[1] In addition, the rope drive must be reeved in the same way as it was reeved with the original wire rope. In particular, make sure that the end attachments of the new rope are fastened in the same way as in the case of the original rope. In cases of doubt, the details contained in operating instructions, prescriptions and standards are decisive.

If the piece of rope required is cut off a length of rope from stock, make sure that the rope structure cannot become slack in the course of time at the separating cut (e.g. by flash butt welding or by serving with wire at both ends).

When pulling the wire rope off the reel, or when uncoiling it from a coil, and when mounting it into the rope drive, make sure that the wire rope is neither untwisted nor twisted more tightly, as otherwise the rope formation will be disturbed, and rope loops, knots and kinks may ensue.

Every time a new wire rope is laid, make sure that the grooves in the rope drums, rope pulleys and compensating pulleys will match the rope diameter (see Section 5).

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1) If a different wire rope is destined to be laid, then the suitability of such a wire rope in respect of the existing rope drive must be demonstrated in accordance with DIN 15 020 Part 1. If any additional data have been incorporated in the operating instruction manual of the lifting appliance by the manufacturer, then such additional information must also be taken into consideration.

Continued on pages 2 to 8
Explanations on pages 8 and 9

Example relating to group grading:

An electric hoist designed for 2000 kg lifting capacity and equipped with a load lifting magnet runs continuously for 4 hours per day — which corresponds to running time category V_2 of Table 9. The following load collective results, on the basis of a sling weight of 1000 kg (weight of magnet plus chain suspension):

40 % of running time with weight of sling — 1000 kg — and 500 kg scrap

$t_1 = 0{,}4 \quad \beta_1 = 500/2000 = 0{,}25 \quad \gamma = 1000/2000 = 0{,}5$

10% of running time with weight of sling — 1000 kg — and 240 kg steel chips

$t_2 = 0{,}1 \quad \beta_2 = 240/2000 = 0{,}12 \quad \gamma = 1000/2000 = 0{,}5$

50 % of running time with weight of sling — 1000 kg —

$t_\Delta = 0{,}5 \qquad \gamma = 1000/2000 = 0{,}5$

The cubic mean value amounts to

$$k = \sqrt[3]{(\beta_1 + \gamma)^3 \cdot t_1 + (\beta_2 + \gamma)^3 \cdot t_2 + \gamma^3 \cdot t_\Delta} =$$

$$= \sqrt[3]{(0{,}25 + 0{,}5)^3 \cdot 0{,}4 + (0{,}12 + 0{,}5)^3 \cdot 0{,}1 + 0{,}5^3 \cdot 0{,}5} =$$

$$= 0{,}634$$

According to the k ranges given in Tables 8 and 9, load collective 2 (medium) applies here. With a running time V_2, Group II is obtained from Table 9. The electric hoist adopted must at least comply with the requirements of drive group II for a 2000 kg lifting capacity." End of quotation

The special cases mentioned in the last paragraph include e.g. vehicle winches (defined in DIN 15 100, February 1967 edition, Section 7.3), pulling winches for forestry work and rope tackles for work in vineyards. In such cases the rope must be as light as possible, so that it can be carried out over long distances by o n e man, if required. For this reason, ropes of special design with high nominal strengths of the individual wires (2160 and 2450 N/mm² or 200 and 250 kp/mm² respectively) are adopted for the rope drives of these lifting appliances. The service life in these cases is largely determined by the careful handling when the rope is pulled out, and by the care taken whilst the work is in progress.

Re Section 4.2

Drive groups $1\,C_m$, $1\,D_m$ and $1\,E_m$ are used mainly for winches with special operating conditions — e.g. vehicle winches — and winches for very light duty operation. Because ropes and with a high nominal strength are used for preference on vehicle winches, the coefficients c and c' for these ropes are only given for the corresponding drive groups. According to experience, the rope design is of decisive significance under these operating conditions, and especially in the case of the high nominal strengths of the individual wires previously mentioned. For this reason, a further reference to these relationships is made in Footnote 5).

Footnote 2 belonging to this section explains the origin and formation of the coefficient c or c'. Some of these coefficients apply to several nominal strengths of the individual wires, and it follows from this that they have been determined on the basis of the lowest nominal strength applicable to them in each case, and on the basis of a filling factor $f = 0{,}46$.

Re Section 5

This section takes a number of influences into consideration, which in part have a considerable effect on the service life of the wire rope, but which cannot be evaluated quantitatively.

Re Section 6

Details relating to rope end attachments and to the technical requirements relating thereto have been incorporated in the standard for the first time. Compliance with these details is mainly concerned with the technical safety stipulations.

Re Section 7

This section contains a series of details which must be observed when designing rope drives, and which cannot be accommodated in any of the other sections. They are mainly concerned with technical safety aspects, and their principal aim is to prolong the service life of wire ropes, either directly or indirectly, by facilitating maintenance work.

Load collective 1

1/10 of running time with lifting capacity = weight of load suspension device and sling + 1/1 useful load

$t_1 = 0{,}1$ $\qquad \beta_1 = 1 - \gamma = 0{,}84$

4/10 of running time with weight of load suspension device and sling + 1/3 useful load

$t_2 = 0{,}4$ $\qquad \beta_2 = (1 - \gamma)/3 = 0{,}28$

5/10 of running time with weight of load suspension device and sling

$t_\Delta = 0{,}5$ $\qquad \gamma = 0{,}16$

Load collective 2

1/6 of running time with lifting capacity = weight of load suspension device and sling + 1/1 useful load

$t_1 = 1/6$ $\qquad \beta_1 = 1 - \gamma = 0{,}68$

1/6 of running time with weight of load suspension device and sling + 2/3 useful load

$t_2 = 1/6$ $\qquad \beta_2 = 2 \cdot (1 - \gamma)/3 = 0{,}453$

1/6 of running time with weight of load suspension device and sling + 1/3 useful load

$t_3 = 1/6$ $\qquad \beta_3 = (1 - \gamma)/3 = 0{,}227$

3/6 of running time only with weight of the load suspension device and sling

$t_\Delta = 0{,}5$ $\qquad \gamma = 0{,}32$

Load collective 3

1/2 of running time with lifting capacity = weight of load suspension device and sling + 1/1 useful load

$t_1 = 0{,}5$ $\qquad \beta_1 = 1 - \gamma = 0{,}37$

1/2 of running time only with weight of the load device and sling

$t_\Delta = 0{,}5$ $\qquad \gamma = 0{,}63$

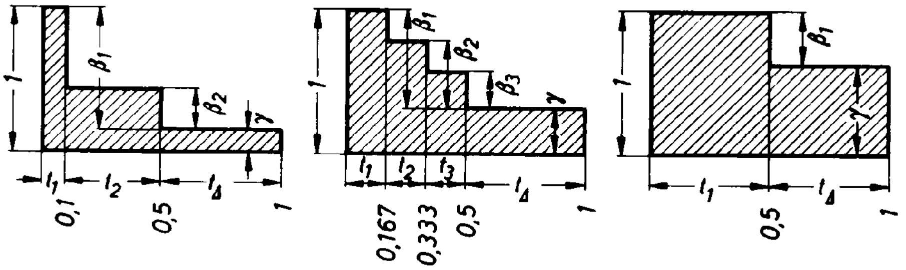


Figure 5. Load collectives in accordance with FEM Section IX

These ideal load collectives have the following cubic mean values:

$$k_1 = \sqrt[3]{(0{,}84 + 0{,}16)^3 \cdot 0{,}1 + (0{,}28 + 0{,}16)^3 \cdot 0{,}4 + 0{,}16^3 \cdot 0{,}5} = 0{,}514 \approx 0{,}53$$

$$k_2 = \sqrt[3]{(0{,}68 + 0{,}32)^3 \cdot 0{,}167 + (0{,}453 + 0{,}32)^3 \cdot 0{,}167 + (0{,}227 + 0{,}32)^3 \cdot 0{,}167 + 0{,}32^3 \cdot 0{,}5} = 0{,}660 \approx 0{,}67$$

$$k_3 = \sqrt[3]{(0{,}37 + 0{,}63)^3 \cdot 0{,}5 + 0{,}63^3 \cdot 0{,}5} = 0{,}855 \approx 0{,}85$$

These cubic mean values, rounded to the nearest preferred number, have a progressive ratio of 1,25 and thus conform with the mathematical interrelationships of the group grading.

3 Grading of the drives

With the aid of the running time categories and of the load collectives, the drives are graded into 6 groups: I_b; I_a; II; III; IV and V, which correspond to Table 9.

The grading of the drives into groups according to Table 9 enables an equal life expectancy (in years) to result for all load collectives and mean running times per day. The prerequisite for this is that the life of the individual structural elements is dependent on the cube of the load.

The doubling of the mean running times per day in the running time categories is achieved:

1. within one group by transition to a lower load collective (progressive ratio 1,25), because $1{,}25^3 = 2$
2. within one load collective by transition to a higher group with reduction of the lifting capacity by the factor 1,25, because $1{,}25^3 = 2$.

Table 9. Group grading of drives

Load collective		Running time category						
		$V_{0,25}$	$V_{0,5}$	V_1	V_2	V_3	V_4	V_5
	Cubic mean value k	Mean running time per day, in hours						
		≦0,5	≦1	≦2	≦4	≦8	≦16	>16
1	$k \leq 0{,}53$			I_b	I_a	II	III	IV
2	$0{,}53 < k \leq 0{,}67$		I_b	I_a	II	III	IV	V
3	$0{,}67 < k \leq 0{,}85$	I_b	I_a	II	III	IV	V	V

Explanations

The present version of this Standard is based on the experience gathered during many years of use of DIN 15 020 Part 1, November 1954 edition, and of DIN 15 010, October 1963 edition. In addition, it takes into account the agreements elaborated by the Fédération Européenne de la Manutention (FEM = European Mechanical Handling and Conveying Technology Federation) in its Sections I — Heavy Cranes and Lifting Appliances — and IX — Serial Lifting Appliances. Moreover, it offers the possibility, more readily than the previous version of the standard, of utilizing a rope drive for differing operating conditions merely by altering the lifting capacity. Furthermore, lighter operating conditions have been included in the standard, so that it can now also be used for serial lifting appliances, which operate under very light duty operating conditions, or in respect of which a relatively short service life of the wire rope can be considered acceptable for operational reasons.

The Standard contains a number of technical safety stipulations, particularly by virtue of the indications contained in Sections 4, 6 and 7. The Standard has been drawn up in close collaboration with the competent technical committees of the Hauptverband der gewerblichen Berufsgenossenschaften (Federation of Industrial Injuries Insurance Associations) and of the Bundesverband der Landwirtschaftlichen Berufsgenossenschaften (Federal Association of Agricultural Injuries Insurance Associations), bearing in mind that the latter association is particularly interested in traction winches for light duty operation.

The following additional explanations are reproduced below, in respect of various individual sections of the standard:

Re Section 1

Thanks to the new formulation of the scope, this Standard now applies as dimensioning basis for rope drives of e v e r y kind of lifting appliances, in so far as no friction pulley drive is involved, or no special provisions (e.g. in respect of elevators, aerial ropeways and winding engines) or no special conditions (e.g. in the case of rope drives on board ships with the exception of deck cranes) have to be taken into consideration.

Re Section 4.1

On the basis of the agreements elaborated by the FEM Sections I and IX, it is intended to draw up a standard covering the principles of calculation of crane drives, which will then constitute a logical complement to DIN 15 018 Part 1 -- Cranes, principles for steel structures; stress analysis.

The present Table 1 of the Standard will then be taken over into the new standard, and only a reference to it will be made in DIN 15 020 Part 1 in future. The standard which is at present in preparation will also contain detailed indications and explanations on the use of this table. Until such time as the new standard is published, the relevant portion of the recommendations elaborated by FEM Section IX is reproduced below:

"Load collective"

The load collective indicates in what measure a drive or a portion of a drive is subjected to its maximum loading or only to lesser loadings.

For the purpose of an accurate grading into a group, the cubic mean value k related to the lifting capacity is required. k is calculated according to the formula below:

$$k = \sqrt[3]{(\beta_1 + \gamma)^3 \cdot t_1 + (\beta_2 + \gamma)^3 \cdot t_2 + \ldots + \gamma^3 \cdot t_\Delta}$$

where

$$\beta = \frac{\text{Useful load or partial load}}{\text{Lifting capacity}}$$

$$\gamma = \frac{\text{Weight of load suspension device and sling}}{\text{Lifting capacity}}$$

$$t = \frac{\text{Running time with useful load or partial load plus weight of load suspension device and sling}}{\text{Total running time}}$$

$$t_\Delta = \frac{\text{Running time only with weight of load suspension device and sling}}{\text{Total running time}}$$

A distinction is made between three load collectives, which are characterized by the definitions and by the ranges of the cubic mean values k of Table 8 below.

Table 8. **Load collective**

Load collective		Definitions	Cubic mean value k
1	light	Drives or parts thereof which are subjected only exceptionally to the maximum loading, and normally to much lower loadings	$k < 0{,}53$
2	medium	Drives or parts thereof which are subjected during approximately equal periods of time to low, medium and maximum loadings	$0{,}53 < k < 0{,}67$
3	heavy	Drives or parts thereof which are for the main part subjected to loadings close to the maximum loading	$0{,}67 < k < 0{,}85$

In the formula for the cubic mean value k, the weight of the carrying device has been ignored. This is permissible if

$$\frac{\text{weight of the carrying device}}{\text{lifting capacity}} \leqq 0{,}05$$

If this is not the case, the calculation must be made in accordance with the following formula:

$$k = \delta \cdot \sqrt[3]{(\beta_1 + \gamma + \alpha)^3 \cdot t_1 + (\beta_2 + \gamma + \alpha)^3 \cdot t_2 + \ldots (\gamma + \alpha)^3 \cdot t_\Delta}$$

where

$$\alpha = \frac{\text{Weight of the carrying device}}{\text{Lifting capacity}}$$

$$\delta = \frac{\text{Lifting capacity}}{\text{Lifting capacity plus weight of the carrying device}}$$

1 Concepts

(see DIN 15 003)

2 Explanations relating to the load collectives

The limiting values given in Table 8 for the cubic mean values k can be calculated from the following ideal load collectives (see Fig. 5):

Appendix

Efficiency of rope drives

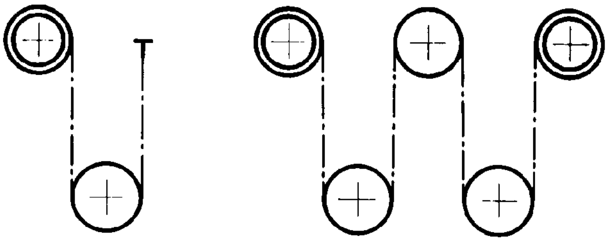
The efficiency of a rope drive, for calculation of the rope traction force in accordance with Section 4.2, is determined in accordance with the following formula:

$$\eta_S = (\eta_R)^i \cdot \eta_F = (\eta_R)^i \cdot \frac{1}{n} \cdot \frac{1-(\eta_R)^n}{1-\eta_R} \qquad (5)$$

where

i = Number of fixed rope pulleys between the rope drum and the pulley block or load (e.g. in the case of lifting gear of jib cranes).

n = Number of rope plies one pulley block.
O n e pulley block consists of the sum total of all the rope plies and rope pulleys for o n e rope winding onto a rope drum (see Fig. 4).



Pulley block
two ply

$n = 2$

Twin pulley block
four ply, consisting of
two pulley blocks, each two ply
$2 \times (n = 2)$

Figure 4.

η_F Efficiency of the pulley block

$$\eta_F = \frac{1}{n} \cdot \frac{1-(\eta_R)^n}{1-\eta_R} \qquad (6)$$

η_R Efficiency of o n e rope pulley

η_S Efficiency of the rope drive

The efficiency of a rope pulley is dependent on the ratio of the rope pulley diameter to the rope diameter ($D : d$), on the rope design and on the rope lubrication, in addition to being dependent on the type of bearing arrangement of the pulley (plain bearings or antifriction bearings). In so far as more accurate values have been proved by means of trials, the following shall be assumed for calculations:

for plain bearings η_R = 0,96

for antifriction bearings η_R = 0,98

The efficiencies in Table 7 are calculated on the basis of the above values.

No efficiency need be taken into consideration in the case of compensating pulleys.

Table 7. **Efficiency of pulley blocks**

	n	2	3	4	5	6	7	8	9	10	11	12	13	14
η_F	Plain bearings	0,98	0,96	0,94	0,92	0,91	0,89	0,87	0,85	0,84	0,82	0,81	0,79	0,78
	Antifriction bearings	0,99	0,98	0,97	0,96	0,95	0,94	0,93	0,92	0,91	0,91	0,90	0,89	0,88

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2) The following relationship exists between the factors:
The ratio of breaking force of the wire rope to the rope traction force is expressed by the safety identification number ν:

$$\nu = \frac{F}{S} = \frac{k \cdot q_m \cdot \sigma_z}{S} = \frac{k \cdot f \cdot \frac{\pi}{4} d^2 \cdot \sigma_z}{S}$$

It follows that $d = \sqrt{\dfrac{\nu \cdot S}{k \cdot f \cdot \frac{\pi}{4} \cdot \sigma_z}} = c \cdot \sqrt{S}$ and $c = \sqrt{\dfrac{\nu}{k \cdot f \cdot \frac{\pi}{4} \cdot \sigma_z}}$

or $d = \sqrt{\dfrac{\nu \cdot S'}{k \cdot f \cdot \frac{\pi}{4} \cdot \sigma_z'}} = c' \cdot \sqrt{S'}$ and $c' = \sqrt{\dfrac{\nu}{k \cdot f \cdot \frac{\pi}{4} \cdot \sigma_z'}}$

where

f = Filling factor
k = Stranding factor } (see DIN 3051)

q_m = Metallic cross-section of wire rope in mm²

F = Breaking force of wire rope in N, namely
for k = 1, the calculated breaking force,
for $k < 1$, the minimum breaking force

σ_z = Nominal strength of single wire in N/mm²

σ_z' = Nominal strength of single wire in kp/mm² accordance with DIN 83 318 with at least 6 1/2 circumferential tucks: Splices on wire ropes for single ply operation must be executed "against the hand of lay"; this splice execution must be agreed at the time of placing the purchase order. The splice must not be jacketed, so that it can be inspected during operation.

6.4 Stressing of components

Rope suspensions must be dimensioned in such a way that they are able to absorb 2,5 times the rope traction force without any permanent deformation.

If a rope socket is used, the free rope end must be secured against pull through even if a self-locking rope wedge is incorporated. This safety device must be capable of absorbing 10% of the rope traction force. No devices which involve the connection of the free rope end to the load carrying rope ply with a positive transmission of force may be used as safety devices.

The rope attachment onto the rope drum must be designed in such a way that 2,5 times the rope traction force can be absorbed by it, taking into account the friction of the remaining turns of rope left on the drum (see Section 7.1). The coefficient of friction between the wire rope and the surface of the drum on which it rests shall be assumed at $\mu = 0{,}1$ for the purposes of the calculation.

6.5 Maintenance facility

Wire rope suspensions must be arranged in such a way that they are easily accessible for maintenance. Working platforms must be provided for this purpose if necessary.

7 Further requirements relating to rope drives

7.1 Number of safety turns

When the carrying device is at its lowest position, there must be at least two complete turns of the rope left on the rope drum before the attachment of the rope end on the drum.

7.2 Sideways deflection

The sideways deflection of the wire rope out of the groove plane diminishes the service life of the wire rope and must, therefore, be kept as small as possible. It is recommended, in the case of multi-reeved wire ropes, to execute the high-speed plies with as small as possible a sideways deflection, and the low-speed plies with a greater sideways deflection. On no account should the sideways deflection exceed 1 : 15 (4°); however, even a sideways deflection as low as 1° in the main operating range can have a detrimental effect on the service life of the wire rope. In the case of non-twisting or non-rotating wire ropes, it is recommended to make sure that the sideways deflection does not exceed 1 : 40 (1,5°).

The sideways deflection of the wire rope must be taken into consideration when designing the shape of the rope grooves.

7.3 Safeguard against running off

Suitable design arrangements must be made to ensure that neither the ascending nor the descending wire rope is able to run off the rope drum or off the rope pulleys sideways, even in the case of a slack rope.

If the rope drum is provided with flanged discs for this purpose, then the projection length of the flanges above the outermost rope layer must be equal to 1,5 times the rope diameter at least.

In the case of rope pulleys, it is recommended that the gap between the outside diameter of the rope pulley and the inside face of the stirrup piece or protective casing surrounding the pulley must not exceed 1/3 rd of the rope diameter or 10 mm, which ever value ist the smaller.

7.4 Contact with stationary structural components

In so far as the wire rope is capable of coming in contact with stationary structural components (e.g. when the load swings to and fro), these structural components must not exhibit any sharp edges in the zone of contact. An adequate radiusing can be achieved e.g. by welding on a round steel bar.

The wire rope whilst in motion must not be allowed to drag over stationary structural components.

7.5 Exposure to heat

All parts of the rope drive must, if necessary, be protected against heat radiation.

7.6 Drum dimensions

Rope drums must be sized in such a way that no more rope layers than originally intended are wound onto the drum when the load carrying device is at its highest elevation, taking into account the rope length tolerance and rope diameter tolerance, and also the kind of winding of the rope onto the rope drum (uncontrolled or controlled).

7.7 Protective casings for rope pulleys and compensating pulleys

Where protective casings are provided for the rope pulleys of carrying devices (e.g. in bottom pulley blocks), these casings must possess adequately large apertures in their bottom region to enable the discharge or removal of dirt and water.

5.2 Wire diameter

In so far as the wire ropes are exposed to mechanical damage, heavy external abrasive wear or strong corrosive attack, rope designs with thick outer wires are advantageous.

5.3 Number of strands

Wire ropes with a large number of strands (e.g. 8 strands) exhibit a more closed surface and, therefore, exert a lower squeeze in the rope groove than wire ropes with a smaller number of strands (e.g. 6 strands).

5.4 Type of stranding of the strands

In the case of wire ropes with strands arranged in parallel stranding (with equal lengths of lay of the wires in the strand layers, e.g. Seale, Warrington or Filler types), the reciprocal pressing action of the wires is less than in the case of wire ropes with an equal lay angle of the wires in all the layers of the strands. In the latter arrangement, the wires of superimposed wire layers cross over one another. Parallel lay ropes, therefore, usually achieve a longer service life and are better suited for drive groups with heavy duty operation than are wire ropes made from strands with an equal lay angle in all the wire layers.

5.5 Type of lay

Crosslay ropes are generally used for rope drives.

Longer service lives can be achieved with long lay ropes. It must, however, be borne in mind that the loading of long lay ropes generates a greater torque than the equivalent loading of crosslay ropes.

5.6 Hand of lay

In the case of grabs with closing ropes and holding ropes arranged in pairs, and also in the case of other load suspension devices suspended in similar fashion, an equal number of wire ropes of the same type must be used in each case, half of which must be right-hand lay and the other half left-hand lay.

It is recommended to lay wire ropes with a right-hand lay of the outer strands on rope drums with a left-handed pitch of the rope grooves, and vice-versa.

5.7 Non-twisting or non-rotating wire ropes

If the load is suspended on o n e ply only and is not guided, then non-twisting or non-rotating wire ropes must be used.

If the hoisting height is considerable and the load is not guided, non-twisting or non-rotating wire ropes shall also be used in the case of multi-ply suspension, unless the twisting together of the rope strands can be prevented by structural or design means.

5.8 Low stress wire ropes

Wire ropes with low stress stranding have the advantage of exhibiting either no or only very little elastic recoil of the stranded wires, and also that the wires and strands will not fly apart, or only fly apart to a limited extent, when the rope is cut. They are easier to handle for laying. Long lay ropes should only be used in the low stress stranding form.

5.9 Steel core

The calculation in accordance with Section 4 also applies to wire ropes with steel core.

5.10 Galvanizing

If there is any risk of corrosion, the use of galvanized wire ropes is recommended, e.g. in the case of maritime climates, of operation in aggressive media, and in the case of wire ropes which lie in the open air for prolonged periods.

5.11 Lubrication of the wire rope

Lubricants in the wire rope diminish friction, both between the groove and the wire rope, and between the individual wires of the wire rope; in addition, corrosion is reduced.

If the lubrication of the wire rope has to be dispensed with for operational reasons, one must reckon with a shorter service life of the rope. The use of non-lubricated wire ropes must be specially agreed.

5.12 Length deviation

In the case of wire ropes supplied in factory lengths ready for use, the length deviation must be agreed, and + 1 % is recommended for this purpose. If several wire ropes of the same length are required for use on o n e lifting gear or one load suspension device, then the length deviation between the several wire ropes must not exceed 0,2 %.

5.13 Marking

The marking of wire ropes supplied in factory lengths ready for use must be agreed.

5.14 Laying of the wire ropes

When pulling the wire rope off the reel or when uncoiling it from a coil, and when mounting it into the rope drive, make sure that the wire rope is neither untwisted nor twisted more tightly.

If the wire rope is liable to drag over sharp-edged structural components in the unloaded state, then such components must be covered.

Before commissioning, make sure that the wire rope is correctly reeved, and that it seats properly in the grooves of rope drums, rope pulleys and compensating pulleys.

6 Rope suspensions and rope attachments

6.1 Condition of the rope end

The rope end must be of such a condition that a durable guarantee exists that the rope structure will not become slack in time (e.g. by flash butt welding or by serving with wire), inasmuch as the rope bond is not unravelled by the nature of the rope attachment (e.g. in the case of splicing or sweating).

6.2 Additional stresses in the rope

Rope flexures and other additional stresses of the wire rope in the region of the rope suspension must be avoided.

The rope suspension, in the case of wire ropes which are not non-twisting, must be designed in such a way that rotations of the wire rope about its longitudinal axis cannot take place. In the case of non-twisting or non-rotating wire ropes, the end attachment may permit rotations of the wire rope about its longitudinal axis.

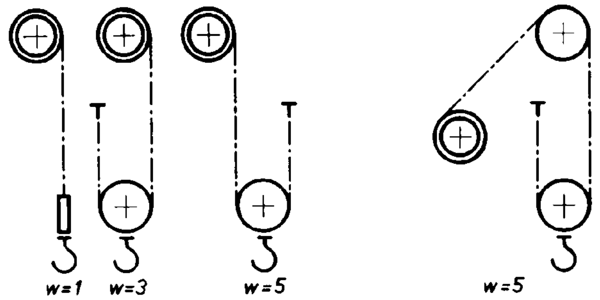
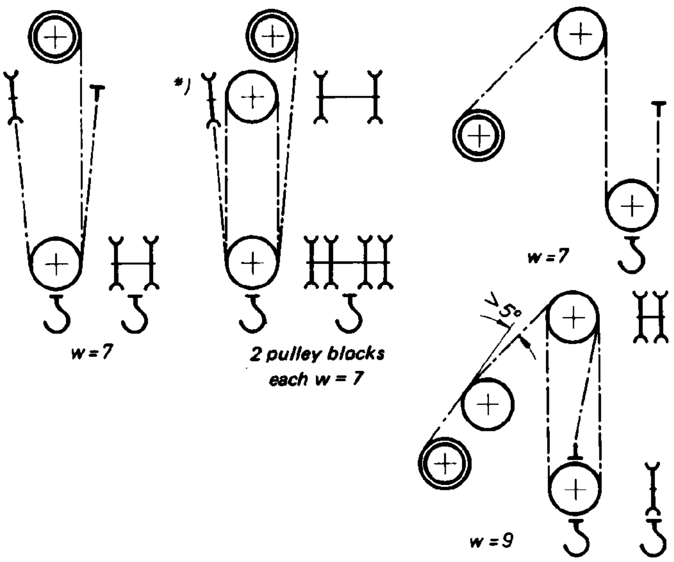
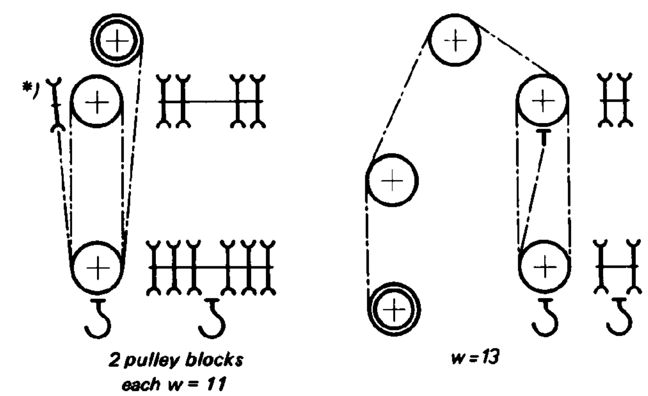
6.3 Construction of components

Rope suspensions must not be effected by means of roller thimbles. Rope eyes must be provided either with solid thimbles (standardization at present in preparation) or with thimbles of shape B or C in accordance with DIN 6899.

Where rope clamps of aluminium flat oval tubing are used in rope suspensions, then the standard at present in preparation must be complied with in respect of the blanks, the compression joint and the manufacture.

Splicings used for rope suspensions must be executed in

Table 5. Coefficients h_2

Examples for arrangements of rope drives			h_2 [7]) for	
Description	Examples of application (drums illustrated in double lines)	w	rope drums, compensating pulleys	rope pulleys
Wire rope runs on rope drum and over no more than 2 rope pulleys with deflection in the same direction or 1 rope pulley with deflection in opposite direction		up to 5	1	1
Wire rope runs on rope drum and over no more than 4 rope pulleys with deflection in the same direction or 2 rope pulleys with deflection in the same direction and 1 rope pulley with deflection in the opposite direction or 2 rope pulleys with deflection in the opposite direction		6 up to 9	1	1,12
Wire rope runs on rope drum and over at least 5 rope pulleys with deflection in the same direction or 3 rope pulleys with deflection in the same direction plus 1 rope pulley with deflection in the opposite direction or 1 rope pulley with deflection in the same direction plus 2 rope pulleys with deflection in the opposite direction or 3 rope pulleys with deflection in the opposite direction		10 and over	1	1,25
For rope pulleys in serial lifting appliances and grabs, h_2 can be assumed at a value of $h_2 = 1$, independently of the arrangement of the rope drive.				

*) Compensating pulley

7) The correlation of w and h_2 in respect of the discription and of the examples of application is only valid on condition that one segment of rope runs through the entire arrangement of the rope drive during one working stroke. For the determination of h_2, only the values of w which occur at the most unfavourable segment of the rope need be considered.

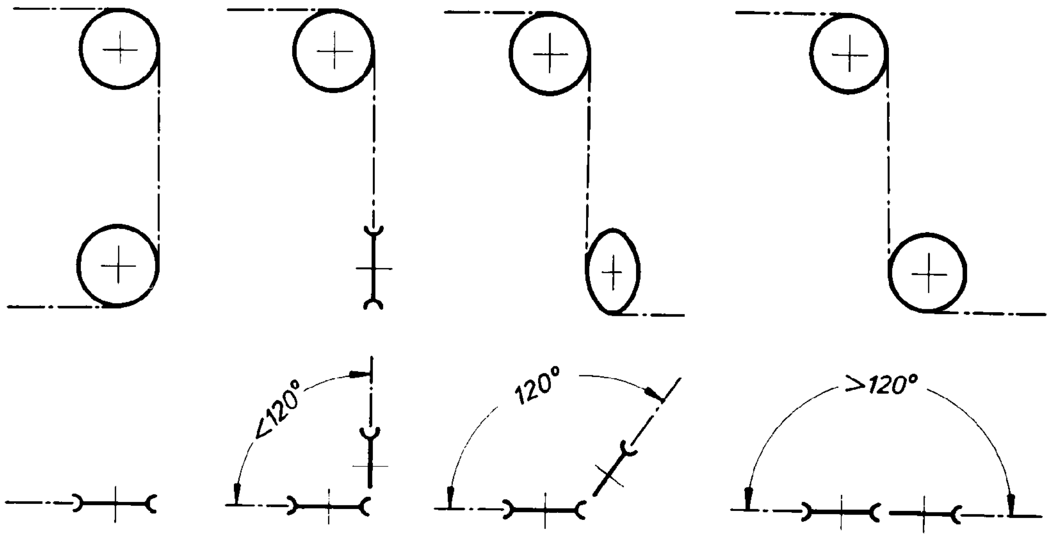


Figure 3. *Deflection in the same direction* *Deflection in the opposite direction*

Thicker wires ropes (up to 1,25 times the calculated rope diameter) may be laid on rope drums, rope pulleys and compensating pulleys having the diameters calculated in accordance with Tables 4 and 5, for the same rope traction force, and without any impairment of the service life, on condition that the permissible groove radius in accordance with Section 4.4 is observed. Larger rope drum, rope pulley and compensating pulley diameters will increase the service life of the wire rope.

For the determination of h_2, the rope drives are classified according to the number w of alternating bending stresses which the most unfavourably stressed portion of the rope has to run through during one working cycle (lifting and lowering of the load) for one working stroke. w is entered as the sum of the following individual values for the elements of the rope drive:

Rope drum $w = 1$

Rope pulley for deflection in the same direction, $\alpha > 5°$: $w = 2$

Rope pulley for deflection in the opposite direction, $\alpha > 5°$: $w = 4$

Rope pulley, $\alpha \leq 5°$ (see Fig. 2)
Compensating pulley:
End attachment of rope: $w = 0$

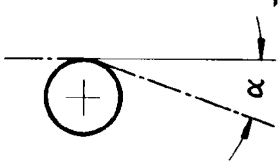


Figure 2.

Deflection in the opposite direction must be taken into consideration if the angle between the planes of two adjacent rope pulleys (traversed by the rope in succession) amounts to more than 120° (see Fig. 3).

(See page 6 for Table 5)

4.4 Dimensioning of the rope grooves (ratio of groove radius to rope diameter)

The service life of a wire rope increases with decreasing squeeze between the wire rope and the grooves. It is, therefore, recommended to match the groove radius r as favourably as possible to the nominal diameter d of the rope laid in the groove.

The minimum recommended value for r is:

$$r = 0{,}525 \cdot d \qquad (4).$$

Table 6. **Nominal groove radii**

d Nominal diameter of wire rope laid in the groove in mm
r Nominal groove radius in mm

d	r	d	r	d	r
3	1,6	21	11	39	21
4	2,2	22	12	40	
5	2,7	23	12,5	41	22
6	3,2	24	13	42	23
7	3,7	25	13,5	43	
8	4,2	26	14	44	24
9	4,8	27	15	45	
10	5,3	28		46	25
11	6	29	16	47	
12	6,5	30		48	26
13	7	31	17	49	
14	7,5	32		50	27
15	8	33	18	52	28
16	8,5	34		54	29
17	9	35	19	56	30
18	9,5	36		58	31
19	10	37	20	60	32
20	10,5	38			

Nominal groove radii have been allotted in Table 6 to the nominal rope diameters.

Permissible deviations for the groove radius shall be in accordance with DIN 15 061 (at present still in draft form).

5 Wire ropes

5.1 Nominal strength of the wires

This Standard applies to wire ropes made of steel wires according to DIN 2078, of 1570, 1770 and 1960 N/mm^2 (160, 180 and 220 kp/mm^2) nominal strength, and also, in the case of conventional transports, to wire ropes which are not non-twisting and which are made of steel wires of 2160 and 2450 N/mm^2 (220 and 250 kp/mm^2) nominal strength (at present not yet standardized).

Formula (1) is the preferred one. The values of coefficient c [2]) (in mm/ $\sqrt{N}$) are given in Table 2 for the various drive groups, and the values of coefficient c' [2]) (in mm/ $\sqrt{kp}$) are given in Table 3. These values apply equally to bright and to galvanized wire ropes.

Wire ropes made of wires of non-standardized nominal strengths (2160 and 2450 N/mm^2 or 220 and 250 kp/mm^2 respectively) should only be used on condition that their adequate operational safety and reliability has been proven by tests, and on condition that the technical details, in particular the rope design, have been mutually agreed with the rope manufacturer.

The calculated rope traction force S or S' is determined from the static traction force in the wire rope (e.g. in the case of lifting gear, solely from the load and from the dead weight of the carrying device, the lifting rope and the lower pulley block, and in the case of travelling gear, from the travelling resistance and the resistance due to gradients), taking into consideration the acceleration forces and the efficiency of the rope drive (in accordance with the "Appendix" section).

Items which need not be taken into consideration include:

Acceleration forces up to 10 % of the static traction forces,

Additional forces resulting from rope straddle up to straddle angles $\beta = 45°$ (see Fig. 1) at the maximum elevation of the hook (rope traction force $\approx$ 10 % greater than in the case of parallel rope plies),

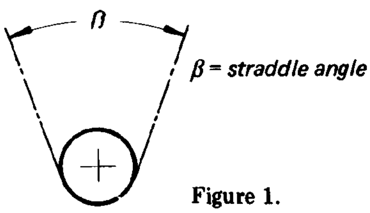


Figure 1.

and in the case of lifting gear, dead weight of the carrying devices and efficiency of the rope drive, on condition that the influence of both these factors together does not exceed 5 % of the forces from the load; in the case of rope drives for vehicle winches, an increase in traction force of up to 15 % of the nominal traction force for horizontal traction or for traction at an incline up to 45°, on condition that a safeguard against overloading has been incorporated.

If the case of rope drives for multiple rope grabs and similar load suspension devices, the load is not always uniformly distributed between the grab closing rope(s) and the holding rope(s) during a working cycle. For this reason, the following distribution of the load onto the closing rope(s) and the holding rope(s) is recommended:

If the system used promptly and automatically ensures the uniform distribution of the load onto the closing rope(s) and holding rope(s):

Closing rope(s) and holding rope(s): 66 % of the load each

If the system used does not ensure the uniform distribution of the load onto the closing rope(s) and the holding rope(s) during the course of the lifting process:

Closing rope(s): 100 % of the load
Holding rope(s): 66 % of the load

4.3 Calculation of the diameters of rope drums, rope pulleys and compensating pulleys [coefficient $(h_1 \cdot h_2)$]

The diameter D of rope drums, rope pulleys and compensating pulleys, related to the centre of the wire rope, is calculated from the minimum rope diameter d_{min} determined according to Section 4.2, in accordance with the formula below:

$$D_{min} = h_1 \cdot h_2 \cdot d_{min} \qquad (3)$$

In the above formula, h_1 and h_2 are non-dimensional coefficients. The factor h_1 is dependent on the drive group and on the rope design, and is listed in Table 4; the factor h_2 is dependent on the arrangement of the rope drive and is listed in Table 5. The values adopted may be lower than those listed in the tables in the case of run-in devices for vehicle winches and of transfer rollers on timber trucks, if this becomes necessary for design or operational reasons.

Table 4. Coefficients h_1

Drive group	h_1 for rope drum and		rope pulley and		compensating pulley and	
	wire ropes which are not non-twisting	non-twisting or non-rotating [6]) wire ropes	wire ropes which are not non-twisting	non-twisting or non rotating [6]) wire ropes	wire ropes which are not non-twisting	non-twisting or non rotating [6]) wire ropes
$1E_m$	10	11,2	11,2	12,5	10	12,5
$1D_m$	11,2	12,5	12,5	14	10	12,5
$1C_m$	12,5	14	14	16	12,5	14
$1B_m$	14	16	16	18	12,5	14
$1A_m$	16	18	18	20	14	16
2_m	18	20	20	22,4	14	16
3_m	20	22,4	22,4	25	16	18
4_m	22,4	25	25	28	16	18
5_m	25	28	28	31,5	18	20
Rope pulleys in grabs may be sized in accordance with drive group $1B_m$ independently of the grading of the remainder of the rope drive.						

[6]) In the case of serial lifting appliances, the same coefficients h_1 may be used for non-twisting or non-rotating wire ropes as for wire ropes which are not non-twisting, on condition that an adequate service life is achieved by virtue of the selection of the rope design.

Table 2. **Coefficients c**

Drive group	c in mm/ $\sqrt{N}$ for conventional transports and: wire ropes which are not non-twisting					non-twisting or non-rotating wire ropes 3)			dangerous transports 4) and: wire ropes which are not non-twisting			non-twisting or non-rotating wire ropes 3)		
	Nominal strength of the individual wires in N/mm²													
	1570	1770	1960	2160 5)	2450 5)	1570	1770	1960	1570	1770	1960	1570	1770	1960
$1E_m$	—	0,0670	0,0630	0,0600	0,0560	—	0,0710	0,0670	—			—		
$1D_m$	—	0,0710	0,0670	0,0630	0,0600	—	0,0750	0,0710	—			—		
$1C_m$	—	0,0750	0,0710	0,0670		—	0,0800	0,0750	—			—		
$1B_m$	0,0850	0,0800	0,0750	—		0,0900	0,0850	0,0800	—			—		
$1A_m$	0,0900	0,0850		—		0,0950		0,0900	0,0950			0,106		
2_m	0,0950			—		0,106			0,106			0,118		
3_m	0,106			—		0,118			0,118			—		
4_m	0,118			—		0,132			0,132			—		
5_m	0,132			—		0,150			0,150			—		

In the case of the drive groups $1E_m$, $1D_m$ and $1C_m$, steps must be taken to ensure, by the provision of the appropriate ropes, that, additionally, the ratio of the calculated rope rupture force to the calculated rope traction force is not less than 3,0.

3) In the case of serial lifting appliances, the same coefficients c may be adopted for non-twisting or non-rotating wire ropes as for wire ropes which are not non-twisting, on condition that an adequate service life is attained by virtue of the selection of the rope design.

4) E.g. the conveyance of molten substances, or the conveyance of reactor fuel elements.
In the case of serial lifting appliances, this grading can be dispensed with on condition that the rope traction force is reduced to 2/3 of the value for conventional transports, whilst retaining unaltered the diameters of the wire rope, of the rope drum and of the rope pulleys.

5) Wire ropes of 2160 and 2450 N/mm² nominal strength in particular must be of a design which makes them entirely suitable for the special application concerned here.

Table 3. **Coefficients c'**

Drive group	c' in mm/ $\sqrt{kp}$ for conventional transports and: wire ropes which are not non-twisting					non-twisting or non-rotating wire ropes 3)			dangerous transports 4) and: wire ropes which are not non-twisting			non-twisting or non-rotating wire ropes 3)		
	Nominal strength of the individual wires in kp/mm²													
	160	180	200	220 5)	250 5)	160	180	200	160	180	200	160	180	200
$1E_m$	—	0,212	0,200	0,190	0,180	—	0,224	0,212	—			—		
$1D_m$	—	0,224	0,212	0,200	0,190	—	0,236	0,224	—			—		
$1C_m$	—	0,236	0,224	0,212		—	0,250	0,236	—			—		
$1B_m$	0,265	0,250	0,236	—		0,280	0,265	0,250	—			—		
$1A_m$	0,280	0,265		—		0,300		0,280	0,300			0,335		
2_m	0,300			—		0,335			0,335			0,375		
3_m	0,335			—		0,375			0,375			—		
4_m	0,375			—		0,425			0,425			—		
5_m	0,425			—		0,475			0,475			—		

In the case of the drive groups $1E_m$, $1D_m$ and $1C_m$, steps must be taken to ensure, by the provision of the appropriate ropes, that, additionally, the ratio of the calculated rope rupture force to the calculated rope traction force is not less than 3,0.

3) In the case of serial lifting appliances, the same coefficients c' may be adopted for non-twisting or non-rotating wire ropes as for wire ropes which are not non-twisting, on condition that an adequate service life is attained by virtue of the selection of the rope design.

4) E.g. the conveyance of molten substances, or the conveyance of reactor fuel elements.
In the case of serial lifting appliances, this grading can be dispensed with on condition that the rope traction force is reduced to 2/3 of the value for conventional transports, whilst retaining unaltered the diameters of the wire rope, of the rope drum and of the rope pulleys.

5) Wire ropes of 220 and 250 kp/mm² nominal strength in particular must be of a design which makes them entirely suitable for the special application concerned here.

1 Scope

This Standard applies to rope drives of cranes (see DIN 15 001) and of serial lifting appliances (see DIN 15 100) of all types.

It does not apply to rope drives with friction pulley drive, to rope drives for excavators, elevators, aerial ropeways and winding engines, nor does it apply to rope drives on board ships with the exception of deck cranes.

Wire ropes which do not run on rope drums and/or over rope pulleys (carrying ropes and tensioning ropes) and sling ropes are not dealt with in this Standard.

2 Purpose

The purpose of the procedure for the calculation of rope drives recommended in this Standard is to ensure an adequate degree of safety of operation of the lifting appliance and to achieve an adequate service life for the wire ropes used.

3 Concepts

A "rope drive" within the meaning of this Standard comprises the wire ropes running on rope drums and on or over rope pulleys, as well as the associated rope drums, rope pulleys and compensating pulleys.

Compensating pulleys are rope pulleys over which the wire rope normally runs during operation, over a segment not exceeding three times the diameter of the wire rope.

The term "grab" in this Standard applies only to the load suspension devices defined in DIN 15 002.

4 Calculation of rope drive

When calculating the rope drives, the following factors which influence the service life of a wire rope must be taken into consideration:

1. Mode of operation (drive group)
2. Wire rope diameter (coefficient c)
3. Diameters of rope drums, rope pulleys and compensating pulleys [coefficient $(h_1 \cdot h_2)$]
4. Rope grooves

4.1 Mode of operation (drive group)

The mechanical components of cranes and serial lifting appliances, i.e including the rope drives, shall be graded according to their mode of operation into a "drive group" in accordance with Table 1 below, in order to achieve an adequately long service life. The grading is made according to running time categories, which take the average running time of the rope drive into account, and also according to load collectives, which take the relative level of the loading or the frequency of full load occurrence into consideration. As regards the grading into running time categories, the mean running time per day, related to one year, is the determining factor.

If the service life is largely a function, in exceptional cases, of factors which lie mainly outside the rope drive itself, then one of the lower drive groups may be adopted for the purpose of calculation, rather than the drive group corresponding to the anticipated operating conditions, providing that

experience indicates that no accidents are likely to be caused thereby

a safeguard against overload is incorporated, and the rope drive is monitored during operation with particular care.

4.2 Calculation of rope diameter (coefficient c)

The rope diameter d (in mm) is determined in accordance with one of the two formulae below, from the calculated traction force on the rope S (in N) or S' (in kp):

$$d_{min} = c \cdot \sqrt{S} \qquad (1)$$

or

$$d_{min} = c' \cdot \sqrt{S'} \qquad (2)$$

Table 1. Drive groups according to running time categories and to load collectives[1])

Running time category		Symbol		V_{006}	V_{012}	V_{025}	V_{05}	V_1	V_2	V_3	V_4	V_5
		Mean running time per day in h, related to one year		up to 0,125	over 0,125 up to 0,25	over 0,25 up to 0,5	over 0,5 up to 1	over 1 up to 2	over 2 up to 4	over 4 up to 8	over 8 op to 16	over 16
Load collective	No	Term	Explanation	Drive group								
	1	light	maximum load occurs only infrequently	$1E_m$	$1E_m$	$1D_m$	$1C_m$	$1B_m$	$1A_m$	2_m	3_m	4_m
	2	medium	low, average and maximum loads occur with roughly equal frequency	$1E_m$	$1D_m$	$1C_m$	$1B_m$	$1A_m$	2_m	3_m	4_m	5_m
	3	heavy	maximum loads occur almost continuously	$1D_m$	$1C_m$	$1B_m$	$1A_m$	2_m	3_m	4_m	5_m	5_m

If the duration of an operating cycle is 12 minutes or longer, the rope drive may be graded one drive group lower than the drive group grading determined from the running time category and from the load collective.

[1]) This Table can be dispensed with as soon as a suitable standard applicable to all drives has been elaborated.

[2]) See page 9

UDC 621.86/.87 : 621.854 : 677.72 DEUTSCHE NORM February 1974

Lifting Appliances

Principles Relating to Rope Drives

Calculation and Construction

DIN 15 020 Part 1

Hebezeuge; Grundsätze für Seiltriebe; Berechnung und Ausführung

As it is current practice in standards published by the International Organization for Standardization (ISO), the comma has been used throughout as a decimal marker.

This Standard incorporates technical safety stipulations within the meaning of the Law on Technical Equipment, see Explanations.

This Standard has been drawn up in collaboration with the Hauptverband der gewerblichen Berufsgenossenschaften, Zentralstelle für Unfallverhütung (Federation of Industrial Injuries Insurance Associations, Central Office for Accident Prevention), Bonn, and with the Bundesverband der landwirtschaftlichen Berufsgenossenschaften, Hauptstelle für landwirtschaftliche Unfallverhütung (Federal Association of Agricultural Injuries Insurance Associations, Central Office for Accident Prevention in Agriculture), Kassel.

For connection with publications of the Fédération Européenne de la Manutention (FEM = European Mechanical Handling and Conveying Technology Federation), see Explanations.

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See DIN 15 020 Part 2 (new edition, at present still in draft form) for principles relating to rope drives, supervision during service.

See DIN 15 018 Part 1, draft February 1967 edition, Section 8, for holding ropes and tensioning ropes

See DIN 15 060 for sling ropes

Translation
Fachtechnisches Übersetzungsinstitut
Henry G. Freeman, Düsseldorf

Continued on pages 2 to 9
Explanations on pages 10 to 12

Examples of stipulations in the operating instructions are as follows:

- From a specific jib length onwards the speed of rotation must not exceed a specified value.
- Loads must not be raised or lowered more quickly than the speeds on which the calculations are based.
- If the lifting capacities apply only to the supported condition, the spring effect of tyres and axle springs must be eliminated by raising them before loading. Wheels providing support are if necessary, underpinned, adequately pre-loaded and locked. In the case of spindle supports the operating instructions usually envisage only pressure of the supports on the ground, but not the release of the axles from the ground.
- Specific lifting capacities may be used only in limited slewing ranges.
- The rotatable upper section of unsupported mobile cranes with pneumatic tyres may be slewed or rotated only in specified ranges or only under special conditions, e.g. with locked springs.
- Information on securing of the unloaded jib, if it is not stable in wind, e.g. release of the slewing gear brakes or lowering of the jib.
- Information on the direction of the loaded jib, if the unsupported crane may operate with a load.
- The unloaded crane is carefully aligned horizontally with a spirit level. During operation the specified tolerances must not be exceeded (see Section 4).
- The crane must be taken out of service at wind speeds above a specified value and with specified jib lengths, e.g. if the wind speed determined from a ten second mean and corresponding to the dynamic pressure limit q_0 is exceeded.

  $$q_0 \leq q - 30 \sqrt{t}$$

  where:

  q = calculated dynamic pressure during operation in N/m^2

  t = time in minutes from the moment the dynamic pressure limit q_0 is exceeded to conclusion of the safety measures.
- The requirements regarding the crane driver must be complied with. Training in accordance with the accident prevention regulations of the Employer's Liability Insurance Associations is a basic prerequisite for the crane driver.
- However, the requirements regarding crane drivers vary according to the type of mobile crane. Hence a crane driver must be a skilled operative who has had special training on the particular type of crane. This applies in particular also to the different equipment conditions and jib combinations and to the safety equipment.

In accordance with Section 4 of this Standard it is sufficient to test the stability with the maximum, mean and minimum working radii. As large mobile cranes often have many possible equipment conditions, the acceptance test shall be limited to a few equipment conditions characteristic of the loading, which is to be agreed between the manufacturer, operator and tester.

The test loading must be carried out in such a way that the working radius for each lifting capacity in accordance with Section 4 and thus the tilting moment corresponding to the test load are not exceeded. The deformation under load also causes slight displacement of the axis of rotation, particularly when the crane is not supported.

The effect of deformation of the supporting structure is, of course, substantially greater. Hence the working radius must not be measured with the working radius meter on the crane during the test loading, because this meter is affected by the deformation of the loaded crane. The actual distance between the centre of gravity of the load and the axis of rotation is to be established.

The conditions in this Standard largely conform to the "European Standard for mobile cranes", which was compiled by Section V "Mobile cranes" of the Fédération Européene de la Manutention (FEM – European Conveying and Handling Association), and the present state of the work in ISO/TC 96/SC 1.

Explanations

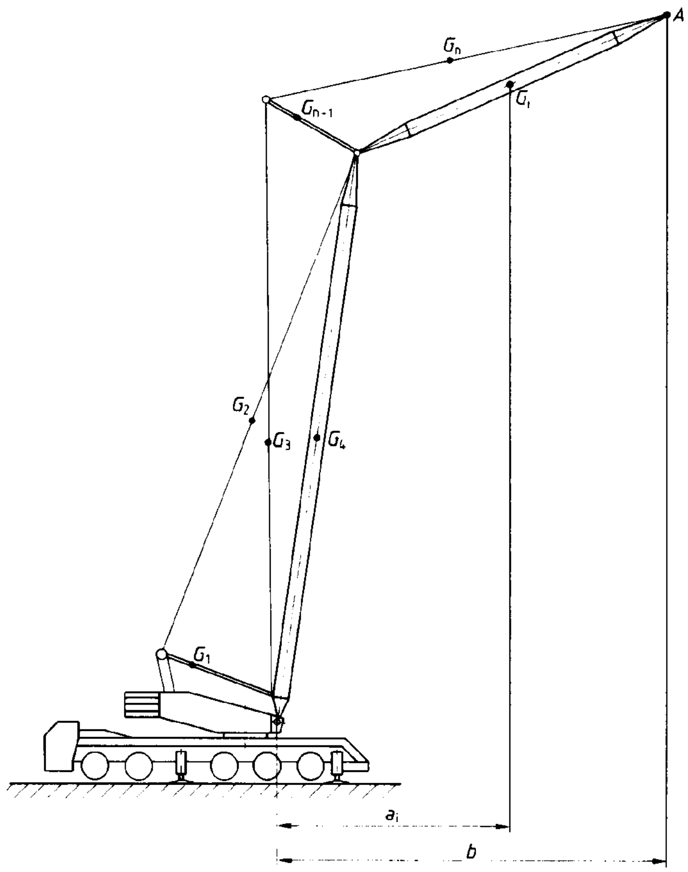
Special Standards for the stability both of mobile cranes and jib and slewing cranes are necessary because of the wide variation in design and operating conditions. Insofar as they use public highways, mobile cranes are also subject to the Road Traffic Licensing Regulations, which limit the possible dead weights of mobile cranes. Hence the Standard for the stability of these cranes is designed to permit any acceptable saving of weight.

This Standard lays down the principles for testing the stability. The specified stability calculations are likewise summarized. The tilting edges for supported and unsupported mobile cranes are also defined.

The P values to be specified by the manufacturer in the lifting load tables may be significantly affected by consideration of

- The strength of load-bearing parts, particularly of the jib, lifting tackle (rope, bottom block) and where applicable the load take-up equipment;
- deformation of the crane under load, in particular when the crane is not supported;
- acceleration and braking forces caused by the special nature of the drive and the design and operation of the gearbox and brakes;
- wind forces during operation;
- the response tolerance of the overload safety device or warning device fitted; attention is drawn to Section 4.2, final paragraph and Table 1, Footnote 2 of this Standard. The response tolerance is expressed as a percentage of the lifting load.

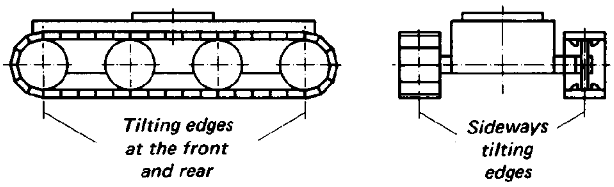
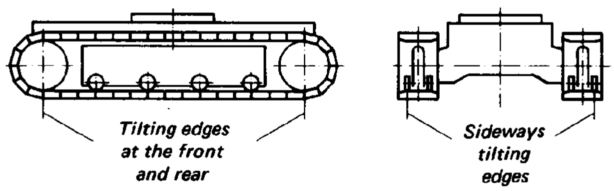
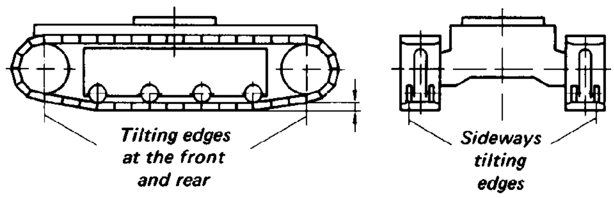
During testing of the stability, the effect of the jib is taken into account by an addition to the test load. Hence, in addition to the lifting load P the weight $0.1\,A$, to be understood as 0.1 times the equivalent weight of the jib acting through the jib tip (see also Footnote 2 to Table 1), must be specified by the manufacturer for acceptance. The method of determining the equivalent jib head weight A for n individual centres of gravity of the jib system is shown in the following example.



$$A = \frac{\sum_{i=1}^{n} G_i \cdot a_i}{b}$$

The Standard is an "Outline Standard" and must, therefore, be of a general nture. It cannot include all lifting capacity restrictions necessary for individual designs but must instead be supplemented by the manufacturer's operating instructions, which must also be complied with in all cases for safe operation of the crane.

Table 2. (Continued)

No.	Represented	Explanation of the tilting edges
12	Unsupported crawler crane with single row of rollers  	The front, rear and sideways tilting edges are the connecting lines between the outer supporting discs
13	Unsupported crawler crane with double rollers  	The tilting edges at the front and rear are the connecting lines between the supporting discs; the sideways tilting edges are the connecting lines between the outer rollers
14	Unsupported crawler crane with double rollers and raised supporting discs  	The tilting edges at the front and rear are the connecting lines between the front and rear rollers, unless the supporting discs are lifted by such a small amount that stability is ensured even when the crane is tilted taking into account the greater working radius. The sideways tilting edges are the connecting lines between the outer rollers

6 Wind area of the load

If the exact size and shape of the load is not known, the wind area of the load (including form factor 1.2) is to be assumed to be 1.2 m^2 per t load.

7 Miscellaneous

7.1 Lifting capacity in wind

The maximum wind speed or dynamic pressure at which the crane remains stable during operation must be specified in the lifting load tables.

If the wind area of the load and/or the form factor is greater than that specified in Section 6, the lifting load or permissible wind speed must be reduced accordingly.

7.2 Operating range

Lifting operation with working radii, for which no lifting loads are specified by the manufacturer, is not permissible.

Further Standards

DIN 15 019 Part 1 (at present still in draft form) Cranes; stability; All cranes except non-rail-mounted mobile cranes without tower and except floating cranes

Table 2. (Continued)

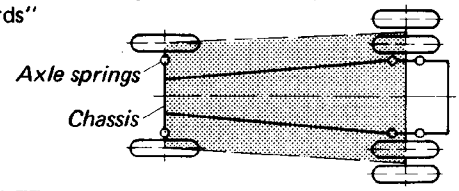
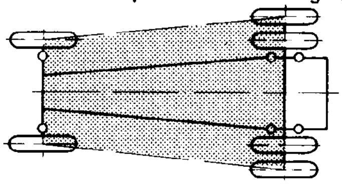
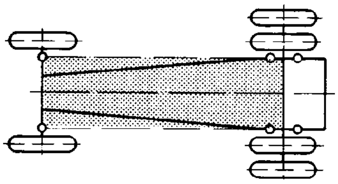
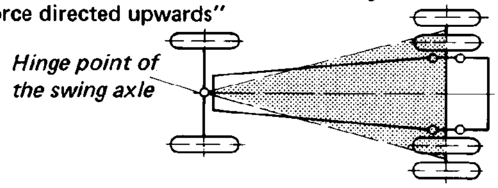
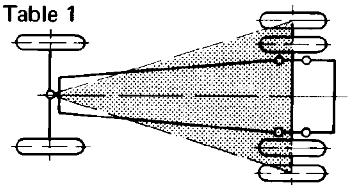
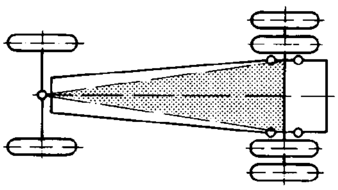
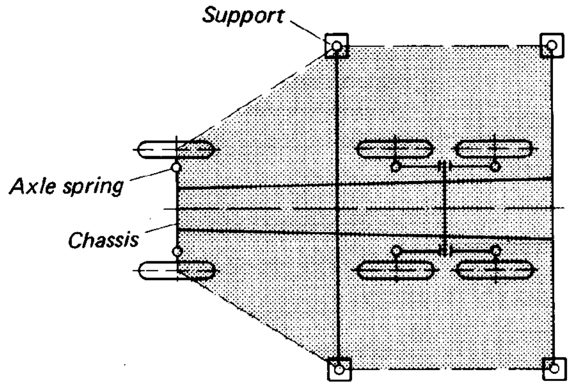
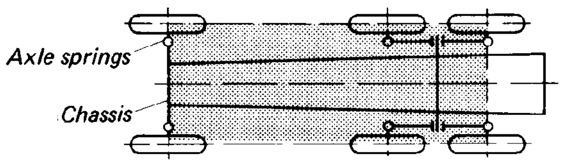
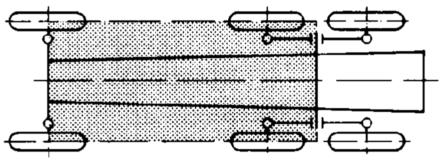
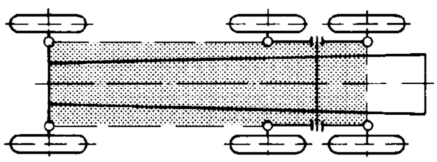
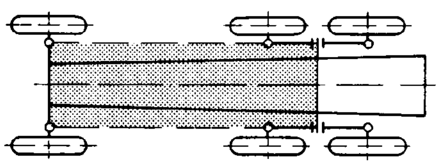
No.	Represented	Explanation of the tilting edges
6	Unsupported mobile crane with locked axle spring suspension or without axle spring suspension, with double tyres, for all load cases according to Table 1, except "force directed upwards" 	The tilting edges are the connecting lines between the centres of the double tyres; with single front tyres, the connecting lines between the ground contact points of the front tyres and the centres of the rear double tyres.
7	Unsupported mobile crane with locked axle spring suspension or without axle spring suspension, with double tyres, for the load case "force directed upwards" according to Table 1 	The tilting edges are the connecting lines between the contact points of the outer tyres
8	Unsupported mobile crane with axle spring suspension freely operating, with double tyres 	The tilting edges are the connecting lines between the points of action of the springs
9	Unsupported mobile crane with locked axle spring suspension or without axle spring suspension, with swing axle, with double tyres, for all load cases according to Table 1, except "force directed upwards" 	The tilting edges are the connecting lines between the centres of the double tyres and the hinge point of the swing axle
10	Unsupported mobile crane with locked axle spring suspension or without axle spring suspension, with swing axle, with double tyres, for the load case "force directed upwards" according to Table 1 	The tilting edges are the connecting lines between the ground contact points of the outer tyres and the hinge point of the swing axle
11	Unsupported mobile crane with axle spring suspension freely operating, with swing axle, with double tyres 	The tilting edges are the connecting lines between the points of action of the springs and the hinge point of the swing axle

Table 2.

No.	Represented	Explanation of the tilting edges
1	Supported mobile crane 	The tilting edges are the connecting lines between the centres of the supports. If flexible supports (e.g. wheels with pneumatic tyres) are located in front of a tilting edge, these supports may be included in the calculation if it is ensured by special measures (e.g. with pneumatically-tyred wheels: adequate pre-loading and locking of the axle springs) that they act like a firm support.
2	Unsupported mobile crane, with locked axle spring suspension or without axle spring suspension, with locked axle rocker 	The tilting edges are the connecting lines between the ground contact points of the wheels.
3	Unsupported mobile crane with locked axle spring suspension or without axle spring suspension, with free axle rocker 	The tilting edges are the connecting lines between the ground contact points of the wheels and the line of action of the axle rocker.
4	Unsupported mobile crane with axle spring suspension freely operating and locked axle rocker, or with individual springs 	The tilting edges are the connecting lines between the points of action of the springs.
5	Unsupported mobile crane with axle spring suspension freely operating, and free axle rocker 	The tilting edges are the connecting lines between the points of action of the springs and the line of action of the axle rocker.

5 Calculation for proof of the stability

A crane is regarded as adequately stable, if – referred to the least favourable tilting edge in each case – the total of all moments is > 0 in the case of stressing by the dead weight loads and the forces and load cases specified in Table 1, the tilting moments being assumed to be negative.

The stability is to be proved by calculation for the following cases with the loads specified in Table 1:

- crane with small overload
- crane with large overload
- crane with force directed upwards
- erection and dismantling
- crane in wind, not operating

The proof of stability is carried out for the least favourable tilting edge, i.e. for the tilting edge at the smallest vertical distance from the centre of gravity of the entire crane.

It is to be noted that the centre of gravity is displaced during rotation of the jib and when the working radius is changed. If different lifting loads P are specified in different jib directions, the proof of stability is carried out separately for each tilting edge, otherwise the proof for the least favourable tilting edge is adequate.

The tilting edges for common mobile cranes are explained and represented schematically in Table 2.

Table 1.

Load case	Calculated lifting load [2]	Vertical and horizontal forces due to inertia [3]	Wind [4]	
			Wind pressure w according to DIN 1055 Part 4 N/m²	Dynamic pressure q N/m²
Smallest test load	$1{,}1 \cdot P$	according to calculated proof	$1{,}0 \cdot w$	125
Large test load [5]	$1{,}25 \cdot P + 0{,}1 \cdot A$	0	0	0
Force directed upwards	$-0{,}1 \cdot P$	0	0	0
Erection and dismantling	$0{,}1 \cdot A$	0	0	0
Wind, not operating	0	0	$1{,}2 \cdot w$	according to DIN 1055 Part 4

[2] The lifting load P is the total of the weights of the load to be lifted, the bottom flange, and the load take-up and slinging tackle, as specified by the manufacturer.
A is the equivalent weight of the jib system acting through the jib tip.

[3] The inertia forces are calculated in accordance with DIN 15 018, Part 1.

[4] These values are used as minimum values, unless restrictive measures to counter the effect of wind are envisaged in the operating instructions. The value used for the dynamic pressure must not be less than 50 N/m².

[5] The large test load must exceed, by at least $0.1 \cdot P$, the load corresponding to the upper tolerance limit for the overload safety device. If this is not the case with the specified values, the overload must be increased accordingly.

Cranes

Stability

for Non Rail-mounted Mobile Cranes
Test Loading and Calculation

DIN 15 019 Part 2

Krane; Standsicherheit für gleitlose Fahrzeugkrane; Prüfbelastung und Berechnung

Translation Fachtechnisches Übersetzungsinstitut Henry G. Freeman, Düsseldorf

This Standard incorporates technical safety stipulations within the meaning of the Law on Technical Equipment.

Start of validity

This Standard takes effect from 1st June 1979

This Standard has been prepared in co-operation with the Hauptverband der gewerblichen Berufsgenossenschaft e. V., Zentralstelle für Unfallverhütung und Arbeitsmedizin (Federation of Industrial Injuries Insurance Associations, Central Office for Accident Prevention and Industrial Medicine), Bonn.

1 Scope

This Standard applies to non rail-mounted mobile cranes, which are fully or partially motor-driven.

Mobile cranes are defined and described in DIN 15 001 Part 1.

2 Other relevant Standards

DIN 1055 Part 4	Load assumptions for structures; live loads, wind loads on structures not susceptible to vibration
DIN 15 001 Part 1	Cranes; definitions, classification according to type
DIN 15 018 Part 1	Cranes; principles for steel structures; stress analysis

3 Proof of stability

The stability of the cranes (safety against overturning) requires proof, i.e.,

– by test loading and

– by calculation

The stability under a high test load can also be proved by test loading alone.

4 Test loading for proof of stability

The unloaded crane must be horizontal on load-bearing soil within limits of ± 0.5 % for the test loading. If greater inclinations are permissible during operation, the crane is to be tested in these inclined positions.

The crane must not overturn during the test loading; one or more supports may lift off the ground.

The test loading is carried out with the small and large test load in accordance with the lifting loads P and working radii specified by the manufacturer.

The test loading is carried out in the lightest possible, gust-free wind, and a dynamic pressure of 50 N/m² must not be exceeded.

The relevant value for the working radius includes the deformation of the crane under the intended lifting or test loads. The working radius is measured from the centre of rotation of the crane to the centre of gravity of the load. Normally the test loads as specified in Sections 4.1 and 4.2 are to be applied.

Testing with the largest, the mean and the smallest working radius with the associated maximum load in each case suffices for a specific equipment condition.

4.1 Small test load

$1.1 \cdot P$

With this test load the cranes must perform all movements permissible during normal operation with the least favourable load positions, but with the care required during normal operation.

4.2 Large test load

$1.25 \cdot P + 0.1 \cdot A$ [1])

This test loading is performed statically.

During acceptance all crane movements (not travelling movements) are also be performed individually at the lowest possible speed and until all gear teeth have engaged at least once. During this procedure the load shall remain near the ground and measures may be taken to restrict swinging of the load.

This test load must exceed, by at least $0.1 \cdot P$, the load corresponding to the upper tolerance limit for the overload safety device. If this is not the case at the specified values, the test load must be increased accordingly.

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[1]) **Note:** For explanation of P and A see Footnote 2 in Table 1

If the portion of A cannot be applied because of operating restrictions during the test loading, the stability calculation must be submitted during acceptance.

Continued on pages 2 to 5
Explanations on pages 6 and 7

by far the greatest majority of crane installations – be they harbour cranes, cranes used in production, or rotating tower cranes used in the construction industry, etc. No special agreement between the supplier and the operator was required for the normal case.

In the case of crane installations which are particularly exposed to attack by the wind and upon which even higher demands are placed than in the normal case – as is often the case with water-side unloaders in ports – it may be desirable to set higher values for the calculated dynamic pressure, which may be as high as q = 500 N/m^2.

In the case of crane installations in which more frequent interruptions of operation, due to the dynamic pressure limit being exceeded, may be tolerated it is permissible for lower levels of dynamic operating pressure to be agreed between the manufacturer and the operator than would be required in the normal case.

The table below contains reference values showing how steeply the number of interruptions of operations climbs as q_0 is reduced, for the statistical yearly average of operating shutdowns which must be reckoned with under 24 hour operation, if reduced levels of operational dynamic pressure are selected. These values apply in the interior of the country; in the vicinity of the coast, there will be a more frequent requirement to take the crane out of service. It should be assumed that this requirement will occur more frequently in those months when wind speed is higher.

Probable frequency of wind velocity corresponding to dynamic pressure limit q_0 (10 second average)

q_0 Operating dynamic pressure limit N/m^2	V_0 Speed of wind corresponding to the operating dynamic pressure limit (10 s average) m/s	Probable frequency per gear of taking the crane out of service as a result of q_0 being exceeded under conditions of 24 hour operation
300	22	2,5
250	20	6
180	17	20
150	16	35
120	14	65
90	12	120

Particular attention is drawn to the effect of a period of time which will be required in order to implement the safety measures which will be necessary for the conversion of the crane from its operating condition to its non-operating condition. This period will include all travelling times and will take into account the time required to complete all additional work. It may vary from a few seconds to many minutes and will depend both on the construction of the crane and on the conditions prevailing at the erection site. Both the time limits and the resulting dynamic pressure limit according to Section 6.1.3, as well as be calculated dynamic pressure, will be subject to the agreement of the manufacturer and the operator, and shall also be included in the operating instructions as essential information.

Where the careful observation of the weather needed when operating the crane is supplemented by the use of wind speed gauges, these should be installed as a rule at the highest point on the crane and in any case in such a manner that the wind may flow over them from all directions without any screening effect. Steps should be taken to ensure that the requirements for wind monitoring increase in line with the extent to which the dynamic pressure limit for cranes in use is reduced in comparison to the standard value of the calculated dynamic operating pressure in any particular case.

In the case of gantry cranes which operate principally inside buildings, but also in the open air, no anti-storm device will be necessary provided that provision is made for the crane to be taken out of service in good time within the protection offered by the building.

Re Section 7 – **Demonstration by calculation of the resistance to toppling over**

Unlike DIN 120 Part 1 para. 22, in which the specific safety values had to be demonstrated for each individual crane type and loading condition, a crane or part of a crane shall now be considered to exhibit adequate stability if, on determining the dead loads and the varying, up-rated hoist loads, mass forces and wind loads which have been calculated from the safety values specified in Table 3 and in accordance with the crane type (Table 1) and the loading condition (Table 2), the total of the moments of all the aforementioned loads around whichever is the most unfavourable tipping edge shall be greater than or equal to zero; in making this calculation, loads which have a tilting effect shall be given a negative value.

Re Section 7.3 – **Load assumptions**

The application of Table 3 presupposes that the greatest forces of inertia which occur under normal conditions of crane operation will be included at their most unfavourable value, e.g. when braking under acceleration.

Re Section 8 – **Demonstration of the resistance to toppling over by the application of test loads**

The application of the low or high test load shall be made by means of the lifting load P as defined in DIN 15018 Part 1 (consisting of the payload plus the inherent loads of the components used for the attachment of the payload, e.g. the bottom block, the traverse, the grab or the lifting magnet, together with the load-carrying medium, e.g. the rope) and an additional load of $0.25 \cdot P$ or $0.33 \cdot P$ ($0.4 \cdot P$) respectively.

Explanations

The reasons for the replacement DIN 120, November 1936 edition, by three Standards, namely DIN 15018 in respect of cranes, DIN 15019 in respect of stability and DIN 4132 for crane runways are given in detail in the Explanations to DIN 15018 Part 1.

DIN 15019 contains – in accordance with DIN 15018 Part 1, April 1974 edition, Section 7.5 – only the rules for the required demonstrations of stability, and in fact in two parts:

Part 2 "Stability of non-rail mounted mobile cranes" and Part 1 of the present Standard, which applies to all other cranes with the exception of floating cranes in accordance with DIN 15018 Part 1.

DIN 15019 Part 1 supersedes para. 22 of DIN 120 Part 1.

This separation enables both the wide range of current models and future developments to be taken into account.

Re Section 1 – **Range of application and purpose**

Cranes which are rigidly connected to foundations or to buildings do not fall under the range of application of this Standard, since in this case it is not the stability, but the stresses in the corresponding structural parts that are to be proven, e.g. compressions in the ground joint, strength of the anchoring ropes and the reliability of the anchorages. When conducting these proofs, it is recommended that the conditions for mobile rotary tower cranes as specified in Table 3 should be used as the basis.

Re Section 4 – **Classification of cranes**

In accordance with Table 1 "Crane types", crane type 2 also includes rotary tower cranes which are moved in a similar fashion to truck-mounted, movable and track-laying cranes, but in which the tower is clamped to the rotating platform and where considerable time and effort would be required on order to remove the tower to ground level, thus escaping the effect of a rising storm.

On the other hand, in the case of truck-mounted, movable and track-laying cranes, the main jib is always hinged to the rotating platform in such a way that it can be rotated about a horizontal axis and can be maintained in its upright operating position by adjusting ropes. Operation of the adjusting mechanism is all that will be required in order to place the jib system on the ground in a reasonably short period of time.

The decisive criterion is the possibility of removing the supporting structure from the effects of a rising storm in a reasonably short period of time.

The rail-mounted rotary cranes on standard gauge or other types of railway track mentioned in Table 1 under crane type 3 are cranes which move only within a limited working area. They may not leave this area; their running gear is not suitable for the speeds usually attained on the roads. On the other hand, railway cranes of crane type 4 are at the disposal of the railway administration departments and are used by them in an extremely wide range of models for the most varied of purposes. The stability requirements also differ greatly depending on the use to which they are put and for this reason may not be included in the general Standard, but remain subject to special agreements.

Also, in the case of cranes of crane type 5 of particularly large capacity, usually in excess of 100 t, manufacturers, operators and the supervisory authorities will as a rule reach special agreements in respect of the exceptional conditions under which cranes require to be operated with the greatest of care on account of their high value, avoiding overloading in operation, and also due to the fact that the correspondingly large test loads can rarely be provided.

Re Section 5 – **Loading conditions**

The loading conditions 1 and 2 for cranes in operation with and without wind are obvious.

The loading condition 3 "Emergency switch-off" is intended to accommodate the effects on stability in the event of a sudden failure in the energy supply or in the case of automatic switch-off due to overload, but in the absence of wind, whereby only the dead loads and the increased hoist loads as specified in Table 3, Column 4, shall apply.

In loading condition 4 the effects are to be investigated of the sudden dropping or detachment of the lifting load or the payload in the absence of wind, but with the effect of the wind in the case of crane type 1. In the event of the lifting load suddenly being dropped, if, for instance the lifting load is able to fall freely or if it is possible for a grab bucket to be emptied suddenly, considerable upward reaction forces may occur. In this case adequate stability against falling over backwards must be demonstrated.

Under loading conditions 5 "Crane out of operation in a storm", the operating instructions prescribed by the manufacturer, the operator and the supervisory authorities, the accident prevention regulations and other similar regulations must be adhered to. The measures which must be taken in each case will depend on the conditions encountered and the type of crane and may thus not be indicated in a general Standard. It is important to observe the prescribed measures in order to be in a position to select the appropriate load assumptions; thus it is specified in the case of rotary tower cranes in general, for instance, that when the crane is taken out of service, the brake on the rotating mechanism should be released and the jib extended to its maximum length so that it will be capable of rotating into the direction of the wind.

Conversely, in the case of harbour cranes, there is a requirement that when the crane is taken out of service the jib be turned parallel to the direction of the track and locked in that position so as not to cause any obstruction to shipping. In order, however, that the moment of rotation due to the wind in the case of wind coming from the appropriate direction should not be too great, the jib must be set as steeply as the luffing gear and the stability requirements in the case of wind coming from the land will allow.

Re Section 6 – **Consideration of the effect of wind**

In the determination of the calculated dynamic pressure q, for those loading cases which take into account the effects of wind, the Standard distinguishes between normal and exceptional cases. A value of $q = 250\ \mathrm{N/m^2}$ has proved its worth for many years in connection with

8 Demonstration of the resistance to toppling over by the application of test loads

8.1 Low test load (in motion)

This test load is to be effected before the first commissioning in conditions of no wind and with the test loads as specified in Table 4, Column 2; when carrying out this test, all authorized movements must be effected individually under the most unfavourable conditions of loading, but exercising the level of care which would be normal in regular operation. The absence of wind may be assumed if the dynamic pressure does not exceed 40 N/m^2.

8.2 High test load (at rest)

The cranes may additionally be tested in pursuance of DIN 15018 Part 1, April 1974 edition, Section 4.3.3 with a static test load as specified in Table 4, Column 3.

8.3 Scale graduations of the indicator device

The scale graduations of the indicator device for the length of the jib in the case of jib and rotating cranes shall be determined with the relevant hoist load attached in each case on account of the deformation which occurs with the crane in its loaded state.

9 Demonstration of the resistance to drifting caused by the wind

9.1 The resistance to drifting caused by the wind shall be demonstrated for all cranes operating in the open air under the following conditions:

- Load condition 1 Cranes operating in a wind at 1.0 times the dynamic pressure specified in Section 6.1.2 or Section 6.2.1
- Load condition 5 Cranes out of operation in a storm at 1.2 times the wind loads specified in DIN 1055 Paart 4, May 1977 edition, Table 1

The resistance to travel due to friction and the coefficients of friction shown in Table 5 shall apply.

9.2 For manually operated rail tongs the hand power required for this may be no more than 300 N.

Table 4. **Test loads**

1	2	3
Crane types according to Table 1	Low test load according to Section 8.1	High test load according to Section 8.2
1	$1.25 \cdot P$	$1.4 \cdot P$
2	$1.25 \cdot P$	$1.33 \cdot P$
3	$1.25 \cdot P$	$1.4 \cdot P$
4	By agreement with the competent supervisory authorities	
5		

Table 5. **Resistance to travel and coefficients of friction**

Ratio: $\frac{\text{Resistance to travel}}{\text{Radial load}}$		Coefficient of friction between the track and	
Plain bearings	Anti-friction bearings	the braked wheel	the rail tongs 1) (with roughened and hardened surface)
0.02	0.005	0.14	0.25

1) Higher coefficients of friction may be allowed for if it can be shown that these are present at all surface conditions and qualities (e.g. oil, dirt, ice).

Table 3. **Load assumptions for dead loads, hoist loads, forces of inertia and wind loads when demonstrating the resistance to toppling over**

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
					Wind		
Crane types according to Table 1	Loading condition according to Table 2	Dead load (according to Section 7.3.1)	Hoist load (according to Section 7.3.2) including vertical mass forces	Forces of inertia from drives (according to Section 7.3.3)	Dynamic pressure q [1] N/m²	Wind load W (according to Section 7.3.4)	Detachable stabilizers
1	1 In operation with wind	1.0 · G	1.4 · P	1.0M	250	1.0 · W	Detached
	2 In operation without wind		1.5 · P	1.0M	0	0	
	3 In operation with sudden energy failure — emergency switch-off		1.7 · P	0	0	0	
	4 In operation with sudden dropping or detachment of the load being lifted		−0.1 · P	0	250	1.0 · W	
	5 Out of operation in a storm		0	0	According to DIN 1055 Part 4	1.2 · W	Attached
2	1 In operation with wind		1.1 · P	1.0M	250	1.0 · W	See Sections 7.2.2 and 7.2.3
	2 In operation without wind		1.45 · P	1.0M	0	0	
	3 In operation with sudden energy failure — emergency switch-off		1.6 · P	0	0	0	
	4 In operation with sudden dropping or detachment of the load being lifted		−0.3 · P	0	0	0	
	5 Out of operation in a storm; Jib free to rotate; from forward		0	0	According to DIN 1055 Part 4	0.8 · W	
	5 Out of operation in a storm; Jib free to rotate; from behind		0	0		1.2 · W	
	5 Out of operation in a storm; Jib not free to rotate; from all sides		0	0		1.2 · W	
3	1 In operation with wind		1.2 · P	1.0 · M	250	1.0 · W	Without
	2 In operation without wind		1.45 · P	1.0M	0	0	
	3 In operation with sudden energy failure — emergency switch-off		1.6 · P	0	0	0	
	4 In operation with sudden dropping or detachment of the load being lifted		−0.3 · P	0	0	0	
	5 Out of operation in a storm		0	0	According to DIN 1055 Part 4	1.2 · W	
4	By agreement with the competent supervisory authority						
5							

[1] For exceptions see Section 6.2.1

6 Consideration of the effect of wind

6.1 Normal case

6.1.1 Each crane must be stable at all points on the track in both operational and non-operational conditions as specified in Table 2. Exceptional cases are dealt with in Section 6.2.

6.1.2 The calculated operational dynamic pressure for cranes when in use shall be set in accordance with DIN 15018 Part 1, April 1974 edition, Section 4.2.1, at $q = 250\ \mathrm{N/m^2}$.

6.1.3 The crane shall be taken out of operation when the wind velocity corresponding to the dynamic pressure limit q_0, determined from a 10 second average, is exceeded.

$$q_0 \leqq q - 30\sqrt{t}$$

Wherein:

q_0 = Dynamic pressure limit in $\mathrm{N/m^2}$

q = Calculated operational dynamic pressure for cranes in use in $\mathrm{N/m^2}$, corresponding to Section 6.1.2 or Section 6.2.1

t = Time in minutes from dynamic pressure limit q_0 being exceeded to completion of safety measures

6.1.4 Crane movements in any direction must be guaranteed for the rated output of their drive unit at the dynamic pressure limit q_0, but also at a minimum of at least 0.6 times the value of the calculated dynamic pressure in accordance with Section 6.1.2 or Section 6.2.1.

6.1.5 The maximum transmittable moments from the drive units, including the brakes, in accordance with Section 6.1.4, must at least correspond with the effects of the calculated dynamic pressure.

6.2 Exceptional cases

6.2.1 The following deviation from the calculated dynamic pressure mentioned in Section 6.1.2 may be agreed between the manufacturer and the operator:

Case a) $125\ \mathrm{N/m^2} \leqq q < 250\ \mathrm{N/m^2}$

if frequent interruption of operation due to the dynamic pressure limit being exceeded is acceptable, and where monitoring of the wind in line with the increased requirements can be assured;

Case b) $250\ \mathrm{N/m^2} < q \leqq 500\ \mathrm{N/m^2}$

if particularly high requirements are placed on the availability of the crane.

6.2.2 When determining the time t in accordance with Section 6.1.3 in the case of cranes which, for any special reasons, are not stable when stopped at any point on the crane runway, the longest travel time to the "out-of-operation" position with increasing dynamic pressure shall additionally be taken into account. The increased requirements for wind monitoring in accordance with Section 6.2.1 apply accordingly.

6.3 Details to be shown in the operating instructions

The operating instructions shall contain details of the calculated dynamic pressure q in accordance with Section 6.1.2, the dynamic pressure limit q_0 and the time t required to take the crane out of service.

7 Demonstration by calculation of the resistance to toppling over

7.1 General information

A crane is considered resistant to toppling over if the total of all moments relating to whichever is the most unfavourable tilting edge $\geqq 0$, where moments having a tilting effect are regarded as negative under the application of the dead loads and also the calculated hoist loads mass forces and wind loads in accordance with Table 3 which shows safety figures of varying magnitude for each of these loading conditions listed in Table 2 at the most infavourable loading conditions.

7.2 Calculation assumptions

7.2.1 Stabilizers may only be considered if it can be shown that the forces transmitted by them can be reliably dissipated.

7.2.2 In the case of cranes of type 2, the effects of detachable stabilizers may not be used in the calculation to prove safety against toppling over.

7.2.3 In the case of cranes of crane type 2, it must be demonstrated in the case of doubt existing that the jib is capable of being swung unhindered into the direction of the wind under loading condition 5.

7.2.4 The runway, standing surface or track system are assumed to be horizontal in Table 3; the degree of tilt must be taken into consideration in any other circumstances.

7.3 Load assumtions

7.3.1 Dead loads

7.3.1.1 All the inherent loads G in accordance with DIN 15018 Part 1, April 1974 edition, Sections 4.1.1 and 4.1.2, which have an effect on stability, shall be taken into account at their most unfavourable values and in their most unfavourable, and yet allocated, positions, but without the dead load factor φ according to Section 4.1.4.1.

7.3.1.2 Special measures may be specified under loading condition 5, the effects of which on the magnitude and position of the dead load shall be taken into account in the calculation.

7.3.2 Hoist loads

The hoist loads P in accordance with DIN 15018 Part 1, April 1974 edition, Section 4.1.3, are to be assumed, but without the hoist load factor ψ as specified in Section 4.1.4.2.

7.3.3 Forces of inertia

7.3.3.1 The forces of inertia which are used shall have the values specified in Table 3, Column 5. The forces of inertia M shall be determined in accordance with DIN 15018 Part 1, April 1974 edition, Section 4.1.5.

7.3.3.2 The individual forces of inertia shall only be included insofar as they may act together with the other forces of inertia and wind loads.

7.3.3.3 The effect of the buffer impact of trolleys and cranes shall be taken into account in accordance with DIN 15018 Part 1.

7.3.4 Wind loads

The wind loads W shall be applied in accordance with DIN 15018 Part 1, April 1974 edition, Section 4.2.1 (for exceptions see Section 6.2.1).

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Cranes
Stability
for All Cranes Except Non-rail Mounted Mobile Cranes and Except Floating Cranes

DIN 15 019 Part 1

Krane; Standsicherheit für alle Krane ausser gleislosen Fahrzeugkranen und ausser Schwimmkranen

This Standard contains safety provisions in line with the Technical Working Materials Act.

Validity
This Standard is applicable as from 1 September 1979.

1 Range of application and purpose

1.1 This Standard is to be applied to all cranes in accordance with DIN 15018 Part 1 where resistance to toppling over and to drifting caused by wind have to be demonstrated, and in addition for any crane parts which are not positively connected to the rest of the supporting structure.
The Standard shall also be applied to non-rail mounted mobile cranes with a fixed tower.

1.2 This Standard is not to be applied to other non rail-mounted mobile cranes or to floating cranes or to cranes which are rigidly connected to foundations or to buildings.

2 Other relevant Standards

DIN 1055 Part 4	Design loads for buildings; live loads; wind loads of structures not susceptible to vibrations
DIN 15018 Part 1	Cranes; principles for steel structures, stress analysis

3 Term and general information

3.1 Stability in accordance with this Standard covers resistance to toppling over and resistance to drifting caused by wind.

3.2 When proving the stability, it is a prerequisite that the operating instructions specified by the manufacturer and by the operator should be adhered to, as well as the Accident Prevention Regulations (UVV "Krane" (cranes) – VBG 9).

3.3 The resistance to toppling over shall be demonstrated by calculation and by the application of test loads.

4 Classification of cranes

Cranes are classified in respect of the proof of their stability in accordance with Table 1 below:

Table 1. **Crane Types**

Crane type	Designation
1	All crane types, except for those covered by Sections 2 to 5
2	Mobile or supported rotary tower cranes for use in the construction of buildings, including truck-mounted rotary tower cranes, movable rotary tower cranes and track-laying rotary tower cranes
3	Rail-mounted rotary cranes running on standard gauge or other types of track, but not crane type 4
4	Railway cranes of special construction running on standard gauge track, and approved for use with trains
5	Cranes of particularly high capacity, usually over 100 t

5 Loading conditions

Five conditions of loading as shown in Table 2 have been defined for use in the demonstration by calculation of the stability.

Table 2. **Loading conditions**

Loading condition	Description
1	Crane in operation with wind
2	Crane in operation without wind
3	Crane in operation with sudden energy failure – emergency switch-off
4	Crane with sudden dropping or detachment of the load being lifted
5	Crane out of operation in a storm

Continued on pages 2 to 4
Explanations on pages 5 and 6

Standards and other documents referred to

See clause 2.

Previous editions

DIN 120 Part 2: 11.36
DIN 15018 Part 2: 04.74

Amendments

The following amendments have been made in comparison with the April 1974 edition.

The corrections mentioned in the *DIN-Mitteilungen* 61, 1982, No. 8, pages 496 to 498 have been incorporated.

Clause 2 Standards and documents referred to

The standards and documents to be observed, and in particular those to which reference is made in the text of the present standard, have been brought up to date. This applies to the following standards and documents in particular:

DIN 8563 Parts 2 and 3;
DIN 17100;
DASt-Richtlinie 009;
DASt-Richtlinie 010;
the dimensional standards on mechanical fasteners and
DIN 2310 Parts 1 and 3;
DIN 6935;
DIN 8551 Part 1;
DIN 8557 Part 1;
DIN 8559 Part 1;
DIN 8560;
DIN 8565;
DIN 18354;
DIN 55928.

The references to Standards DIN 741, DIN 4100 and DIN 83315 have been dropped, as these standards have been withdrawn.

DIN 1142, DIN 3092 and DIN 3093 Parts 1 to 3 have been included for the first time, because reference is made to these standards in subclause 9.3 of the present standard.

DIN 18800 Part 7 has been included for the first time, because reference is made in the text of the present standard to subclauses 3.4.2, 3.4.3, 6.2 and 6.3 of the aforementioned standard. (This replaces the references to DIN 8563 and DIN 4100 in the April 1974 edition of DIN 15018 Part 2, subclauses 6.2.1.1 and 6.2.2.3.)

Subclause 4.1 Steel quality groups for welded members

The second paragraph has been deleted (as quality group 1 in accordance with DIN 17100 has been dropped.)

Subclause 6.2.1.1 Welding shops and
subclause 6.2.1.2 Supervision of welding operations

The suitability of the firms to carry out welding work has been specified in accordance with DIN 18800 Part 7, subclauses 6.2 and 6.3. In this connection, a distinction has been made between the "comprehensive form of proof of suitability for welding" and the "limited form of proof of suitability for welding"; the terminology and reference standards have been adapted accordingly.

Clause 9 Holding ropes and guy ropes

The terminology has been brought up to date.

Explanatory notes relating to the November 1984 edition

The present standard has been revised following an abridged procedure, as already notified in the *DIN-Mitteilungen* 61, 1982, No. 8, pages 496 to 498, and brought in line as far as possible with the most recent state of the relevant standards concerned. In this context, certain references and printing errors have been corrected, and certain editorial changes have been made.

Various comments and more far-reaching suggestions for amendments have been discussed and taken into consideration in so far as it was possible to do so within the framework of the abridged procedure.

The other comments have been duly noted and are to be discussed at a later date yet to be arranged.

International Patent Classification

B 66 C 5-02

Explanatory notes relating to the April 1974 edition

DIN 120 Part 1, November 1936 edition, was subdivided into several Parts. The present standard complements DIN 15018 Part 1.

The fundamentals applying to the fabrication of steel structures by welded, riveted and bolted connections are assumed to be known.

DIN 4100, Welded steel structures with predominantly static loading; design and construction, has been taken into consideration in so far as it is capable of being applied to cranes subjected predominantly to frequently repeated variations of pulsating or alternating loading.

Field of application

The field of application covers, in addition to cranes and equipment for cranes, mobile structures for continuous conveyors, but not craneways, excavators, wagon tipplers and mining machinery.

Standards and other technical rules

Included in the "Further standards and documents to be observed" clause are standards which always apply without requiring any special mention, and other standards which are only important in respect of the particular reference mentioned in the text.

An exact knowledge of the loading groups and notch cases as defined in DIN 15018 Part 1 is of particular importance to the manufacturers and operators of cranes.

General

The structures shall be so designed that their systems correspond to the calculated values.

All members and connections in respect of which analyses in accordance with DIN 15018 Part 1 have to be carried out shall be deemed to be loadbearing.

Cambers and other preforms are not limited to specific dimensions. The stiffnesses (vibrations) need only be compensated or reduced if the operation of the crane would otherwise be hindered.

Materials

The suitable steel grades are specified in DIN 15018 Part 1, April 1974 edition, subclause 6.4. The relevant quality groups, steelmaking and casting processes are specified in DIN 17100.

The steel grades for welded members shall be selected in accordance with *DASt-Richtlinie* 009 published by the *Deutscher Ausschuß für Stahlbau* (German Committee for Structural Steelwork).

The use of several different grades of steel in one and the same members is permitted. The steel grades shall be designated accurately in all the other manufacturing documents.

Members

Members and connections shall be designed for ready assembly, accessibility and weldability. Unless other steps and precautions have been taken in respect of corrosion prevention (see clause 8) and of accessibility for maintenance and repair work, the minimum spacings between adjacent edges and walls, depending on the shape and height of the members, which are specified in table 2, shall be adhered to.

Flame-cut surfaces shall be at least of quality class II as specified in DIN 2310 Part 1, with the exception of members to which the notch cases W01 and W11 described in DIN 15018 Part 1, apply.

Connections

All connections shall be arranged as compactly as possible, and the centroidal axes of the groups of welds, rivets or bolts shall coincide with the centroidal axes of the members and connecting elements, in order to avoid any additional stresses.

Standards DIN 8563, DIN 4100 and DIN 15018 Part 1 specifying the requirements to be fulfilled by the welding shops, welding specialists and welders have been mentioned in the text; they deal with the classification of cranes into loading groups, with the weld qualities and the classification of members into notch cases. The welders shall satisfy the requirements of test group B II in accordance with DIN 8560. However, if fillet welds only are made on loadbearing members, test group B I is sufficient. Welders engaged in welding tubular structures shall be tested as specified for test group R I.

The welders shall be under the constant supervision of approved welding specialists. Equipment for non-destructive testing of the welds by radiographic, ultrasonic and/or air test methods shall be available in the welding shop or available for use elsewhere.

Rails and rail fastenings

The processes and conditions used for the welding of rails shall be adapted to the specific chemical and mechanical properties of the rail steel concerned.

The welds shall encompass the entire cross section of the rail. The rails may be fastened to the sleepers either by "shear-resistant" fastening (a) or by "non-shear-resistant" fastening (b).

In case a), no rivets shall be used; in case b), the creeping of the rails and also the abrasive wear for cranes assigned to loading groups B 4 to B 6, shall be restricted by the use of suitable devices and wearing plates.

Protection against corrosion

All members shall be adequately protected against corrosion if such protection is not already ensured by the grade of steel used.

Holding ropes and guy ropes

Ropes made of steel wire complying with DIN 2078 are specified, as is their protection against corrosion, and fully locked spiral ropes or open spiral ropes shall be used for preference. Only in the case of cranes which change their location frequently, such as tower cranes used on building sites, may heavily galvanized single-layer or multilayer stranded ropes with steel core be used, if necessary without a topcoat of paint. Guy ropes arranged in parallel, with several ropes acting together, shall all be of the same rope type.

sion. As regards members through the interior of which persons can walk, the application of a protective coating on the internal surfaces less complex than that applied to the external surfaces is recommended.

c) Hollow members with riveted or bolted joints covered by butt straps are not airtight and shall be provided on their internal surfaces with a protective coating consisting of non-swelling, e.g. bituminous, coating materials. In addition, water drain holes of not less than 25 mm in diameter shall be provided, and they shall be arranged in such a way that any water which may have penetrated inside the hollow space is able to flow out again, whatever position the component concerned may be in, but on the other hand it must not be possible for any water to enter through these drain holes. Water drain holes are not required on cranes operating indoors.

8.2.3 Riveted connections

Prior to assembly, the overlapping surfaces of members in riveted connections shall receive a coating of lead-free paint, e.g. a coating of red iron oxide/zinc oxide.

8.2.4 Connections made with fit bolts or non-fit bolts

Prior to assembly, the overlapping surfaces of the members in bolted connections (with the exception of connections made with high strength friction grip bolts, see subclause 8.2.5) shall receive the same priming coat as specified for the external surfaces in subclause 8.1.

8.2.5 Connections made with high strength friction grip bolts

Connections made with high strength friction grip bolts shall comply with the requirements specified in *DASt-Richtlinie* 010.

8.2.6 Sealing of grooves

In connections as specified in subclauses 8.2.3 to 8.2.5, all joints shall be sealed against the ingress of moisture.

8.3 Embedding in concrete

Steel members partially embedded in concrete shall be protected against the effects of weather at their points of exit from the casing, e.g. by sealing with bituminous compounds or plastics such as polysulfide.

8.4 Other types of protection against corrosion

Protective systems consisting of metal coatings such as coatings applied by hot dip galvanizing or spray galvanizing as specified in DIN 8565, with or without an additional coat of paint are permitted. Plastics coatings may also be used if their suitability has been verified.

9 Holding ropes and guy ropes

9.1 Rope construction and protection against corrosion

Wire ropes made from heavily galvanized or normally galvanized steel wire specified in DIN 2078 shall preferably be used as holding ropes and guy ropes. The ropes shall be additionally protected by at least two topcoats. Fully locked spiral ropes or open spiral ropes shall preferably be used.

Each holding rope or guy rope shall consist of a single undivided length.

Wire ropes arranged in parallel for the anchoring of a member shall be of identical rope type.

In the case of cranes designed and equipped for regular and frequent changes of location, heavily galvanized single-layer or multilayer stranded ropes with steel core may be used. In such cases, no topcoats are required.

9.2 Rope anchorages and connections

The ropes shall be anchored as free from bending stresses as possible by structural measures, such as articulated joints for example. As a general rule, the ropes shall be capable of retensioning, e.g. by means of turnbuckles, without being subjected to torsional stress.

9.3 Rope terminations

Depending on their construction and diameter, the ropes can be fastened by thimbles (spliced, for example, as specified in DIN 83 318 or pressed as specified in DIN 3093 Part 1, Part 2 or Part 3), pressed steel sockets, (wedged or sweated) taper sockets or by means of rope clamps. As a general rule, fully locked spiral ropes and open spiral ropes shall be sweated as specified in DIN 3092. Rope terminations fastened in rope clamps shall be secured against pulling out if there is a possibility of the wedge losing its grip when the rope slackens. Rope teminations secured by knots are not permitted. Wire rope grips (e.g. as specified in DIN 1142) are only tolerated by way of exception, and then only to effect temporary connections, on condition that they are carried out with the greatest care and under very strict supervision).

9.4 Rope saddles and bollards

The minimum radii of rope saddles and the minimum diameters of bollards specified in table 4 shall be adhered to.

Table 4. **Rope saddles and bollards**

Rope construction	Minimum values	
	Radii of rope saddles R	Diameters of bollards D
Fully locked spiral ropes	$25\,d$	–
Open spiral ropes	$20\,d$	$40\,d$
Stranded ropes	$15\,d$	$30\,d$

Rope saddles shall, wherever possible, be provided with a groove sized to accommodate the rope diameter d.

Table 3. **Spacings between adjoining holes**

No.	Type of centre-to-centre distances of rivet or bolt holes 1)		Centre-to-centre distance max.1)		min.
1	End distance in the direction of force application		$4d$	$8t$	$2d$
2	Edge distance at right angles to the direction of force application		$4d$	$8t$ 2)	$1{,}5d$
3	Spacing in loadbearing members and principal connections		$6d$	$12t$	$3d$
4	Spacing in loadbearing members subjected to compressive stresses	Stresses in rivets and bolts below 50% of the permissible values	$7d$	$14t$	
5	Spacing in loadbearing members subjected to tensile stresses		$8d$	$16t$	
6	Spacing in subordinate members	of cranes operating outdoors	$10d$	$50\sqrt{t}$	
7		of cranes operating indoors	$15d$	$75\sqrt{t}$	

In the above table
d is the diameter of hole;
t is the smaller thickness of external parts.

In wide members with more than two rows of rivets or bolts, the outer rows shall be arranged according to the above specifications. Double spacings are permitted for inner rows, see figure 3.

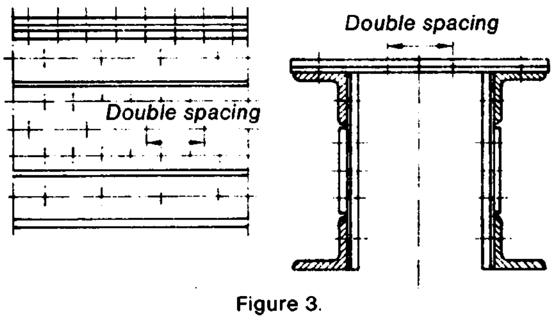


Figure 3.

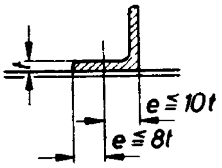


Figure 4.

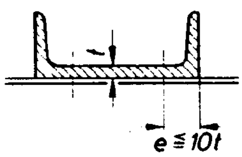


Figure 5.

1) The smaller value is the value to be considered.
2) The edge distance may be $10t$ in the case of the stiffened edge of steel bars and steel sections, see figures 4 and 5.

6.3.9 Indirect overlap

In the case of indirect overlap via m intermediate plates, the number n' of rivets or bolts (but not high strength friction grip bolts) shall be increased above the number n calculated for direct overlap to:

$$n' = n(1 + 0{,}3 \cdot m)$$

6.3.10 Bolt locking devices

Bolts and nuts shall be secured against loosening. In the case of high strength friction grip bolts, the prestress shall be deemed to be an adequate locking.

7 Rails and rail fastenings

7.1 Welding processes and welding conditions

When welding rails, the welding processes and welding conditions shall be compatible with the properties of the rail material.

7.2 Butt welds

Butt welds shall encompass the entire cross section.

7.3 Shear-resistant rail fastening

Where a shear-resistant connection of the rails to the rail girder has been assumed in the calculation, the rails shall be attached using appropriate fasteners. Rivets shall not be used for this purpose.

7.4 Non-shear-resistant rail fastening

In the case of rails not connected to the rail girder by a shear-resistant fastening, creeping of the rails shall be restricted. Wearing plates shall be provided for cranes assigned to loading groups B 4 to B 6.

8 Protection against corrosion

8.1 General

All members shall be adequately protected against corrosion insofar as such a protection is not ensured by the grade of steel used. A coating system appropriate to the corrosion conditions shall be chosen (surface preparation, priming, compatibility of materials, paint layer thickness, time sequence) (see DIN 18364 and DIN 55928 in this connection) or another protective system such as metallic coatings shall be chosen. The renovation of the corrosion protection on crane supporting structures is a difficult job because of the permanently attached items of mechanical and electrical equipment, which might be damaged during the renovation work. For this reason, the initial corrosion protection shall be carried out with particular care.

The surface preparation and the priming coat shall as a general rule be carried out at the manufacturer's works. Damage to the priming coat during transport and erection shall be avoided as far as possible, and any damage which occurs shall be repaired.

Subclause 9.1 shall also be referred to for protection of wire ropes against corrosion.

8.2 Special protective measures

8.2.1 External surfaces

The minimum spacings specified in table 2 shall be adhered to in order to ensure that the anticorrosion coating can be easily applied and renewed.

8.2.2 Internal surfaces of hollow members

a) The internal surfaces of hollow members which are enclosed in airtight fashion, e.g. box sections or pipes, shall not be provided with a protective coating against corrosion.

b) The internal surfaces of enclosed hollow members fitted with an access aperture which normally remains tightly closed by a manhole cover or handhole cover do not as a general rule require a protective coating against corro-

6.2.1.3 Welders

The welders shall have passed a qualification test and shall be supervised by a welding specialist as described in DIN 8560, test group B II. If only fillet welds are to be made in loadbearing members, test group B I shall be considered sufficient. Welders engaged in welding tubular structures shall be tested according to test group R I.

6.2.1.4 Non-destructive testing

The welding shops shall either possess equipment for non-destructive testing specified in DIN 15018 Part 1, or they shall have the facility of using such equipment elsewhere.

6.2.2 Fabrication

6.2.2.1 Welding filler metals

Welding filler metals shall comply with DIN 1913 Part 1, DIN 8557 Part 1 and DIN 8559 Part 1.

6.2.2.2 Type and quality of welds

The welds shall be designated in the manufacturing documents according to type, shape, preparation, machining and testing, as specified in DIN 1912, DIN 8551 Part 1, DIN 8563 Part 3 and DIN 15018 Part 1.

The weld qualities assigned to the notch cases laid down in DIN 15018 Part 1 shall be complied with.

6.2.2.3 Execution of welds

The execution shall comply with the requirements of the manufacturing documents and with DIN 18800 Part 7, May 1983 edition, subclauses 3.4.2 and 3.4.3.

6.2.2.4 Cleanliness of surface

All traces of dirt, rust, scale, slag from flame cutting operations and paint (except for shop primers suitable for welding) shall be removed prior to welding.

6.2.2.5 Fabricating conditions

In order to enable the welds to be made in workmanlike fashion, suitable measures shall be taken to protect both the welders and the weld area from the weather, i.e. from exposure to wind, rain, snow and especially from exposure to cold.

In the event of low temperatures at the welding site, proper welding conditions shall be created, e.g. by preheating the parts concerned and by preventing too rapid a cooling down.

6.2.2.6 Restraining of shrinkage and cooling rate

The restraining of shrinkage and rapid rates of cooling shall be avoided as far as possible; where necessary, the parts in the weld area shall be preheated.

6.2.2.7 Striking of arc on members

The arc may only be struck in the weld groove.

6.2.2.8 Thickness of welds

The minimum thicknesses of fillet welds as shown in figure 1 and of double-bevel butt welds with large thickness of root face c as shown in figure 2 shall be limited to the larger of the following two values:

$$a_{\min} = \sqrt{\max t} - 0{,}5\,\text{mm} \qquad (1)$$

$$a_{\min} = 2\,\text{mm} \qquad (2)$$

The maximum thickness of flank fillet welds and of welds as shown in figure 2 for single-T joints and for cross joints in which the continuous plate is the thinner one ($t_2 < t_1$) shall be:

$$a_{\max} = 0{,}7 \cdot \min t \qquad (3)$$

For welds as per figure 2, the following value shall be entered:

$$a = a_1 + \frac{t_1 - c}{2} \qquad (4)$$

In equations (1) to (4)

a is the thickness of the weld, in mm;

$\left.\begin{array}{l}\max t \text{ is the larger}\\ \min t \text{ is the smaller}\end{array}\right\}$ of the plate thicknesses t_1 or t_2, in mm;

c is the thickness of the root face without penetration, in mm.

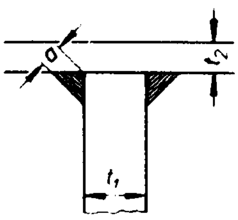


Figure 1.

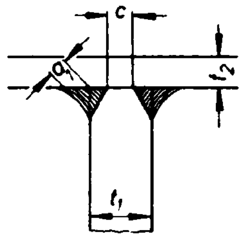


Figure 2.

6.2.3 Butt joints between flange plates and members

Flange plates and members shall be joined at right angles.

6.2.4 Welding in cold worked zones

Welding in cold worked zones is only permitted if steel of quality group 2 at least, as defined in DIN 17100, is used, also if the thickness of the members does not exceed 8 mm, and if the ratio of the radius of curvature r of the inner curvature to the plate thickness t is not less than 1,5.

6.3 Riveted and bolted connections

6.3.1 Hole diameters and bolt threads

The smallest permissible hole diameters and the smallest permissible bolt threads are given in table 1.

6.3.2 Types of rivet

As a general rule, round head rivets specified in DIN 124 Part 1 and DIN 660 and, in special cases, countersunk head rivets specified in DIN 302 shall be used for loadbearing members and principal connections.

6.3.3 Grip lengths and shank lengths

The maximum grip length for rivets shall be $s_{\max} = 0{,}2 \times d^2$, with the hole diameter d and the grip length s in mm.

If bolts complying with DIN 7990 are used, the fitting washers shall conform to DIN 7989, and the shank lengths of the bolts shall be selected in such a way that the threaded portion does not reach into the members to be jointed. Where high strength friction grip bolts are used, the washers shall comply with DIN 6916, DIN 6917 and DIN 6918.

6.3.4 Fit bolts

The fit of fit bolts shall be H 11/h 11 for members subjected to pulsating stresses, and H 11/k 6 or smaller for members subjected to alternating stresses.

6.3.5 Black bolts

Black bolts may only be used for transmitting forces in subordinate members.

6.3.6 Spacings between adjoining holes

The limit values of hole spacings are given in table 3.

6.3.7 Making of holes

Holes in loadbearing members shall be drilled.

6.3.8 Number of rivets and bolts

At least two rivets or bolts shall be provided in joints and connections. The number of rivets, fit bolts or black bolts that may be arranged one behind the other in each row in the direction of the applied force in one part of the cross section shall be limited to five.

4 Materials

4.1 Steel quality groups for welded members

The steel quality groups of welded members shall be determined in accordance with *DASt-Richtlinie* 009.

4.2 Designations to be used in the documentation

The materials shall be clearly designated in the manufacturing documents.

4.3 Members incorporating different grades of steel

It is permitted to use different grades of steel in one and the same member or loadbearing structure.

5 Structural members

5.1 Centroidal axes and system lines

The centroidal axes of members shall coincide wherever possible with the system lines. In the case of chords composed of members with differing locations of their centroidal axes, the averaged centroidal axis shall be laid on the system line; see also subclause 6.1.2.

5.2 Ease of assembly and accessibility

Members shall be designed in such a way that all parts can be easily machined, assembled and maintained.

Water shall be able to flow off and water pockets shall be avoided.

Connections shall be designed for ready fabrication, and shall be accessible on the finished structure wherever possible.

Convenient welding positions shall be provided as far as possible.

5.3 Minimum dimensions

In view of the adverse consequences of a possible loss of cross section of the members during their service life, the minimum dimensions specified in table 1 shall be adhered to; see also clause 8. The risk of corrosion depends on environmental influences and on the kind of corrosion protection selected.

5.4 Minimum spacings

The minimum spacings specified in table 2 shall be adhered to between adjacent edges and walls, in so far as protection against corrosion and accessibility for maintenance work are not assured by other means, see also subclause 8.2.

5.5 Points of introduction of forces, bends, cutouts

In the zone of points of introduction of forces, bends or kinks, cutouts and penetrations, the changes in stress and stability conditions brought about by these features shall be allowed for by suitable structural measures.

5.6 Quality of flame-cut surfaces

Flame-cut surfaces shall be at least of quality class II specified in DIN 2310 Part 1 and Part 3, with the exception of members assigned to notch cases W 01 and W 11 described in DIN 15018 Part 1, November 1984 edition.

6 Connections

6.1 Junctions, joints and other connections

6.1.1 Arrangement

All welded, riveted or bolted connections shall be arranged as compactly as possible.

6.1.2 Centroidal axes

The centroidal axes of the groups of welds, rivets or bolts shall coincide as far as possible with the centroidal axes of the members and fasteners, see also subclause 5.1.

6.1.3 Partial connecting forces

The individual parts of a member etc. shall each be connected, or jointed and covered separately, in accordance with their calculated share in the stress resultants, except for wire ropes; see clause 9.

6.1.4 Lining plates

With the exception of connections made with high strength friction grip bolts, all force-transmitting lining plates thicker than 6 mm and larger than one third of the part to be lined shall be provisionally attached by means of not less than two rivets or two bolts or corresponding welds (taking the appropriate notch case into consideration). In the case of indirect connection of a lined part, the procedure described in subclause 6.3.9 shall be followed.

6.1.5 Concerted action of fasteners

The transmission of the stress resultant of a member jointly via welds, rivets and high strength friction grip bolts is permitted if the shares of the stress resultant are capable of being determined unambiguously in the individual parts of the cross section, and if they are transmitted via one particular type of connection in each part of the cross section.

6.1.6 Angle cleats and welded-on lug plates

In riveted and bolted connections, any angle cleats used shall be connected so as to transmit either 1,5 times the value of the share in the stress resultant for one leg and 1,0 times the value for the other leg, or 1,25 times the value for both legs; welded-on lug plates shall be connected to transmit 1,5 times the value of the stress resultant.

6.2 Welded joints

6.2.1 Conditions required for welding shops and welding specialists

6.2.1.1 Welding shops

The welding shops shall be in possession of the "comprehensive form of verification of suitability for welding" for steel structures described in DIN 18800 Part 7, May 1983 edition, subclause 6.2, and for tubular structures described in DIN 4115. The welding shops shall also have at their disposal the necessary qualified personnel and suitable equipment to comply with requirements of the above standards.

For the purpose of fabricating and repairing simple and standardized loadbearing steel structures for cranes and crane equipment, the welding specialist of a firm possessing the "comprehensive form of proof of suitability for welding" may appoint as subcontractors one or several firms possessing the "limited form of proof of suitability for welding" described in DIN 18800 Part 7, May 1983 edition, subclause 6.3; the responsibility for such subcontracting rests with the welding specialist.

6.2.1.2 Supervision of welding operations

The welding specialist charged with the supervision of the welding operations within the framework of the "comprehensive form of proof of suitability for welding" shall satisfy the requirements of DIN 8563 Part 2, and in addition shall be conversant with and observe the requirements of DIN 15018 Part 1 (November 1984 edition), in particular the classification of crane types into loading groups given in table 23, and the relationships between weld qualities and notch cases specified in tables 25 to 32. The welding specialist of a subcontracting firm shall also possess adequate knowledge of the relationships between weld qualities and notch cases laid down in DIN 15018 Part 1, and experience in the construction of steel structures for cranes in accordance with DIN 15018 Part 2.

	fications for construction work; works for protection against corrosion of steel and aluminium structures
DIN 18800 Part 7	Steel structures; fabrication, verification of suitability for welding
DIN 55928	Protection against corrosion of steel structures by organic and metallic coatings
DIN 83318	Splices for wire ropes

3 General

3.1 Static systems

When designing and constructing structural members (hereinafter briefly referred to as members) and connections, the static systems on which the calculation is based shall be implemented in accordance with the recognized rules of the art.

3.2 Loadbearing members and principal connections

For the purposes of this standard, loadbearing members and principal connections are members and connections respectively which require a stress analysis as specified in DIN 15018 Part 1.

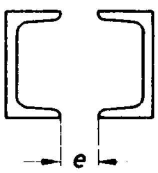
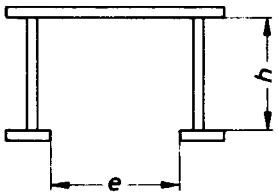
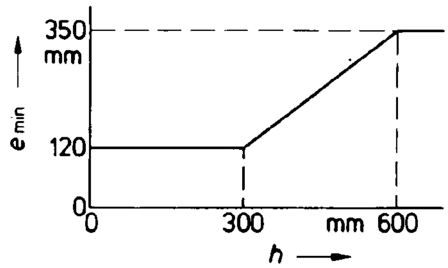
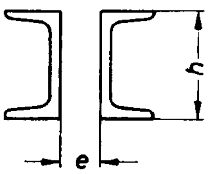
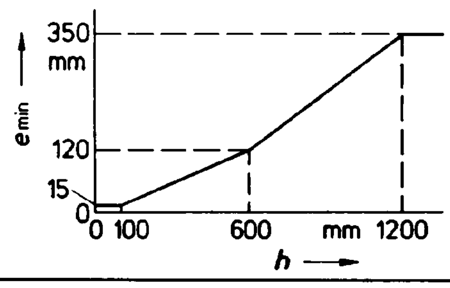
3.3 Cambers

Cambers and other preforms which may be required for the crane operation shall be specified in the manufacturing documents.

Table 1. **Minimum dimensions**

No.	Corrosion risk	Minimum thicknesses of loadbearing members		Hole diameter	Bolt thread
		Plate and sheet, flats, wide flats, steel bars and webs of steel sections in members exposed to corrosion on all sides	Walls of enclosed members and tubing	min.	min.
1	Slight	3	2	6,4	M 6
2	Medium	5	4	8,5	M 8
3	High	7	6	11	M 10

Table 2. **Minimum spacings**

Description and illustration	h	e_{min}	Diagram $e = f(h)$
Spacing between the flange edges of steel channels or similar sections 	–	120	–
Spacing between the chord edges of built-up members or of members made of open box sections 	≦300	120	
	>300 ≦600	$120 + 0{,}767\,(h - 300)$	
	>600	350	
Spacing between the walls of built-up members 	≦100	15	
	>100 ≦600	$15 + 0{,}21\,(h - 100)$	
	>600 ≦1200	$120 + 0{,}383\,(h - 600)$	
	>1200	350	

1 Field of application

This standard applies to the steel structures of cranes of all types, and also to mobile steel structures for continuous conveyors, with the exception of vibrating conveyors. It does not cover to craneways, excavators, ropeways and wagon tipplers.

2 Standards and documents referred to

The following standards and documents shall be complied with unless otherwise specified in this standard.

DIN 4115	Lightweight and tubular steel construction in building; rules relating to approval, design and construction
DIN 8563 Part 2	Quality assurance of welding operations; requirements regarding the firm
DIN 8563 Part 3	Quality assurance of welding operations; fusion-welded joints in steel; requirements, evaluation groups
DIN 15018 Part 1	Cranes; steel structures; verification and analyses
DIN 17100	Steels for general structural purposes; quality specifications

DASt-Richtlinie (DASt guideline) 009 *Empfehlung zur Wahl der Stahlgütegruppen für geschweißte Stahlbauten* [1]) (Recommendation on the selection of steel quality groups for welded steel structures)

DASt-Richtlinie (DASt guideline) 010 *Anwendung hochfester Schrauben im Stahlbau* [1]) (Use of high strength bolts in structural steelwork)

Reference is also made in the text of the present standard to the following standards or to certain parts thereof.

DIN 124	Round head rivets; nominal diameters 10 to 36 mm
DIN 127	Barbed or plain spring lock washers with rectangular cross section
DIN 128	Curved or crinkle type spring washers (high compression load spring washers)
DIN 302	Countersunk head rivets; nominal diameters 10 to 36 mm
DIN 407 Part 1	Symbols for rivets, bolts and hole diameters used in steel structures
DIN 601	M 5 to M 52 hexagon head bolts; product grade C (modified version of ISO 4016)
DIN 609	Hexagon fit bolts with long threaded dog point
DIN 660	Round head rivets; nominal diameters 1 to 9 mm
DIN 741	Wire rope grips for rope terminations for light duty applications
DIN 997	Tracing dimensions for steel sections and steel bars
DIN 998	Hole pitches in unequal angle steels
DIN 999	Hole pitches in equal angle steels
DIN 1080 Part 1	Terms, symbols and units used in civil engineering; principles
DIN 1080 Part 2	Terms, symbols and units used in civil engineering; statics
DIN 1080 Part 4	Terms, symbols and units used in civil engineering; steel construction; composite steel construction and steel girders in concrete
DIN 1142	Wire rope grips for rope terminations to meet safety requirements
DIN 1912	Symbolic representation of welded, soldered and brazed joints
DIN 1913 Part 1	Covered electrodes for the welding of unalloyed and low alloy steel; classification, designation, technical delivery conditions
DIN 2078	Steel wires for wire ropes
DIN 2310 Part 1	Thermal cutting; concepts and nomenclature
DIN 2310 Part 3	Thermal cutting; oxygen cutting, bases of process, quality, dimensional deviations
DIN 3092	Metallic wire rope cappings in rope sockets; safety requirements and testing
DIN 3093 Part 1	Wrought aluminium alloy compression clamps; blanks made from flat oval tubing with uniform wall thickness; technical delivery conditions
DIN 3093 Part 2	Wrought aluminium alloy compression clamps; compression joints using blanks with uniform wall thickness; types, correlation
DIN 3093 Part 3	Wrought aluminium alloy compression clamps; compression joints using blanks with uniform wall thickness; manufacture, quality requirements, testing
DIN 6914	Hexagon bolts with large widths across flats for high tensile bolting in steel structures [2])
DIN 6916	Round washers for high tensile bolting in steel structures
DIN 6917	Square washers for high tensile bolting of I sections in steel structures
DIN 6918	Square washers for high tensile bolting of channels in steel structures
DIN 6935	Cold bending of steel flat products
Supplement 1 to DIN 6935	Cold bending of steel flat products; values of compensation factors v for calculating the flat length
DIN 7968	Hexagon fit bolts for steel structures
DIN 7989	Plain washers for steel structures
DIN 7990	Hexagon bolts with hexagon nuts for steel structures
DIN 8551 Part 1	Edge preparation for welding; groove forms on steel, gas welding, manual arc welding and gas-shielded arc welding
DIN 8557 Part 1	Filler metals for submerged-arc welding; welding of unalloyed and alloy steels; designation, technical delivery conditions
DIN 8559 Part 1	Filler metals for gas-shielded arc welding; wire electrodes and filler wires for gas-shielded metal arc welding of unalloyed and low alloy steels
DIN 8560	Qualification testing of welders for welding steel
DIN 8565	Protection against corrosion of steel structures by thermal spraying of zinc and aluminium; general principles
DIN 18364	Contract procedure for construction work. Part C: General technical speci-

[1]) *Stahlbau-Verlag*, Köln.

[2]) Termed "high strength friction grip bolts" in this standard.

UDC 621.873.3 : 624.96.014.2.002 DEUTSCHE NORM **November 1984**

Cranes
Steel structures
Principles of design and construction

DIN 15 018 Part 2

Krane; Stahltragwerke; Grundsätze für die bauliche Durchbildung und Ausführung

Supersedes April 1974 edition.

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

Dimensions in mm

DIN 15 018 Part 1 and Part 2 have been published following an abridged procedure as specified in DIN 820 Part 4, in the form of corrected editions. This method of proceeding, as well as the corrections that have now been made, were notified and explained in the *DIN-Mitteilungen* (DIN News) 61, 1982, volume No. 8, pages 496 to 498.

It would have been inadvisable to revise the content of the standard at the present time, in view of the general approval which has greeted its publication, and mainly because of the current discussions on the national basic standards relating to steel structures (DIN 18 800); furthermore, the efforts of ISO/TC 96 to achieve an internationally approved ruling with regard to the loads and load combinations which are to be assumed for the verification by calculation of the performance characteristics of cranes had to be borne in mind.

The principal corrections, including those which have arisen from the processing of the comments received, are described in the Explanatory notes.

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Continued on pages 2 to 9

Translation
Fachtechnisches Übersetzungsinstitut
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Standards and documents referred to

See clause 2.

Previous editions

DIN 120 Part 1: 11.36xxxx

DIN 15018 Part 1: 04.74

Amendments

The following amendments have been made in comparison with the April 1974 edition:

the corrections mentioned in the *DIN-Mitteilungen* 61, 1982, No. 8, pages 496 to 498 have been incorporated.

Clause 2 Standards and documents referred to

The standards and documents to be observed, and in particular those to which reference is made in the text of the present standard, have been brought up to date. This applies to the following standards and documents in particular:

DIN 1080 Part 1, Part 2 and Part 4;
DIN 1055 Part 4 and Part 5;
DIN 8563 Part 3;
DIN 15019 Part 1;
DASt-Richtlinie 010;
DIN 267 Part 3;
DIN 2310 Part 1 and Part 3;
DIN 6917;
DIN 6918;
DIN 17100;
DIN 17111;
DIN 18800 Part 1.

The references to Standards DIN 741, DIN 1050 and DIN 4100 have been dropped, as these standards have been withdrawn.

DIN 18800 Part 1 has been included for the first time, because reference is made to subclauses 3.4, 7.3.1.1 and 7.3.1.2 of the above-mentioned standard in the text of the present standard. (This replaces the references to DIN 4100 in subclause 6.5 of the April 1974 edition of DIN 15018 Part 1.)

Subclause 7.2.1 Load cases and permissible stresses

The USt 36-1 material for rivets has been altered to USt 36 in agreement with DIN 17111.

(The RSt 44-2 material for rivets is no longer included in DIN 17111. For the sake of completeness, it is still specified in the present standard.)

Subclause 7.4.4 Permissible stresses

In table 19 reference is made to the reduced shear stresses in welded joints specified in DIN 4132, February 1981 edition, subclause 4.4.5.

Subclause 10.3 Examples of classification of commonly used structural shapes into notch cases

The qualities of flame-cut surfaces have been designated by symbols '11' and '22' in accordance with DIN 2310 Part 1 and Part 3, in respect of components with the code numbers W 01 and W 11.

Explanatory notes relating to the November 1984 revised edition

The present standard has been revised following an abridged procedure, as already notified in the *DIN-Mitteilungen* 61, 1982, No. 8, pages 496 to 498, and brought in line as far as possible with the most recent state of the relevant standards concerned. In this context, certain references and printing errors have been corrected, and certain editorial changes have been made.

Various comments and more far-reaching suggestions for amendments have been discussed and taken into consideration in so far as it was possible to do so within the framework of the abridged procedure.

Those suggestions which could not be incorporated here have been duly noted and their inclusion has, by common consent, been postponed until such time as the content of the standard will be under review.

A short summary of the most important amendments to the text is given below.

The *Vorläufige Richtlinien für Berechnung, Ausführung und bauliche Durchbildung von gleitfesten Schraubenverbindungen* (Provisional guidelines for the calculation, design and construction of friction grip bolted connections) have temporarily been superseded by *DASt-Richtlinie* 010 *Anwendung hochfester Schrauben im Stahlbau*, because in the current edition of DIN 18800 Part 1 specifications are included relating to loadbearing members subjected to loadings which are not predominantly static, such specifications being of vital importance to crane structures.

The normal load case consisting of main loads and additional loads as described in table 7, column 4, has been specified to conform to anticipated international specifications. Accordingly, it must be assumed that the crane is travelling in steady state condition, and that skewing forces and possibly also wind forces are acting. Consequently, the lifted load shall also be multiplied by the self weight factor φ.

On the basis of recent tests which are not yet completely concluded, it would appear advisable to reduce the values of permissible shear stress in the verification of service strength relative to fillet welds. As a result, an appropriate reference has been made in table 19 to take into consideration in a suitable fashion the reduced shear stresses specified in DIN 4132, February 1981 edition, subclause 4.4.5, in respect of fillet welds and of welds with root notches.

International Patent Classification

B 66 C 17-00

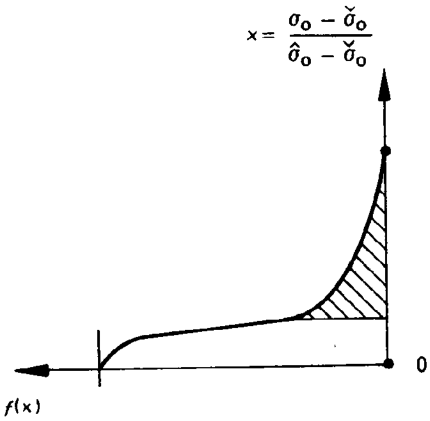


Figure 14b).
Probability density $f(x)$ corresponding to all the stress amplitudes $\sigma_o - \check{\sigma}_o$[7]), related to the greatest difference of the maximum stress amplitudes $\hat{\sigma}_o - \check{\sigma}_o$.

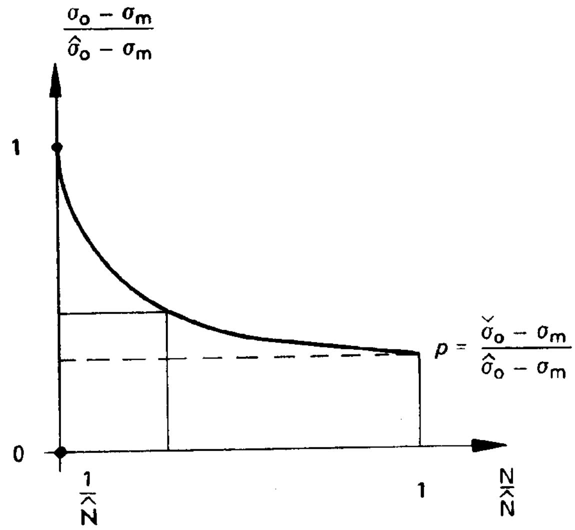


Figure 14c).
Distribution function/relative cumulative frequency stress collective related to the largest stress amplitude

$$N/\hat{N} = 2 \int_{x}^{\infty} f(x)\,dx$$

groups using a uniform and simple scheme involving approximately equal factors of safety. As regards the five notch cases for welded components made of St 37 and St 52 steels, the tests indicated that the bearable stresses were approximately equal, and these five cases could therefore be handled in the same way. The values of the stress scheme given in table 17 are based on the alternating stresses with limiting stresses of equal magnitude but opposite sign ($\varkappa = -1{,}0$). Between these basic values there exist constant step ratios depending on the steel grade, the loading group and the notch case. The remaining values for any optional limiting stress ratios between $\varkappa = -1{,}0$ and $+1{,}0$ can be derived with the aid of the established Smith diagram shown in figure 9. The equations for this are given in tables 18 and 19 as a function of the limiting stress ratios. In addition, all the figures are specified in tabular and diagrammatic form in a Supplement to the present standard. If electronic data processing facilities are employed, such tables become superfluous, because the mathematical notations for the permissible stresses in tables 18 and 19 can be incorporated in the computer programmes.

In explanation of figure 8 (idealized related stress collectives) and of table 15 (related stresses $\sigma_o - \sigma_m / \hat{\sigma}_o - \sigma_m$ of the idealized stress collectives), the relationship between a related stress/time pattern $\sigma_{(t)}/\hat{\sigma}_o$ with σ_m = constant, the frequency $f(x)$ and the cumulative frequency

$$N/\hat{N} = 2 \int_{\sigma_o}^{\infty} f(x)\,dx$$

is illustrated in figures 14a) to 14c). The multistage tests for the determination of the bearable working stresses carried out by the *LBF* in Darmstadt[6]), were based on such stress/time patterns and on a Gaussian normal distribution of the stress amplitudes $\sigma_o - \check{\sigma}_o / \hat{\sigma}_o - \check{\sigma}_o$. The frequency for the purposes of the test was standardized and specified as follows:

$$f(x) = \frac{1}{\sqrt{2\pi}} \exp \left\{ -\frac{1}{2} \frac{[(\sigma_o - \check{\sigma}_o)/(\hat{\sigma}_o - \check{\sigma}_o)]^2}{0{,}217} \right\}$$

Re 8 Holding ropes and guy ropes

The rules for the calculation of holding ropes and guy ropes are also different from those given in DIN 120 Part 1. The values of permissible stress had to be derived from relatively few experimental values.

Re 9 Tension on prestressed bolts

The data on this subject are new and are based on scientific investigations and on industrial data. Reference is made in this connection to the further work being carried out by *VDI* on the *Systematische Berechnung hochbeanspruchter Schraubenverbindungen* (Systematic calculation of highly stressed bolted connections), (*VDI-Richtlinie* 2230).

Re 10 Tables

Re 10.2 Welds

Simultaneously with the conclusion of the consultations on the present standard, DIN 8563 Part 3 was published; it deals with the evaluation groups for the quality assessment of welded joints. DIN 8563 Part 3 incorporates a new kind of specification of the evaluation groups for welded joints. The previously used designations "Quality 1", "Quality 2" and "special quality" specified in the previous edition of DIN 8563 Part 1 will no longer be used in future.

Attention is also drawn to the fact that the details relating to the symbolic representation of welds are being revised.

[6]) *Laboratorium für Betriebsfestigkeit* (Laboratory for service strength), Darmstadt, Technical Bulletin No. 15/65; *Verwendung eines Einheitskollektivs bei Betriebsfestigkeits-Versuchen* (Use of a standard collective for service strength tests).

[7]) R. Zurmühl. *Praktische Mathematik für Ingenieure und Physiker* (Practical mathematics for engineers and physicists).

respect of bulging, then the factors of safety against bulging applying to the full panel shall also be adhered to for the partial panels.

Complementing DIN 4114, factors of safety against bulging have also been specified for all load cases in respect of circular cylindrical shells, and a formula has been included for the determination of the bulging stresses.

Re 7.4 Verification of service strength

The verification of service strength has been modified in comparison with DIN 120 Part 1, as a result of recent experiments and fresh knowledge. Both the somewhat dubious "compensating factors", ψ, formerly used for this and other unrelated purposes, and the coefficients γ of DIN 120 Part 1 have been discarded. The specifications relating to welded railway bridges have been drawn upon as a useful aid when establishing the more elaborate differentiating system of permissible stresses.

The verification of service strength relating to safety against failure as a result of frequently repeated stresses variable with time need only be carried out for load cases H as described in table 7, for all cranes subjected to more than 20 000 stress cycles.

The permissible stresses in this case had to be specified in a different way, according to the following characteristics: according to loading groups, which comprise combinations of differently distributed specific stress collectives with different absolute number of stress cycles, which are likely to cause approximately an equal degree of damage to the members or to the connections, also according to steel grades, types of stress, notch cases and limiting stress ratios.

Since the service strength decreases with increasing stress cycle numbers, N 1 to N 4, and with increasing fullness ratios of the stress collectives, S_0 to S_3 (see figure 8), six loading groups, B 1 to B 6, are listed in table 14 in accordance with the correlations of these two parameters to one another; thus, for example, loading group B 5 applies for the correlations S_1/N 4 and S_2/N 3 and S_3/N 2. The usual types of crane have been classified in table 23 into six loading groups in accordance with the aspects described above, depending on their stressing during operation throughout their intended life.

The classification of a crane is governed by the part of the crane subjected to the most unfavourable stressing; just as in the case of the adoption of self weight factors and nominal load spectrum factors, it is permitted to classify certain individual structural assemblies or members which are clearly separated from one another into different loading groups as specified in table 23, on condition that the service conditions described in table 14 are well known.

In comparison with DIN 120 Part 1, the differentiation in accordance with notch effects of the individual members and connections within each loading group has been included in the present standard for the first time. By analogy with the stress lines dealt with in the specifications for welded railway bridges, the present standard establishes the experimentally verified relationship between permissible stresses, structural shape, type of connection and design of the member concerned and of the connection. Accordingly, a distinction has to be made between eight notch cases for each loading group, viz. W 0, W 1 and W 2 for non-welded components, riveted and bolted connections and K 0 to K 4 for welded components and their joints. Tables 25 to 32 give examples and details for the classification of frequently used structural shapes and connections or joints into these notch cases, including symbols for the welds and test methods in accordance with table 24. All these notch cases are given code numbers to facilitate comparison.

Extensive tests at various limiting stress ratios made it possible to develop, for each steel grade, the values of permissible stress in the verification of service strength for the eight notch cases assigned to each of the six loading

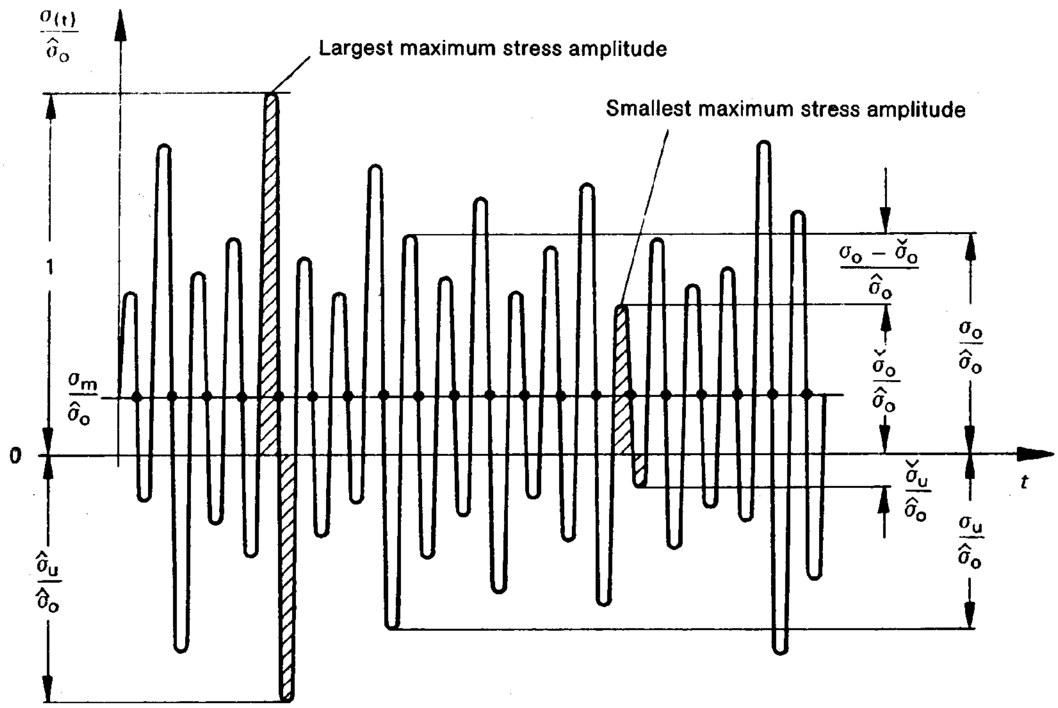


Figure 14 a).

Portion of a stress/time pattern related to the largest maximum stress, with $N = 20$ stress cycles, showing the largest and smallest maximum stress amplitudes and characterized by:

$$\sigma_m = \frac{1}{2}(\min\sigma + \max\sigma) = \text{constant and } \varkappa = \min\sigma/\max\sigma,$$

with $\min\sigma \triangleq \hat{\sigma}_u$, $\max\sigma \triangleq \hat{\sigma}_o$ and $|\hat{\sigma}_o| > |\hat{\sigma}_u|$.

Deutscher Eisenhüttenleute (Society of German Ferrous Metallurgy Engineers).

Re 4.3 Special loads

The following special loads have been introduced into the standard for the first time: the tilting force acting on crane trolleys with positive guidance of the lifted load, on impact against an obstacle, the buffer forces generated when the crane hits stops or buffers, and the test loads applied during loading tests.

The buffer forces are to be determined from the kinetic energy of the colliding crane, assuming certain given travelling speeds, and from the energy diagram of the buffers. The distribution of the buffer forces depends on the location of the centre of mass, on the freedom of movement of the crane on the craneway and on the buffer characteristics; this distribution is to be determined in agreement with the structure and driving mechanism.

The purpose of taking into account "small" and "large" test loads and the associated special load cases is to ensure that the steel structures of those cranes which are subjected to a test loading for inspection tests or at some later inspection date exhibit adequate safety margins in the general stress analysis and in the verification of stability. This special load case may prove to be of significance for the dimensioning of steel structures or members which exhibit a non-linear transmission pattern (loads – stress resultants – stresses); this applies, for example, to all supporting structures or components which are prestressed or which have a variable structural configuration.

The specification of the test loads and details relating to the necessity for, and the actual performance of load tests on cranes in respect of which no verification of stability need be carried out, are dealt with elsewhere.

Re 5 Load cases

All the above-mentioned main loads and additional loads, including the related coefficients, are summarized in table 7 under the heading of "normal load cases" and the special loads are listed under the heading of "special load cases", and the determining interaction of the individual loads can be gathered from this table for each type of crane. All the loads listed in the same column represent a separate load case, and in addition a distinction is made in the case of the normal load cases between H load cases (framed by a thick line) and HZ load cases.

Re 6 Calculation

In addition to the conventional computational stress analysis, the results of strain measurements may also be included in the evaluation if the required safety margins are observed.

As compared with DIN 120 Part 1, the crane manufacturer may now also proceed on the assumption that the craneway is correctly laid, and if that is not the case, the plant operator is under obligation to supply the relevant details.

In addition to structural steel of the conventional steel grades St 37 and St 52, and to tube steel St 35 specified in table 8, other steel grades may also be used on condition that their mechanical and chemical properties and their weldability are adequately guaranteed. In these cases, the permissible stresses are to be derived from the guaranteed yield stress and are to be substantiated from the service strengths at 90% survival probability by tests closely approximating actual service conditions. The stresses shall be determined separately for the individual load cases with the usual cross-sectional values, and as a general rule it is recommended to calculate the stresses for the individual loads and finally to superimpose them as specified in table 7.

In the case of system-dependent non-linear relationships between loads and stresses, the procedure described in DIN 4114 Part 2, February 1953x edition, Ri 10.2, shall be followed as appropriate.

Re 7 Verification and analyses

Re 7.1 General

In the verification and analyses it shall be demonstrated separately for each individual load case as per table 7 that the permissible stresses and/or the required safety factors depending on the load case, type of crane and verification are in fact adhered to in the members and principal connections and joints. Only in certain exceptional cases, involving minor deviations from the design loads, unintentional changes in the support conditions, and conditions prevailing during construction work on site, may the permissible stresses relating to load case HZ specified in table 9 be exceeded, and the maintenance of the required factors of safety relating to load case HZ be no longer compulsory.

Re 7.2 General stress analysis

The general stress analysis is intended to demonstrate by calculation the safety against attainment of the yield point, separately for the H and HZ load cases. The permissible stresses listed in tables 10 to 12 have been adjusted to the values normally used today in structural engineering; the 1,1 times the values specified for load case HZ shall apply for special load case HS as described in table 7. In cases where several stresses act simultaneously, comparison stresses are to be calculated in addition with the stresses assigned to one another in each case.

Re 7.3 Verification of stability

Verification of stability in respect of safety against buckling, collapsing and bulging shall be carried out as described in DIN 4114. As a departure from DIN 4114, different factors of safety against bulging have been specified for full panels and partial panels of flat plates for all load cases (H, HZ, HS). The higher factors of safety specified for full panels now correspond, for $\psi = 1$, to those applying to the permissible compressive stresses in the general stress analysis. These factors are readily and economically achievable in stiffened full panels by appropriately sizing the stiffeners, which are to be designed as continuous members and/or be rigidly supported laterally at the ends. The factors of safety for the partial panels have been adjusted, for $\psi = 1$, to the relative smaller factors of safety to be considered for the permissible tensile stresses in the general stress analysis. Hence the required factors of safety against bulging harmonize with those which are generally required in DIN 4114 Part 1 for web plates, for $\psi = -1$.

The different types of verification of safety against bulging, applicable to "web plates" and to "rectangular plates which are components of a member in compression" (flange plates) as given in DIN 4114 are designed to take into account the differing loadbearing capacity of the plates as a function of the stress distribution. Since the steel structures of cranes normally consist of members subjected to three-dimensional loading, it becomes impossible to make a clear-cut distinction between "web plates" and "flange plates", with the typical stress distributions associated with these terms. In order therefore to take adequate account of the differing loadbearing behaviour of the plates as a function of the stress distribution, differing factors of safety against bulging have been established as a function of ψ; if a plate is subjected to stresses acting on all its edges (web plate subjected to wheel load, web plate at one corner of a frame) then the larger, i.e. the more unfavourable value of ψ shall be used to determine the required factor of safety against bulging.

Furthermore, if in the case of stiffened plates the stiffeners have been designed for the minimum stiffness specified in DIN 4114 Part 2, subclause 18.1 (February 1953x edition), and if only the partial panels have been calculated in

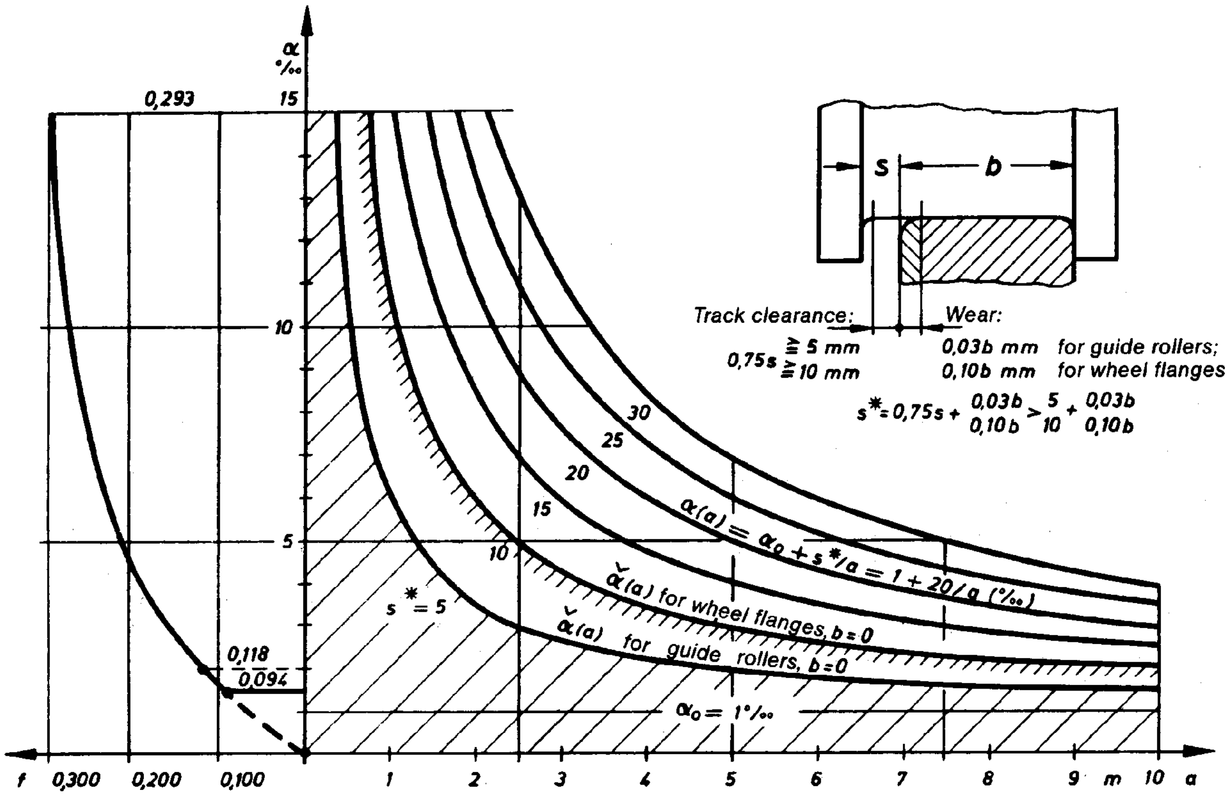


Figure 13.

In the above illustration,

s is the track clearance between rail and guiding means;

b is the width of rail;

a is the centreline distance of wheels or guiding means (see figure 4 in this connection);

α is the skew angle;

f is the coefficient of frictional contact.

mobile cranes and of tower slewing cranes in order to enable the lifting capacity of such cranes to be exploited more fully in wind conditions below the "standard case". This flexible approach to the specification of the design dynamic pressure for cranes in service is in harmony with the views expressed by ISO/TC96/SC1, who recommended 125 N/m^2 and 500 N/m^2 as the lower and upper limits respectively for the design dynamic pressure for cranes in service for the calculation of the steel structures. Naturally, where a dynamic pressure deviating from the standard is selected, this pressure is to be taken into account both in the calculation (as described in DIN 15018 Part 1) and in the verification of stability (as described in DIN 15019 Part 1 and Part 2).

Re 4.2.2 Forces arising from skewing

Forces arising from skewing are generated when the resultant direction of rolling movement of the travelling crane no longer coincides with the direction of the craneway rail, and when the front positive guiding means come into contact with the rail. As is well known, this unavoidable abnormality is caused by tolerances and inaccuracies which arise in the manufacture of the crane (bores of track wheels) and of the craneway (bends, kinks). The values and distribution of these forces depend chiefly on the clearances of wheel flanges or rollers, also on the number, arrangement, bearing arrangement and rotational speed synchronization of the track wheels and on the location of the guide rollers (if any), or in other words on the systems of the travel mechanism and of the supporting structure. Depending on the possible skew angle α, which consists of several components as a result of the causes mentioned, on the centreline distance of the wheels relative to the front guiding means, on the location of the centre of mass of the entire system depending on the position of the crane trolley, and on the location of the slip pole, a positive contact force S is generated at the front guiding element (wheel flange or horizontal guide roller) and a group of frictionally transmitted forces is also generated at the contact faces of the track wheels.

Guideline values have been specified for the standard case, on the basis of which the possible skew angle determining the skewing forces can be calculated as a function of the type of guiding means, the track clearance, the wear, and the tolerances of the crane and craneway; only a 75 % track clearance has been taken into consideration, because the skewing crane normally straightens out again before attaining the maximum skew position.

Just as it is permissible, subject to agreement, to deviate from these guideline values and to use a different, well-founded (smaller or larger) value for the skew angle in the calculation, so is it equally permissible to take into account the influence of the overall and local yieldings of the crane and craneway on the forces arising from skewing.

Figure 13 illustrates the relationship between the guideline values, the skew angle and the corresponding coefficient of frictional contact f.

The method of calculation described here has been derived from the tracking technique of railborne vehicles, and from the results of detailed investigations carried out by the Braunschweig Technical University, using an experimental crane amongst other things, under the sponsorship of the *Verein Deutscher Maschinenbau-Anstalten* (Association of German Mechanical Engineering Plants) and of the *Verein*

(φ) and nominal load spectrum factors (ψ), by which the vertically acting loads, the stress resultants, or the stresses arising therefrom, are to be multiplied.

The self weight factors (φ) apply exclusively for the self weights of the crane, including its associated equipment, as a function of the travelling speed or of the circumferential velocity v_F, and of the condition of the runway; these factors are situated between 1,1 and 1,2. It may be necessary to select higher values of φ in the case of speeds exceeding 200 m/min and of road travel. In such cases, the reasons for the choice of a higher value are to be substantiated and particularly agreed.

In cases where several motions take place simultaneously, it is permitted to use several different self weight factors in order to achieve a closer approximation of true working conditions for the individual groups of components concerned, according to their partial self weights and their partial conditions. The vertical inertia forces due to self weights alone are to be entered in the calculation in the same way as before, in accordance with DIN 120 Part 1.

The inertia forces due to the sudden picking up of lifted loads, which is the condition normally considered here, and which forces in this standard are still assumed to act exclusively in the vertical direction, depend on the one hand on the springing of the system, i.e. on the elasticity of the hoisting ropes and of the crane structure, and on the other hand on the instantaneous hoisting speed at the start of the hoisting operation, which depends on the nominal hoisting speed v_H and on the crane driver's mode of driving. Based on measurement results and on experimental data, the conventional cranes have been classified into lifting classes H 1 to H 4 (table 2) with the nominal load spectrum factors ψ ranging from 1,1 to 1,3 in the case of H 1, and from 1,4 to 2,2 in the case of H 4, in accordance with table 2 and figure 1. The lifted loads, the stress resultants or the stresses deriving therefrom are to be multiplied by these factors. These factors are also intended to make allowance for various uncertainties in the determination of other influences. As in the case of the self weight factors φ, it is permitted, when selecting the nominal load spectrum factors ψ, to approximate the true conditions more closely in individual cases by correlating certain individual structural assemblies which are clearly separated from one another into different lifting classes, if the hoisting conditions are accurately known.

The above comments make it clear that the nominal load spectrum factor ψ has been defined more precisely than was the former compensation factor ψ specified in DIN 120 Part 1; these former compensation factors were designed to allow both for the increased stresses resulting from inertia forces due to hoisting motions and for the reduced service strengths of the materials when subjected to frequently repeated variable stressing. This mixing of two phenomena and characteristics which are entirely unrelated to one another has now been eliminated (see clause 7.4).

Re 4.1.5 Inertia forces arising from driving mechanisms

The inertia forces which arise during the acceleration and deceleration of crane motions depend for their origin on the approximately equal driving and braking torques generated during every operating cycle. As a general rule, the quasi-static inertia forces shall be calculated for both processes (acceleration and deceleration) taking into consideration the mechanical system (distribution of masses, velocity conditions), as well as the efficiencies and the other resistances to motion. In the case of mechanisms, such as travelling gear units, where the transmissibility of the driving forces is restricted by frictional contact, e.g. between a track wheel and a rail, the calculation may be based on an upper limiting value, which depends on the coefficient of frictional contact ($f = 0{,}20$) and on the minimum wheel loads to be considered for the transmissibility of the largest possible driving force. This applies because the forces must be capable of being frictionally transmitted even under unfavourable conditions, such as the minimum wheel load or the minimum wheel loads, because the proper functioning of the mechanism demands it.

To allow for unavoidable transient oscillation phenomena set up during sudden changes in the drive forces, it is permitted to multiply the difference of the quasi-static force before and after the sudden action of the drive forces by an oscillation coefficient of 1,50 instead of carrying out a more accurate calculation of the dynamic forces. The inertia force effects determined in this way shall be supported in complete harmony with the loadbearing structure and driving mechanism; rules are given in the standard, by way of example, for the distribution of the reactions on the individual track wheels, and for the lateral forces arising therefrom. Subsequent changes of the driving mechanism will involve a change in the design loads of the structure and will always require renewed calculation.

In cases of wide-span cranes equipped with mechanically independent travelling bogies fitted with an electrical straight-line running control and/or an anti-skewing safety device, the necessary allowance shall be made in the calculation for the dynamic effect of the operational error, or (in emergencies) the maximum permissible control error (see DIN 19226) (elastic forward motion).

Re 4.1.6 Centrifugal forces

From now on, centrifugal forces are to be taken into consideration in slewing cranes.

Re 4.1.7 Impact from bulk material

The transient forces generated by the impact of bulk material, which are of very short duration, need only be taken into account as local loads whose action is limited to the loadbearing members immediately affected, and this action need not be followed down to the bearings and track wheels.

Re 4.2 Additional loads

Apart from the additional loads already mentioned, such as the wind loads specified in DIN 1055 Part 4, the thermal effects, the snow loads specified in DIN 1055 Part 5 and the loads on walkways, stairways etc. an important new factor has been added, viz. the forces arising from skewing.

Re 4.2.1 Wind loads

The design dynamic pressure for cranes in service, $q = 250\ \text{N/m}^2$, and the design dynamic pressures for cranes out of service, which are to be entered in the calculation as specified in DIN 1055 Part 4, include the dynamic pressure peaks (wind gusts) and their dynamic effects on the supporting structure. The mean dynamic pressure corresponding to these wind conditions is considerably smaller.

The design dynamic pressure for cranes in service corresponds to a wind condition under which the moving of loads with the aid of the crane remains barely just possible in normal cases. Consequently, there may well be instances where it would be reasonable to specify a higher or a lower design dynamic pressure for cranes in service. Steps shall however always be taken to ensure that crane operation is immediately discontinued when the wind condition approaches a state corresponding to the selected design dynamic pressure for the crane in service.

The adoption of different design dynamic pressures within the context described above may, for example, be considered appropriate in the case of coastal cranes, in order to delay the moment in time when such cranes must be shut down because of the "normal case" wind conditions which occur more frequently along the coast; they may also be considered appropriate in the case of truck-mounted

Explanatory notes relating to the April 1974 edition

Standard DIN 120 Part 1, November 1936 edition, and its supplements issued at later dates were originally intended to serve as guidelines for the building inspectorate, covering steel structures for both cranes and craneways. Such structures shall be designed and constructed in accordance with most modern techniques of current engineering practice. Since crane structures are constituent parts of machines, whereas craneways are static structures or components thereof, different conditions obviously apply to these two cases; consequently, it was decided right from the start when revising DIN 120 Part 1 to separate the standards according to the subject matter covered by them (DIN 15 018 to deal with cranes and DIN 4132 to deal with craneways). They differ where necessary, as in the case of the design loads, but they agree wherever possible, such as in the verification of service strength of the components and connections and joints. The technical committee entrusted with the revision was able on the one hand to make good use of the many years of experience gained with DIN 120 Part 1, and on the other hand to take into account the most recent and well substantiated results of research. In this context, the Supplement to DIN 120, November 1944 edition, has also been withdrawn.

The purpose of the new standards is to enable designers to achieve an economic design and construction which fully meets all safety requirements, on the basis of assumptions closely reflecting actual conditions, and of an adequate computation.

The new features and the changes in comparison with DIN 120 Part 1 are dealt with in these explanatory notes relating to DIN 15 018 Part 1, as far as cranes are concerned.

The specifications of this standard are to be applied in their entirety and neither supplemented nor substituted by parts of DIN 120 Part 1, or by other crane standards. In addition, the "Principles of design and construction" (DIN 15 018 Part 2) shall be taken into account for the design of crane structures.

The terminology and nomenclature are in harmony with DIN 1080 (symbols used in structural analysis in civil engineering), for the sake of uniformity and clearer understanding. Thus, for example, all external forces, i.e. forces acting in one direction only, are referred to as loads, whereas all internal forces acting in two directions at the banks of cuts are referred to as stress resultants; it should therefore be borne in mind that the term "load" always represents a comprehensive concept not restricted to describing such things as a useful load, a lifted load or an imposed load, as was formerly the case.

Like all similar recently published design principles, DIN 15 018 is not intended as a pocket guide for the design and dimensoning of supporting structures. On the contrary, it contents itself with the enunciation of generally valid rules for the design loads, the load cases and the required analyses and verification. The proper application of the present standard presupposes a clear understanding of the relationships between the mode of operation and the design of cranes, allied with a comprehensive engineering grasp of mechanics and with a very thorough knowledge of the behaviour of materials and of structural steel fabricating methods.

Although this standard applies basically to structures made of steel, its principles are equally applicable to other structural materials, such as light metals, on condition that the influences due to the other material are taken into account fully and correctly as regards quantitative relationship.

Re 1 Field of application

Apart from cranes and crane equipment, the field of application also covers mobile steel structures for continuous conveyors, but not craneways, excavators, waggon tippers and mining machinery.

Re 2 Standards and documents referred to

A list is given of those standards and guidelines which are to be observed in all cases without further individual reference and a further list of standards and guidelines to which reference is made in the text of this standard, involving either the entire standard concerned or extracts thereof.

Re 3 Details to be given for design purposes

The following details shall be provided for design purposes: mode of operation, classification into the relevant lifting classes and loading groups, the assumed static system which reflects actual service conditions as closely as possible, or, where appropriate, a suitably simplified static loadbearing system which nevertheless results in an indisputably safe supporting structure, the steel grades used, the cross-sectional values, the stress analyses and verification of stability of all the loadbearing members and essential connections and joints.

Re 4 Design loads

Under this heading, a new approach has been made with regard to the distinction between individual loads.

Crane structures in service are subjected to repeated loads variable with time, which, for their part, trigger variable stresses in the structural components and connections via the interaction of the static system and of the cross-sectional shape. The purpose of making a distinction between main loads, additional loads and special loads is to clearly define these loads and to avoid the risk of dangerous limiting stress conditions, such as damaging stress (H), attainment of the yield point or of instability states (H, HZ, HS), due to the behaviour of the material.

Consequently, all loads which have an effect on the service strength through their actions shall now be regarded as main loads; these include the self weights which are always present, the lifted loads which act during each operating cycle, including their vertical inertia forces, the inertia forces arising from the motion of cranes, crane components and lifted loads, and also the centrifugal forces during slewing.

All the remaining load effects such as wind loads, forces arising from skewing, thermal effects, snow loads, loads on walkways, etc. shall be regarded as additional loads and shall only be taken into consideration in respect of the general stress analysis and of the verification of stability. The same applies for the special loads, such as the tilting forces on crane trolleys with positive guidance of the lifted load, buffer forces and test loads; they are subject to special rules with regard to their interaction with the other loads. The object of introducing these special loads into the overall picture is to ensure that the crane structure, as an essential component of the production tool "crane", is unlikely to suffer any substantial damage which might adversely affect the production sequence, even in the event of unexpected, rare, but nevertheless unavoidable occurrences.

Re 4.1.4 Vertical inertia forces

A distinction has been made between the causes of the vertical inertia forces, i.e. they have been classified into forces due to the motion (travelling, slewing etc.) of cranes or crane components, and into forces due to the hoisting or lowering of lifted loads; both these causes lead to vibrations of the supporting structure, which is therefore subjected to higher stresses than those which arise from assumed static self weights and lifted loads alone. These increased stresses are allowed for in a simplified manner by the adoption of vibration factors, subdivided into self weight factors

Table 32. **Notch case K 4 (very strong notch effect)** (continued)

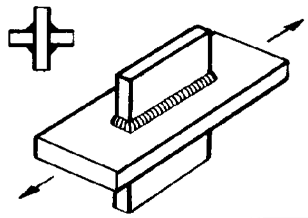
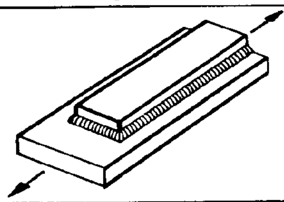
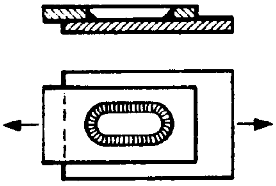
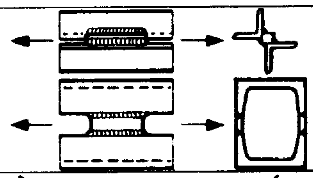
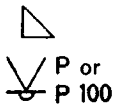
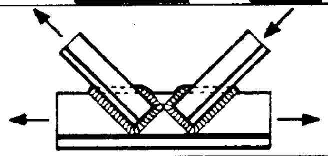
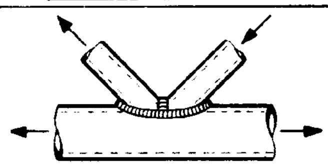
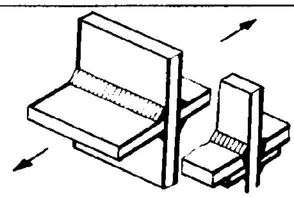
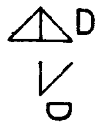
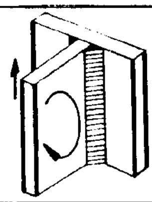
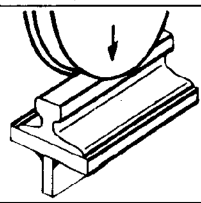
Code	Description and illustration		Symbol
443	Continuous component slotted to accommodate a plate with right-angled ends which is welded on by standard quality double fillet weld.		
444	Continuous component onto which a flange plate is welded by a fillet weld.		
445	Holed or slotted components welded to other components by fillet welds in the holes or slots.		
446	Continuous components with batten plates welded in between by standard quality fillet weld or butt weld.		
447	Continuous components onto which members are welded by fillet weld.		
448	Tubular members welded together by fillet weld.		
451	Components jointed by cross joint, by standard quality double fillet weld or by one-sided single-bevel butt weld with fillet weld and root backing, running at right angles to the direction of force.		
452	Standard quality double fillet weld used for connections subjected to bending and shear.		
453	Standard quality double fillet weld between flange and web for concentrated loads acting in the web plane at right angles to the weld.		

Table 31. **Notch case K 3 (strong notch effect)** (continued)

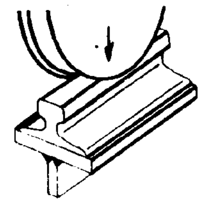
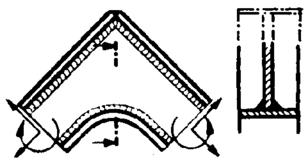
Code	Description and illustration		Symbol
353	Standard quality double bevel butt weld with double fillet weld between flange and web for concentrated loads acting in the web plane at right angles to the weld.		K
354	Web plate and curved flange plate jointed by standard quality double fillet weld.		△

Table 32. **Notch case K 4 (very strong notch effect)**

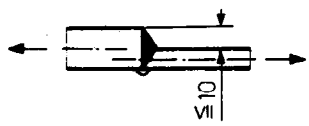
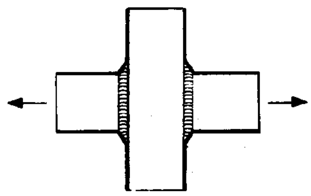
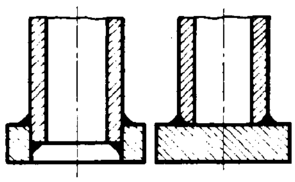
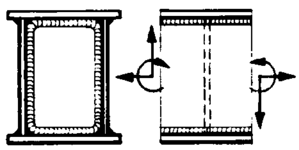
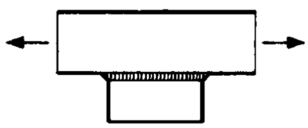
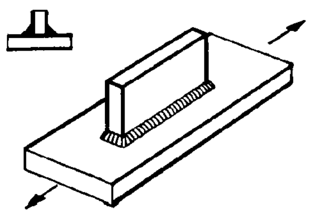
Code	Description and illustration		Symbol
412	Components of different thicknesses jointed eccentrically by standard quality butt weld running at right angles to the direction of force, with supported asymmetric joint without slope.		V P X P
413	Components jointed by standard quality butt weld running at right angles to the direction of force, at flange plate junctions.		V P X P
414	Flanges and pipes jointed by two fillet welds or by single-bevel butt weld with fillet weld.		◺ ⟍
433	Flange plates and web plates onto which transverse bulkheads are welded by standard quality one-sided continuous fillet weld running at right angles to the direction of force.		◺
441	Continuous component onto the edge of which other components with right-angled ends are welded longitudinally to the direction of force.		
442	Continuous component onto which other components or stiffeners with right-angled ends are welded by standard quality double fillet weld running longitudinally to the direction of force.		△

Table 31. **Notch case K 3 (strong notch effect)** (continued)

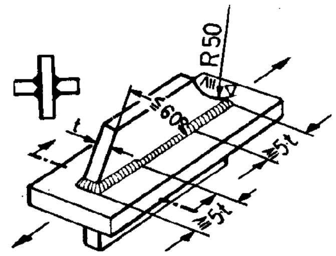
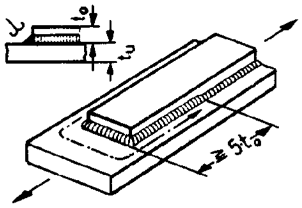
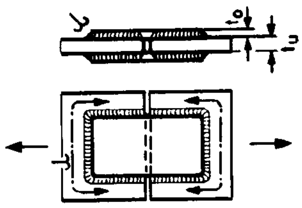
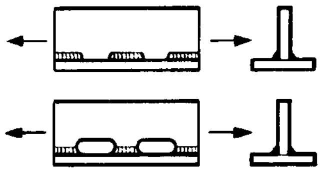
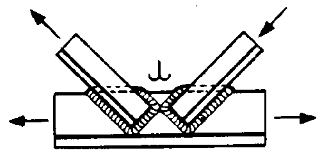
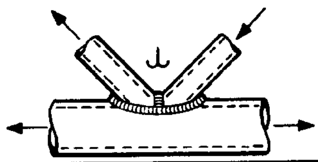
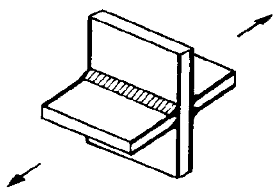
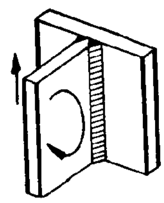
Code	Description and illustration		Symbol
343	Continuous component slotted to accommodate a plate with chamfered or radiused ends, which is welded on. The end welds in the zone not less than $5 \times t$ in width are made in the form of double bevel butt weld with double fillet welds and machined to avoid notch effect.		 End weld only.
344	Continuous component onto which a flange plate is welded with t_o not exceeding $1{,}5 \times t_u$. The end welds in the zone not less than $5 \times t_o$ in width (as shown in the illustration) are made in the form of special quality fillet welds.		 End weld only.
345	Components onto the ends of which butt straps of t_o not exceeding t_u are welded by special quality fillet weld. The end welds are in the form of special quality fillet welds in the zone shown in the illustration. In the case of one-sided overlapping of the joint, the eccentric force effect shall be taken into account.		 End weld only.
346	Continuous component onto which longitudinal stiffeners are welded by intermittent double fillet weld or by standard quality double fillet cut-out weld. The classification into notch case K 3 applies to the weld between the end welds as designed for the stiffeners.		
347	Continuous component onto which members made from steel sections or steel bars are welded by special quality fillet weld running all round.		
348	Tubular members welded together by special quality fillet weld.		
351	Components jointed by cross joint by standard quality double bevel butt weld with double fillet weld running at right angles to the direction of force.		
352	Standard quality double bevel butt weld with double fillet weld used for connections subjected to bending and shear.		

Table 31. **Notch case K 3 (strong notch effect)** (continued)

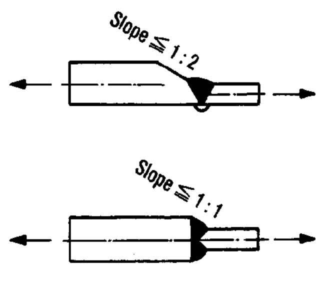
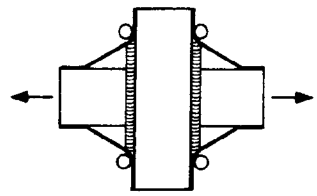
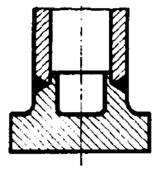
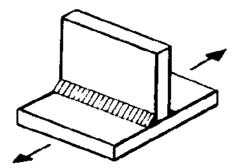
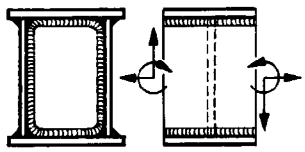
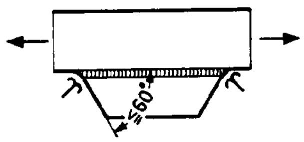
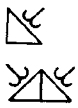
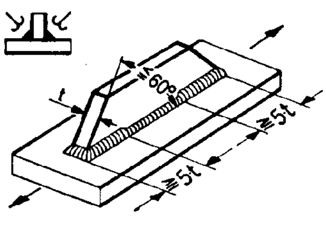
Code	Description and illustration		Symbol
312	Components of different thicknesses jointed by standard quality butt weld running at right angles to the direction of force, with supported asymmetric joint and slope not exceeding 1 : 2 or with symmetric joint and slopes not exceeding 1 : 1.		 P or P 100 P or P 100
313	Normal quality butt weld and continuous component, both at right angles to the direction of force, at flange plate junctions, with welded-on corner plates. Weld ends machined to avoid notch effect.		 P or P 100 P or P 100
314	Pipes jointed by backed butt weld without sealing weld.		
331	Continuous component onto which other components are welded by standard quality double fillet weld running at right angles to the direction of force.		
333	Flange plates and web plates onto which transverse bulkheads or stiffeners are welded by standard quality continuous double fillet weld running at right angles to the direction of force. The classification into notch case K 3 applies only to the zone of the fillet welds.		
341	Continuous component onto the edge of which other components with chamfered ends are welded by special quality fillet weld running longitudinally to the direction of force. Weld ends machined to avoid notch effect.		
342	Continuous component onto which other components or stiffeners with chamfered ends are welded longitudinally to the direction of force. The end welds in the zone not less than 5 × t in width are made in the form of special quality double fillet welds.		 End weld only.

Table 30. **Notch case K 2 (medium notch effect)** (continued)

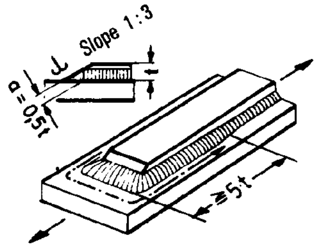
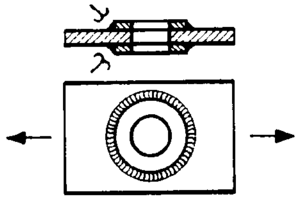
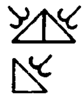
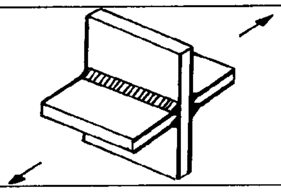
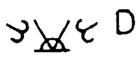
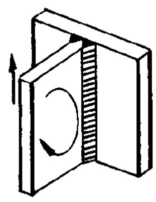
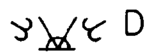
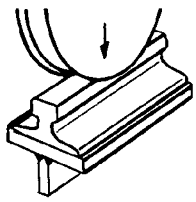
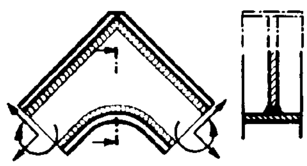
Code	Description and illustration		Symbol
244	Continuous component onto which a flange plate with chamfered end (slope ≦ 1 : 3) is welded. The end weld in the zone not less than ≧ 5 × *t* in width (as shown in the illustration) is made in the form of a special quality fillet weld with $a = 0{,}5 \times t$.		 End weld only.
245	Continuous component onto which bosses are welded by special quality fillet welds.		
251	Components jointed in a cross joint by special quality double bevel butt weld with double fillet weld running at right angles to the direction of force.		
252	Special quality double bevel butt weld with double fillet weld used for connections subjected to bending and shear.		
253	Special quality double bevel butt weld with double fillet weld between flange and web for concentrated loads acting in the web plane at right angles to the weld.		
254	Web plates and curved flange plates jointed by standard quality double bevel butt weld with double fillet weld.		

Table 31. **Notch case K 3 (strong notch effect)**

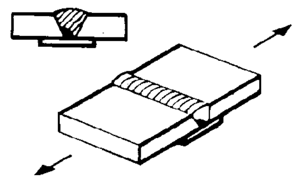
Code	Description and illustration		Symbol
311	Components jointed by one-sided butt weld with root backing, running at right angles to the direction of force.		

Table 30. **Notch case K 2 (medium notch effect)** (continued)

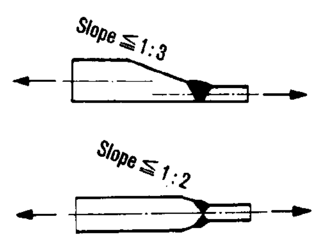
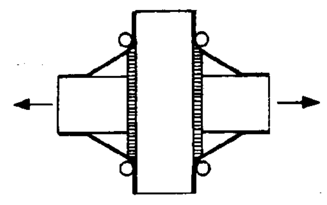
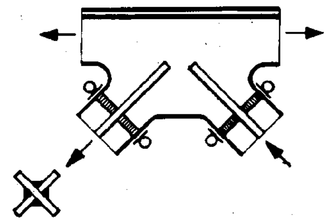
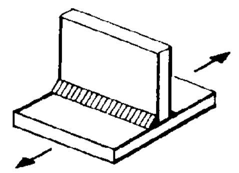
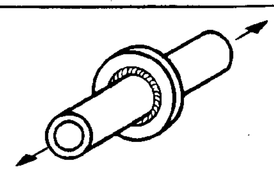
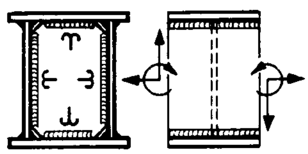
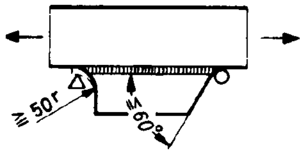
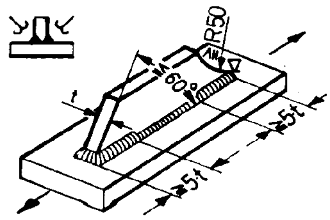
Code	Description and illustration		Symbol
212	Components of different thicknesses jointed by normal quality butt weld running at right angles to the direction of force, with supported asymmetric joint and slope not exceeding 1 : 3 or with symmetric joint and slopes not exceeding 1 : 2.		 P or P 100  P or P 100
213	Special quality butt weld and continuous component, both at right angles to the direction of force, at flange plate junctions, with welded-on corner plates. Weld ends machined to avoid notch effect.		 P 100  P 100
214	Components welded onto gusset plates by special quality butt weld running at right angles to the direction of force.		 P 100  P 100
231	Continuous component onto which other components are welded by continuous special quality double fillet weld running at right angles to the direction of force.		
232	Continuous component onto which discs are welded by special quality double fillet weld running at right angles to the direction of force.		
233	Flange plates and web plates onto which transverse bulkheads or stiffeners with cut-off edges are welded by special quality double fillet weld running at right angles to the direction of force.		
241	Continuous component onto the edge of which other components with chamfered or radiused ends are welded by a normal quality butt weld running longitudinally to the direction of force. Weld ends machined to avoid notch effect.		 
242	Continuous component onto which other components or stiffeners with chamfered or radiused ends are welded longitudinally to the direction of force. The end welds in the zone not less than 5 × t in width are made in the form of special quality double bevel butt weld with double fillet weld.		 End welds only.

Table 29. **Notch case K 1 (moderate notch effect)** (continued)

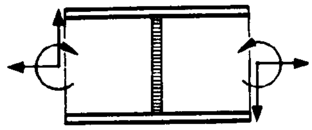
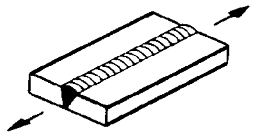
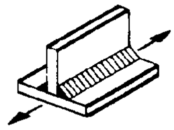
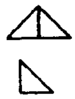
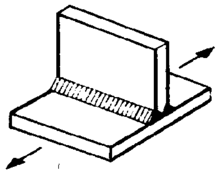
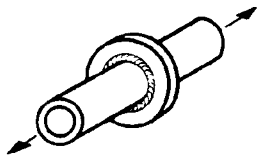
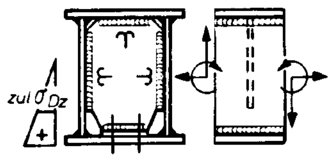
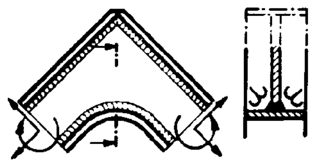
Code	Description and illustration		Symbol
114	Web plates jointed transversely by standard quality butt weld.		 P or P 100  P or P 100
121	Components jointed by standard quality butt weld running longitudinally to the direction of force.		
123	Components jointed by standard quality fillet weld running longitudinally to the direction of force.		
131	Continuous component onto which other components are welded by special quality continuous double bevel butt weld with double fillet weld running at right angles to the direction of force.		
132	Continuous component onto which discs are welded by special quality double bevel butt weld with double fillet weld running at right angles to the direction of force.		
133	Compression flanges and web plates onto which transverse bulk-heads or stiffeners with cut-off edges are welded by special quality double fillet welds. The classification into the present notch case applies only to the zone of the double fillet welds.		
154	Web plates and curved flange plates jointed by special quality double bevel butt weld with double fillet weld.		

Table 30. **Notch case K 2 (medium notch effect)**

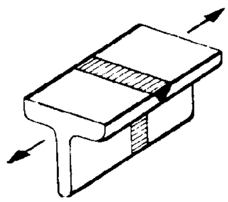
Code	Description and illustration		Symbol
211	Components made from steel sections or steel bars, with the exception of flat steel, jointed by special quality butt weld running at right angles to the direction of force.		 P 100  P 100

Table 28. **Notch case K 0 (slight notch effect)** (continued)

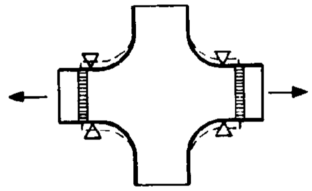
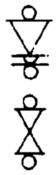
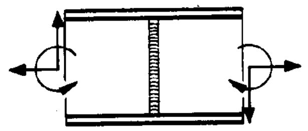
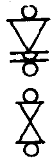
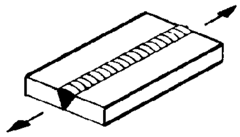
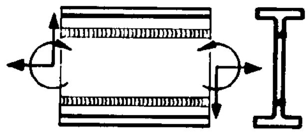
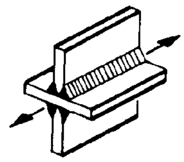
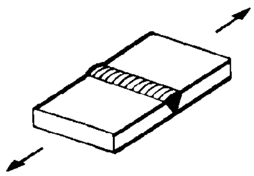
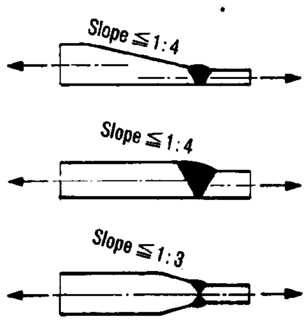
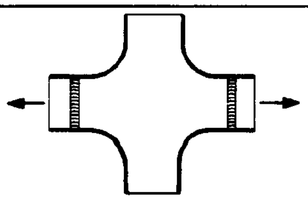
Code	Description and illustration		Symbol
013	Gusset plate welded-in by special quality butt weld running at right angles to the direction of force.		 P 100 P 100
014	Web plates jointed transversely by special quality butt weld.		 P 100 P 100
021	Components jointed by normal quality butt weld running longitudinally to the direction of force.		 P or P 100 P or P 100
022	Web plates and flange plates made from steel sections or steel bars, with the exception of flat steel, jointed by normal quality butt weld.		 P or P 100 P or P 100
023	Components jointed longitudinally to the direction of force by double bevel butt weld with double fillet weld.		

Table 29. **Notch case K 1 (moderate notch effect)**

Code	Description and illustration		Symbol
111	Components jointed by normal quality butt weld running at right angles to the direction of force.		 P or P 100 P or P 100
112	Components of different thicknesses jointed by normal quality butt weld running at right angles to the direction of force, with supported asymmetric joint and slope not exceeding 1 : 4 or with symmetric joint and slopes not exceeding 1 : 3.		 P or P 100 P or P 100
113	Gusset plate welded-in by standard quality butt weld running at right angles to the direction of force.		 P or P 100 P or P 100

10.3 Examples of classification of commonly used structural shapes into notch cases

Table 25. **Notch case W 0**

Code	Description and illustration		Symbol
W 01	Non-perforated components with normal surface finish, if no notch effects are present, or if they are taken into account in the stress analysis. The quality of flame-cut surfaces shall be not inferior to the quality specified under symbol 11 in DIN 2310 Part 1 and Part 3.		–

Table 26. **Notch case W 1**

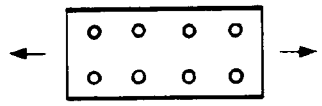
Code	Description and illustration		Symbol
W 11	Components with flame-cut surfaces at least of the quality specified under symbol 22 in DIN 2310 Part 1 and Part 3.		–
W 12	Perforated components, also with rivets and bolts, where the rivets and bolts are stressed to 20 % max. of the permissible values, or to 100 % max. of the permissible values in the case of high strength friction grip bolts.		–

Table 27. **Notch case W 2**

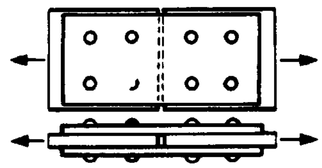
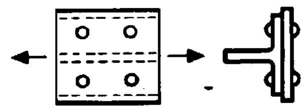
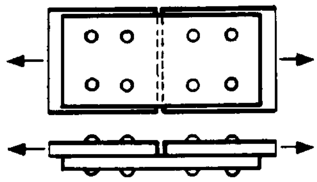
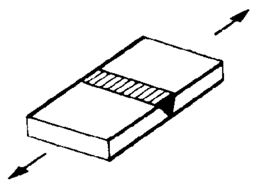
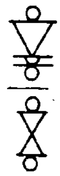
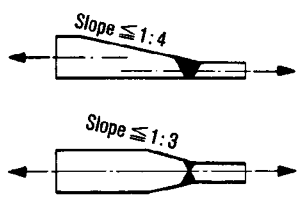
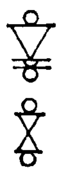
Code	Description and illustration		Symbol
W 21	Perforated components in double-shear riveted or bolted connection.		–
W 22	Perforated components in single-shear, but supported, riveted or bolted connection.		–
W 23	Perforated components in single-shear, but unsupported riveted or bolted connection, the eccentric force effects being verified.		–

Table 28. **Notch case K 0 (slight notch effect)**

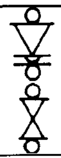
Code	Description and illustration		Symbol
011	Components jointed by special quality butt weld running at right angles to the direction of force.		 P 100 P 100
012	Components of different thicknesses jointed by special quality butt weld running at right angles to the direction of force, with supported asymmetric joint and slope not exceeding 1 : 4 or with symmetric joint and slopes not exceeding 1 : 3.		 P 100 P 100

Cranes which are designed to operate using two different useful loads and under different conditions may be classified separately if the plant operator demands it. The higher of the two useful loads shall be referred to as "exceptional load" and shall not be given on the nameplate of the crane.

10.2 Welds

In addition to the welds satisfying the requirements of the quality classes laid down in DIN 8563 Part 3, the present standard specifies welds which meet more exacting requirements in table 24.

Table 24. **Special quality welds**

Type of weld	Quality of weld	Execution of weld	Symbol, examples	Test for flawless execution	
				Test method	Symbol
Butt weld	Special quality	Root broached, back-welded sealing run, weld machined flush with plate surface in the direction of stress, no end craters.		Non-destructive testing of the weld along 100 % of the weld length, e.g. by radiographic examination.	P 100
Butt weld	Standard quality	Root broached, back-welded sealing run, no end craters.		As for special quality welds, but only for tensile stresses (specified in subclause 7.2) amounting to max. $\sigma_z \geqq 0{,}8 \cdot \text{zul}\ \sigma_z$; in the pulsating tensile stress range (specified in subclause 7.4), amounting to max $\sigma_z \geqq 0{,}8 \cdot \text{zul}\ \sigma_{zD}$; in the alternating stress range (specified in subclause 7.4), amounting to max $\sigma_z \geqq 0{,}8 \cdot \text{zul}\ \sigma_{zD}$, or max $\sigma_d \geqq 0{,}8 \cdot \text{zul}\ \sigma_{dD}$.	P 100
				Non-destructive testing, e.g. radiographic examination, of the most important remaining welds on a random sample basis, amounting to not less than 10 % of the total length of welds made by each welder.	P
Double-bevel butt weld with double fillet weld	Special quality	Root broached, through-welded (root fusion), weld interface notch-free, machined if necessary.		Non-destructive testing of the plate subjected to tension at right angles to its plane, in respect of lamination and structure discontinuities in the weld zone, e.g. by ultrasonic testing.	D
Double-bevel butt weld with double fillet weld	Standard quality	Width of residual root gap up to 3 mm or up to 0,2 times the thickness of the piece welded on, whichever is the smaller.			
Fillet weld	Special quality	Weld interface notch-free, machined if necessary.			
Fillet weld	Standard quality	–			

In order to simplify the captions in tables 25 to 32 which follow, the term "fillet weld" in the "Description and illustration" column shall be deemed to apply also to double fillet welds if both symbols are depicted. In cases where a double fillet weld is required for a given notch case, this is specified in the "Description and illustration" and "Symbol" columns.

9.3 Verification of service strength

Bolted connections complying with the specifications laid down in subclauses 9.1 and 9.2 shall be deemed as meeting the requirements in respect of service strength if a calculated factor of safety of 1,33 in respect of the tensile forces actually arising and permissible is allowed for.

10 Tables

10.1 Examples of classification of types of crane into lifting classes and loading groups

Table 23. **Lifting classes (subclause 4.1.4.2) and loading groups (subclause 7.4.2)**

Item No.	Type of crane		Lifting classes	Loading groups
1	Hand-operated cranes		H 1	B 1, B 2
2	Erection cranes		H 1, H 2	B 1, B 2
3	Powerhouse cranes		H 1	B 2, B 3
4	Storage cranes	Intermittent operation	H 2	B 4
5	Storage cranes, spreader bar cranes, scrap yard cranes	Continuous operation	H 3, H 4	B 5, B 6
6	Workshop cranes		H 2, H 3	B 3, B 4
7	Bridge cranes, ram cranes	Grab or magnet operation	H 3, H 4	B 5, B 6
8	Casting cranes		H 2, H 3	B 5, B 6
9	Soaking pit cranes		H 3, H 4	B 6
10	Stripper cranes, charging cranes		H 4	B 6
11	Forging cranes		H 4	B 5, B 6
12	Transporter bridges, semi-portal cranes, portal cranes with trolley or slewing crane	Hook operation	H 2	B 4, B 5
13	Transporter bridges, semi-portal cranes, portal cranes with trolley or slewing crane	Grab or magnet operation	H 3, H 4	B 5, B 6
14	Travelling belt bridges with fixed or sliding belt(s)		H 1	B 3, B 4
15	Dockyard cranes, slipway cranes, fitting-out cranes	Hook operation	H 2	B 3, B 4
16	Wharf cranes, slewing cranes, floating cranes, level luffing slewing cranes	Hook operation	H 2	B 4, B 5
17	Wharf cranes, slewing cranes, floating cranes, level luffing slewing cranes	Grab or magnet operation	H 3, H 4	B 5, B 6
18	Heavy duty floating cranes, gantry cranes		H 1	B 2, B 3
19	Shipboard cargo cranes	Hook operation	H 2	B 3, B 4
20	Shipboard cargo cranes	Grab or magnet operation	H 3, H 4	B 4, B 5
21	Tower slewing cranes for the construction industry		H 1	B 3
22	Erection cranes, derrick cranes	Hook operation	H 1, H 2	B 2, B 3
23	Rail-mounted slewing cranes	Hook operation	H 2	B 3, B 4
24	Rail-mounted slewing cranes	Grab or magnet operation	H 3, H 4	B 4, B 5
25	Railway cranes authorized on trains		H 2	B 4
26	Truck cranes, mobile cranes	Hook operation	H 2	B 3, B 4
27	Truck cranes, mobile cranes	Grab or magnet operation	H 3, H 4	B 4, B 5
28	Heavy-duty truck cranes, heavy-duty mobile cranes		H 1	B 1, B 2

Table 21. **Prestressing forces and tightening torques for property class 10.9 high strength friction grip bolts (complying with DIN 6914 to DIN 6918)**

Bolt diameter	Prestressing force, in N P_v	Tightening torque, in Ncm M_a
M 16	93300	28400
M 20	145600	55400
M 22	180100	76200
M 24	209800	95800
M 27	272800	142000

The tightening torque which has to be applied with torque wrenches in order to achieve the required prestressing force produces a combined tensile and torsional load calculated at 90% of the minimum yield stress ($\sigma_{0,2}$ = 90000 N/cm^2). All calculations are based on the more unfavourable of the two limit coefficients of friction, $\mu = 0{,}14$ or $\mu = 0{,}18$[4].

9.2 General stress analysis

The tensile force to be absorbed in load cases H, HZ and HS specified in table 7 shall not exceed the permissible tensile forces zul Z_1 or zul Z_2:

$$\text{zul}\,Z_1 = \frac{S_1}{\Phi} \quad \text{or zul}\,Z_2 = \frac{S_2}{1-\Phi}$$

where

S_1 is the longitudinal bolt force specified in table 22, which is just sufficient to increase the state of stress of the bolt prestressed according to table 21 until the minimum yield stress is attained, when subjected to a ν-fold tensile force.

S_2 is the longitudinal bolt force specified in table 22, which is just sufficient to cancel out the surface contact pressure of the bolt prestressed according to table 21, when subjected to a ν-fold tensile force; the joint just begins to gape open. This verification is only of any significance for $\Phi < \Phi_0 = 0{,}2038$.

Φ is the clamping factor[5] shown in figure 12, which is dependent on the clamping length l_k and on the nominal diameter d of the bolt.

Table 22. **Longitudinal bolt forces S_1 and S_2, in N**

Bolt diameter d	Load case H		Load case HZ		Load case HS	
	S_1	S_2	S_1	S_2	S_1	S_2
M 16	10000	39000	11400	44450	12650	49400
M 20	15600	60850	17750	69350	19750	77050
M 22	19250	75250	21950	85750	24400	95300
M 24	22450	87650	25600	99950	28450	111050
M 27	29200	114000	33250	129950	36950	144350
Factor of safety	1,71		1,50		1,35	

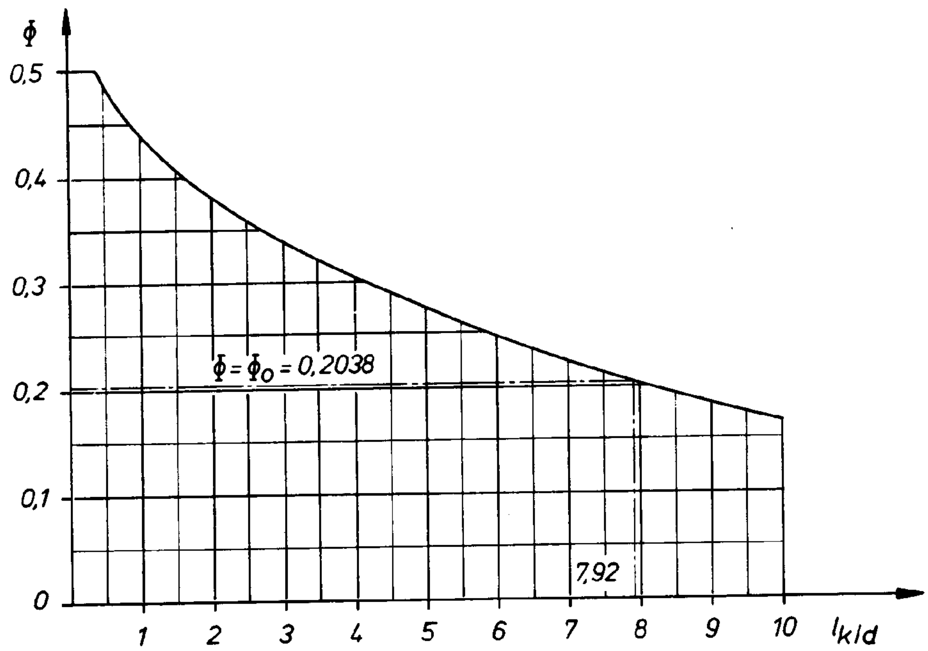


Figure 12.
Clamping factor Φ for solid steel plates and hexagon head bolts complying with DIN 6914, hexagon nuts complying with DIN 6915, washers complying with DIN 6916 and square washers complying with DIN 6917 and DIN 6918

[4]) *Neue Wege einer systematischen Schraubenberechnung* (New methods of systematic calculation of bolted connections), by *G. Junker* and *D. Blume*. Scientific publication of Messrs. *Bauer und Schaurte*, Neuss/Rhein, published by *Michael Triltsch Verlag*, Düsseldorf, 1965.

[5]) *Grundlagen einer genauen Berechnung statisch und dynamisch beanspruchter Schraubenverbindungen* (Fundamental principles for the precise calculation of statically and dynamically loaded bolted connections), by *Fritsche*, dissertation at Berlin Technical University 1962.

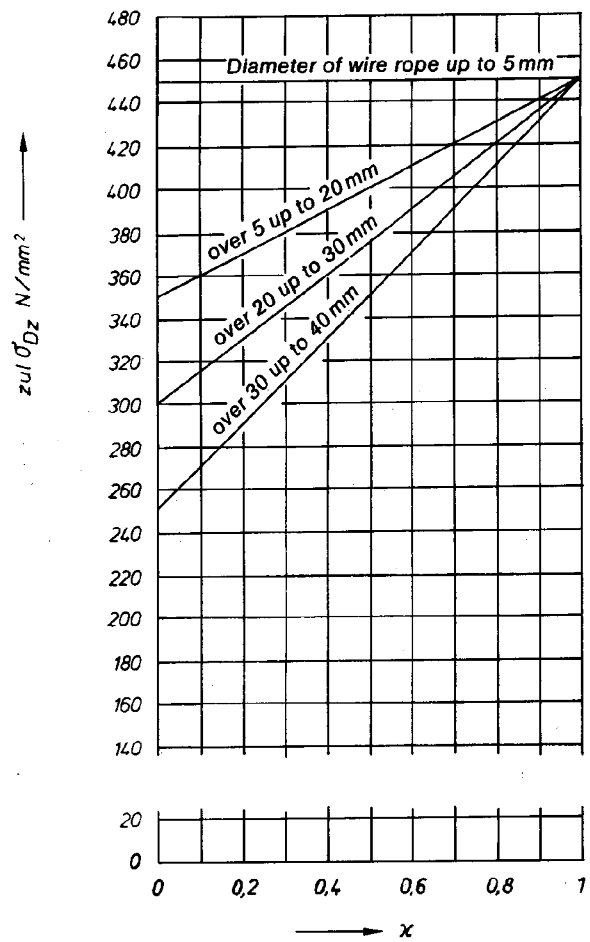


Figure 10. Permissible stresses for loading groups B 1, B 2 and B 3

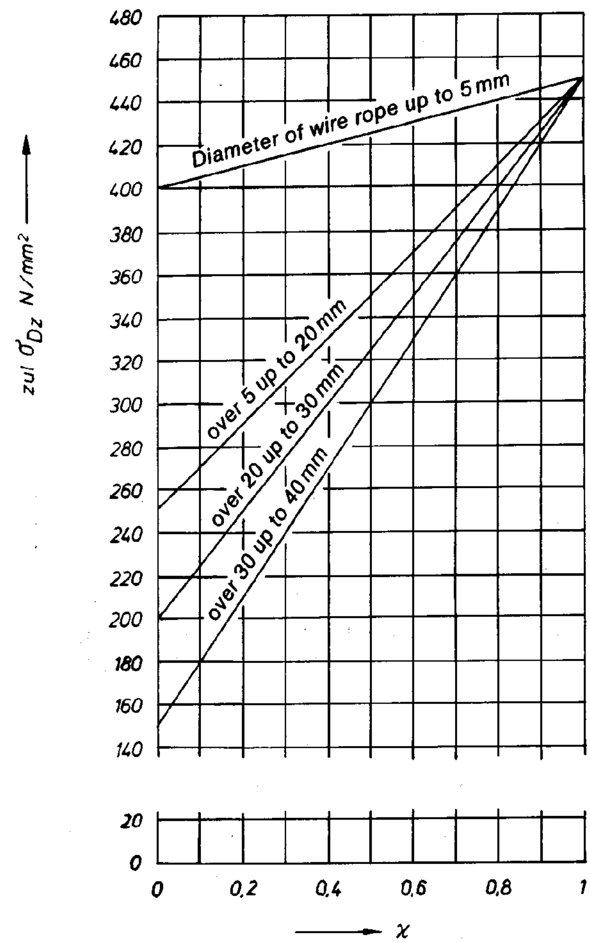


Figure 11. Permissible stresses for loading groups B 4, B 5 and B 6

Table 20. **Permissible stresses for holding ropes and guy ropes composed of individual wires with a nominal strength of 1570 N/mm² for the verification of service strength**

Diameter of wire rope, in mm	Permissible stress zul σ_{Dz}, in N/mm², for loading groups	
	B 1, B 2 and B 3	B 4, B 5 and B 6
Up to 5	450	$400 + 50 \cdot x$
Over 5 up to 20	$350 + 100 \cdot x$	$250 + 200 \cdot x$
Over 20 up to 30	$300 + 150 \cdot x$	$200 + 250 \cdot x$
Over 30 up to 40	$250 + 200 \cdot x$	$150 + 300 \cdot x$

All the permissible stresses shall apply for stranded ropes and until further notice also to fully locked coil ropes and to open spiral ropes; they may be exploited to the following extent, depending on the method of rope fastening adopted:

securing by sweating or by attachment to bollards, up to 100 %;
securing by compression clamps, up to 90 %**);
securing by rope sockets or splicing, up to 80 %;
securing by rope clamps, up to 40 %;

The modulus of elasticity depends on the design and construction of the rope and increases with the frequency and magnitude of the pull force exerted on the rope; in the case of fully stretched ropes, it may be assumed to be

90 000 to 120 000 N/mm² for stranded ropes with hemp core;
100 000 to 130 000 N/mm² for stranded ropes with steel core;
140 000 to 170 000 N/mm² for fully locked coil ropes and open spiral ropes.

9 Tension on prestressed bolts

9.1 General

Bolted connections consisting of non-treated (non-galvanized, non-cadmium plated) bolts, nuts and washers complying with DIN 6914 to DIN 6918, assigned to property class 10.9, which are prestressed against plane parallel, and in certain cases machined solid steel plates specified in table 21, with a deviation not exceeding ±10 %, and wich are intended to transmit a tensile force Z, shall be verified in accordance with subclause 9.2 for the applicable load cases H, HZ and HS specified in table 7.

**) The permissible stresses may only be exploited up to the above specified values if the compression clamps and the mode of their attachment permit it.

Table 19. **Permissible stresses zul $\tau_{D\,(x)}$ for members and welds and permissible stresses zul $\tau_{aD\,(x)}$ and zul $\sigma_{lD\,(x)}$ for fasteners**

Members	$\text{zul}\,\tau_{D\,(x)} = \dfrac{\text{zul}\,\sigma_{Dz\,(x)}}{\sqrt{3}}$	zul $\sigma_{Dz\,(x)}$ as for W 0
Weld*)	$\text{zul}\,\tau_{D\,(x)} = \dfrac{\text{zul}\,\sigma_{Dz\,(x)}}{\sqrt{2}}$	zul $\sigma_{Dz\,(x)}$ as for K 0
Multiple-shear rivets and fit bolts	$\text{zul}\,\tau_{aD\,(x)} = 0{,}8 \cdot \text{zul}\,\sigma_{Dz\,(x)}$ $\text{zul}\,\sigma_{lD\,(x)} = 2{,}0 \cdot \text{zul}\,\sigma_{Dz\,(x)}$	zul $\sigma_{Dz\,(x)}$ as for W 2
Single-shear (unsupported) rivets and fit bolts	$\text{zul}\,\tau_{aD\,(x)} = 0{,}6 \cdot \text{zul}\,\sigma_{Dz\,(x)}$ $\text{zul}\,\sigma_{lD\,(x)} = 1{,}5 \cdot \text{zul}\,\sigma_{Dz\,(x)}$	zul $\sigma_{Dz\,(x)}$ as for W 2

*) Until further notice, the permissible shear stresses specified in DIN 4132, February 1981 edition, subclause 4.4.5, second paragraph and equation (5) shall be taken into consideration as appropriate for fillet welds and for welds with root notches.

7.4.5 Combined stresses

In the case of combined stresses, the following condition shall also be satisfied, paying attention to the plus or minus signs and to the applicable limiting stress ratios for the members or for the weld or for both:

$$\left(\frac{\sigma_x}{\text{zul}\,\sigma_{xD}}\right)^2 + \left(\frac{\sigma_y}{\text{zul}\,\sigma_{yD}}\right)^2 - \left(\frac{\sigma_x \cdot \sigma_y}{|\text{zul}\,\sigma_{xD}| \cdot |\text{zul}\,\sigma_{yD}|}\right) + \left(\frac{\tau}{\text{zul}\,\tau_D}\right)^2 \leq 1{,}1$$

where

σ_x, σ_y is the calculated normal stress in x and y directions;

zul σ_{xD}, zul σ_{yD} is the permissible normal stress corresponding to stresses σ_x and σ_y respectively;

$|\text{zul}\,\sigma_{xD}|$, $|\text{zul}\,\sigma_{yD}|$ is the amount of zul σ_{xD} and zul σ_{yD} respectively;

τ is the calculated shear stress:

zul τ_D is the permissible shear stress corresponding to the stress τ.

If the worst case for the above condition is not evident from the correlated stresses σ_x, σ_y and τ, separate verification shall be made for the conditions max σ_x, max σ_y and max τ using the correlated worst case stresses for these conditions.

7.5 Verification of stability

The stability and the safety against drifting under wind pressure shall be verified as specified in DIN 15019 Part 1 and Part 2 respectively.

8 Holding ropes and guy ropes

Holding ropes and guy ropes are wire ropes which are not guided over pulleys or drums, and over which no pulleys travel.

The strength of such ropes, without local transverse loading, e.g. via clips or saddles, depends amongst other things on the construction, diameter and fastening of these ropes.

The general stress analysis shall be carried out for load cases HZ and HS. The verification of service strength specified in subclause 7.4 shall be carried out for load case H and only for such ropes as are intended as permanent members of the crane structure.

The permissible stresses in the metallic cross section of wire ropes composed of individual wires with a nominal strength $\sigma_z = 1570\,\text{N/mm}^2$ are specified at a value of zul $\sigma_z = 450\,\text{N/mm}^2$ in the general stress analysis for all load cases HZ; as regards the verification of service strength, the permissible stresses shall be those listed in table 20 and shown in figures 10 and 11, depending on the wire rope diameter and on the loading group concerned.

If individual wires with a nominal strength of more than $1570\,\text{N/mm}^2$ are used, it is not permitted to increase the permissible stresses proportionately. A justification shall be submitted for the increase in permissible stresses adopted.

7.4.4 Permissible stresses

The permissible maximum stress values of the normal stresses and shear stresses in members and welds, and of the shear stresses and hole bearing stresses in fasteners and perforated members are specified in tables 18 and 19 as a function of the basic values of the permissible stresses zul $\sigma_{D(-1)}$ (table 17) and of the limiting stress ratio.

All permissible stresses for the verification of service strength are limited on the upper side by the permissible stresses applicable to load case HZ in the general stress analysis specified in subclause 7.2.1, tables 10 to 12. With regard to compressive stresses in members, the values in the zul σ_z column shall apply.

The permissible stresses zul $\sigma_{D(-1)}$ listed in table 17 correspond, at a factor of safety of $\nu_D = 4/3$, to the bearable stresses based on a 90% survival probability.

The relationships illustrated in figure 9 exist between the permissible stresses zul $\sigma_{D(-1)}$ and zul $\sigma_{D(x)}$.

The relationships specified in table 18 shall apply for the permissible normal stresses in members.

The relationships specified in table 19 shall apply for the permissible shear stresses in members and welds and for the permissible shear stresses and hole bearing stresses in fasteners and perforated members.

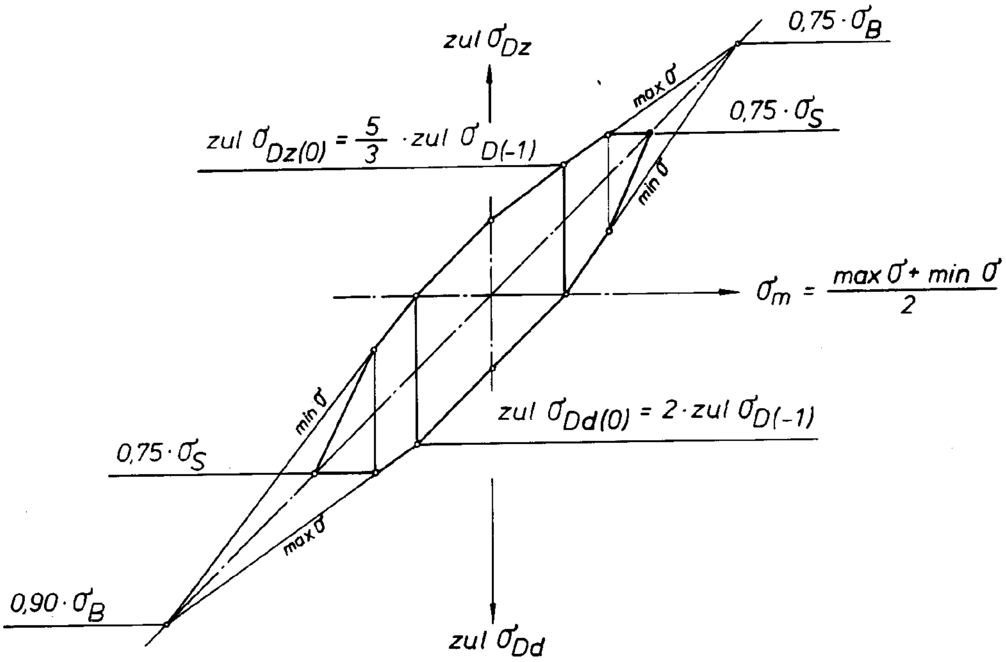


Figure 9. Relationships between zul $\sigma_{D(x)}$ and zul $\sigma_{D(-1)}$

Table 18. **Equations relating to the permissible maximum stresses according to figure 9 as a function of $\varkappa$ and of zul $\sigma_{D(-1)}$ as specified in table 17**

Alternating stress range $-1<\varkappa<0$	Tension	$\text{zul}\,\sigma_{Dz(\varkappa)} = \frac{5}{3-2\varkappa}\cdot \text{zul}\,\sigma_{D(-1)}$
	Compression	$\text{zul}\,\sigma_{Dd(\varkappa)} = \frac{2}{1-\varkappa}\cdot \text{zul}\,\sigma_{D(-1)}$
Pulsating stress range $0<\varkappa<+1$	Tension	$\text{zul}\,\sigma_{Dz(\varkappa)} = \dfrac{\text{zul}\,\sigma_{Dz(0)}}{1-\left(1-\dfrac{\text{zul}\,\sigma_{Dz(0)}}{0{,}75\cdot\sigma_B}\right)\cdot\varkappa}$
	Compression	$\text{zul}\,\sigma_{Dd(\varkappa)} = \dfrac{\text{zul}\,\sigma_{Dd(0)}}{1-\left(1-\dfrac{\text{zul}\,\sigma_{Dd(0)}}{0{,}90\cdot\sigma_B}\right)\cdot\varkappa}$

Table 16 deleted.

Table 17. **Basic values of the permissible stresses zul $\sigma_{D\,(-1)}$, in N/mm^2, for $\varkappa = -1$ in members, for the verification of service strength**

<table>
<tr><td>Steel grade</td><td colspan="3">St 37</td><td colspan="3">St 52-3</td><td colspan="5">St 37</td><td colspan="5">St 52-3</td></tr>
<tr><td>Notch case</td><td>W 0</td><td>W 1</td><td>W 2</td><td>W 0</td><td>W 1</td><td>W 2</td><td>K 0</td><td>K 1</td><td>K 2</td><td>K 3</td><td>K 4</td><td>K 0</td><td>K 1</td><td>K 2</td><td>K 3</td><td>K 4</td></tr>
<tr><td>Loading group</td><td colspan="16">Permissible stresses zul $\sigma_{D\,(-1)}$ for $\varkappa = -1$</td></tr>
<tr><td>B 1</td><td rowspan="3">180</td><td rowspan="2">180</td><td>180</td><td rowspan="2">270</td><td>270</td><td>247,2</td><td rowspan="3">180</td><td rowspan="3">180</td><td rowspan="2">180</td><td>180</td><td>152,7</td><td rowspan="2">270</td><td rowspan="2">270</td><td>270</td><td>254</td><td>152,7</td></tr>
<tr><td>B 2</td><td>168</td><td>249</td><td>199,2</td><td>180</td><td>108</td><td>252</td><td>180</td><td>108</td></tr>
<tr><td>B 3</td><td>161,4</td><td>141,3</td><td>252,2</td><td>200,6</td><td>160,5</td><td>178,2</td><td>127,3</td><td>76,4</td><td>237,6</td><td>212,1</td><td>178,2</td><td>127,3</td><td>76,4</td></tr>
<tr><td>B 4</td><td>169,7</td><td>135,8</td><td>118,8</td><td>203,2</td><td>161,1</td><td>129,3</td><td>168</td><td>150</td><td>126</td><td>90</td><td>54</td><td>168</td><td>150</td><td>126</td><td>90</td><td>54</td></tr>
<tr><td>B 5</td><td>142,7</td><td>114,2</td><td>99,9</td><td>163,8</td><td>130,3</td><td>104,2</td><td>118,8</td><td>106,1</td><td>89,1</td><td>63,6</td><td>38,2</td><td>118,8</td><td>106,1</td><td>89,1</td><td>63,6</td><td>38,2</td></tr>
<tr><td>B 6</td><td>120</td><td>96</td><td>84</td><td>132</td><td>105</td><td>84</td><td>84</td><td>75</td><td>63</td><td>45</td><td>27</td><td>84</td><td>75</td><td>63</td><td>45</td><td>27</td></tr>
<tr><td colspan="17">The step ratio between the stresses of two consecutive loading groups is 1,1892 for St 37 and 1,2409 for St 52-3, for notch cases W 0 to W 2; for notch cases K 0 to K 4, the step ratio is 1,4142 for St 37 and for St 52-3.</td></tr>
</table>

Table 14. **Loading groups according to stress cycle ranges and stress collectives**

Stress cycle range	N 1	N 2	N 3	N 4
Total number of anticipated stress cycles $\hat{N}$	Over $2 \cdot 10^4$ up to $2 \cdot 10^5$ Occasional irregular use with long periods of non-use	Over $2 \cdot 10^5$ up to $6 \cdot 10^5$ Regular use in intermittent operation	Over $6 \cdot 10^5$ up to $2 \cdot 10^6$ Regular use in continuous operation	Over $2 \cdot 10^6$ Regular use in heavy-duty continuous operation
Stress collective	Loading group			
S_0, very light	B 1	B 2	B 3	B 4
S_1, light	B 2	B 3	B 4	B 5
S_2, medium	B 3	B 4	B 5	B 6
S_3, heavy	B 4	B 5	B 6	B 6

The four stress cycle ranges, N 1 to N 4, given in table 14 comprise the probable total number or the cumulative frequency $\hat{N}$ at which the smallest maximum stress $\check{\sigma}_o$ of the stress collective is attained or exceeded. The total number $\hat{N}$ of stress cycles imposed on a member can be equal to the number of load cycles or of operating cycles, or to a multiple thereof, depending on the type of crane; in this respect, a load cycle shall be deemed to mean a single lifting motion and a single lowering motion taking place between the picking up and the setting down of a lifted load, whilst an operating cycle shall be deemed to mean all the motions necessary for the performance of a complete transport and handling operation.

The four stress collectives, S_0 to S_3, denote the relative cumulative frequency with which a specific maximum stress σ_o is attained or exceeded. The anticipated stress collectives shall be correlated roughly to the idealized stress collectives; if necessary, a cumulative damage calculation may be carried out for this purpose. The idealized stress collectives are defined by the maximum and minimum limit values of the stress amplitudes, $\hat{\sigma}_o - \sigma_m$ and $\check{\sigma}_o - \sigma_m$, and by a distribution approximating the Gaussian distribution (see figure 8 in this respect).

The eight notch cases, W 0 to W 2 and K 0 to K 4, as specified in subclause 7.4.3 and in tables 25 to 32 allow for the decrease in service strength of conventional structural shapes with increasing influence of notch effects.

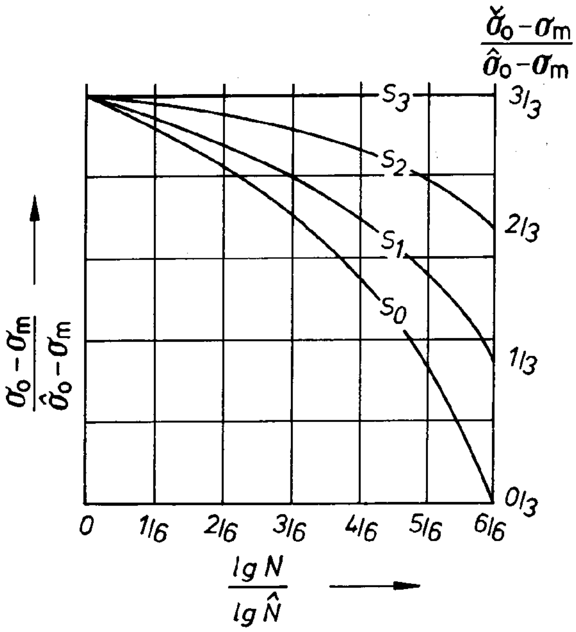


Figure 8. Idealized related stress collectives

7.4.2 Loading groups

The loading groups listed in table 14 are correlated to the stress cycle ranges and to the stress collectives.

The cranes may be classified into loading groups according to the operating conditions of the most severely loaded part of the crane. Individual elements which are clearly separated from the rest, or which form self-contained structural units may be classified into different loading groups on condition that their operating conditions are precisely known.

Table 15. **Related stresses** $\frac{\sigma_o - \sigma_m}{\hat{\sigma}_o - \sigma_m}$ **of the idealized stress collectives**

	$\frac{\lg N}{\lg \hat{N}}$	0	1/6	2/6	3/6	4/6	5/6	6/6
Stress collective	S_3	1	1	1	1	1	1	1
	S_2	1	0,975	0,944	0,906	0,856	0,787	0,666
	S_1	1	0,952	0,890	0,814	0,716	0,579	0,333
	S_0	1	0,927	0,836	0,723	0,576	0,372	0,000

where

$\sigma_m = \frac{1}{2}(\max \sigma + \min \sigma)$ = amount of the constant mean stress;

σ_o is the amount of the maximum stress which is attained or exceeded N times;

$\hat{\sigma}_o$ is the amount of the largest maximum stress of the idealized stress collective;

$\check{\sigma}_o$ is the amount of the smallest maximum stress of the idealized stress collective;

$\hat{N} = 10^6$, extent of the idealized stress collective.

7.4.3 Notch cases

The most widely used structural shapes, connections and joints are correlated to the eight notch cases, W 0 to W 2 and K 0 to K 4, as specified in subclause 10.3, tables 25 to 32, according to the notch influences dependent on their shape, structural design, hole pattern or type and quality of the welds etc.

The most widely used types of welds are classified in table 24 of subclause 10.2 according to grades in relation to their execution and inspection.

where

$$\bar{\sigma}_x = \frac{\text{zul}\,\sigma_z}{\text{zul}\,\sigma_{wz}} \cdot \sigma_x \text{ or } \bar{\sigma}_x = \frac{\text{zul}\,\sigma_z}{\text{zul}\,\sigma_{wd}} \cdot \sigma_x$$

$$\bar{\sigma}_y = \frac{\text{zul}\,\sigma_z}{\text{zul}\,\sigma_{wz}} \cdot \sigma_y \text{ or } \bar{\sigma}_y = \frac{\text{zul}\,\sigma_z}{\text{zul}\,\sigma_{wd}} \cdot \sigma_y$$

with the permissible tensile stresses zul σ_z in members as specified in table 10, the permissible tensile stresses zul σ_{wz} and the permissible compressive stresses zul σ_{wd} in welds as specified in table 11, and with the calculated stresses σ_x, σ_y and τ in the welds.

If the worst case under the above conditions is not evident from the correlated stresses σ_x, σ_y and τ, separate verification shall be made for the conditions max σ_x, max σ_y and max τ, using the correlated worst case stresses for these conditions.

7.3 Verification of stability

7.3.1 General

The verification of stability in respect of safety against buckling, collapsing and bulging of the web plates and bulging of the rectangular plates forming part of a compression member shall be carried out as described in DIN 4114 Part 1 and Part 2 for load cases H, HZ and HS.

Load case H corresponds to load case 1 as defined in DIN 4114 Parts 1 and 2, and load case HZ corresponds to load case 2.

In the special load case HS, the safety against buckling shall be $\nu_{Ks} = \nu_{K1} \cdot \frac{1{,}35}{1{,}71}$, ν_{K1} being the safety against buckling in load case 1 as defined in DIN 4114 Parts 1 and 2.

Verification of the safety against bulging of plates shall also be carried out in accordance with DIN 4114 Part 1 and Part 2, but in lieu of the factors of safety, ν_B, specified in DIN 4114, the values given in subclause 7.3.3, table 13, shall be used.

Table 13. **Factors of safety against bulging** ν_B

	Load case	ν_B
Full panel	H	$1{,}71 + 0{,}180\ (\psi - 1)$
	HZ	$1{,}50 + 0{,}125\ (\psi - 1)$
	HS	$1{,}35 + 0{,}075\ (\psi - 1)$
Partial panel	H	$1{,}50 + 0{,}075\ (\psi - 1)$
	HZ	$1{,}35 + 0{,}050\ (\psi - 1)$
	HS	$1{,}25 + 0{,}025\ (\psi - 1)$
Circular cylindrical shells	H	1,71
	HZ	1,50
	HS	1,35

A full panel, stiffened or non-stiffened, extends over the area of a plate in compression, the edges of which are rigidly supported transversely in the direction of bulging by other members such as transverse bulkheads, flange plates or web plates; a partial panel is a non-stiffened partial area of the full panel. In the factors above, ψ is the larger of the two quotients $\psi_x = \sigma_{x2} : \sigma_{x1}$ or $\psi_y = \sigma_{y2} : \sigma_{y1}$ from the correlated normal stresses σ_{x1}, σ_{x2} or σ_{y1}, σ_{y2} at the corners of the respective edges of a full panel or of a partial panel; see also DIN 4114 Part 1, subclause 16.5 (July 1952xx edition) and DIN 4114 Part 2, subclause 17.1 (February 1953x edition).

In cases where ψ is less than -1, ψ shall be entered at a value of -1.

7.3.2 Verification of safety against bulging of circular cylindrical shells

Thin-walled circular cylindrical shells, such as large-diameter pipes, which are subjected to systematic centric or eccentric axial loading shall be verified in respect of local bulging if

$$\frac{t}{r} \leq \frac{25 \cdot \sigma_s}{E}$$

where

- t is the wall thickness;
- r is the radius related to the center of the wall thickness;
- σ_s is the yield stress of steel grade specified in table 8;
- E is the modulus of elasticity specified in table 8.

The ideal bulging stress σ_{Bi} can be determined by means of the relationship

$$\sigma_{Bi} = 0{,}2 \cdot \frac{E \cdot t}{r}$$

In all cases where σ_{Bi} is situated above the proportionality limit of the structural steel, it shall be reduced to σ_B, as specified in DIN 4114 Part 1 (July 1952xx edition), table 7.

Transverse stiffenings shall be arranged at spacings not exceeding $10 \times r$, whose moment of inertia J, calculated in accordance with DIN 4114 Part 2 (February 1953x edition), Ri 18.13, shall be not less than

$$J = \frac{r \cdot t^3}{2} \cdot \sqrt{\frac{r}{t}}$$

It may be assumed that the above verification of safety against bulging of circular cylindrical shells makes adequate allowance for geometric deviations between the actual and the ideal shell centre plane resulting from inaccuracies of fabrication in magnitudes up to $t/2$.

7.3.3 Safety against bulging

The factors of safety against bulging of the flat plates,

$$\nu_B = \frac{\sigma_{VKi}}{\sigma_V} \text{ or } \nu_B = \frac{\sigma_{VK}}{\sigma_V},$$

and the factors for circular cylindrical shells with σ_d as the largest edge compressive stress,

$$\nu_B = \frac{\sigma_{Bi}}{\sigma_d} \text{ or } \nu_B = \frac{\sigma_B}{\sigma_d},$$

shall not be lower than the values specified in table 13 for each load case.

7.4 Verification of service strength

7.4.1 Concepts

A verification of service strength in respect of safety against failure under frequently repeated stresses variable with time need only be carried out for members and fasteners for load cases H and for numbers of stress cycles exceeding 2×10^4.

The permissible stresses are equal for each loading group and are dependent upon the stress collective and the number of stress cycles; they have been laid down for various steel grades, types of stress, notch cases and limiting stress ratios, see subclause 7.4.4.

The limiting stress ratio $\varkappa = \min\sigma / \max\sigma$ or $\min\tau / \max\tau$ etc. is the ratio of the numerically smaller limiting stress (min σ, min τ) to the numerically larger limiting stress (max σ, max τ). Depending on the (plus or minus) sign of these limiting stresses, the ratio fluctuates from -1 to 0 in the alternating stress range, and from 0 to $+1$ in the pulsating stress range.

The six loading groups, B 1 to B 6, are correlated to specific ranges of the stress cycles and to specific stress collectives in accordance with subclause 7.4.2 and table 14.

Table 11. **Permissible stresses in welds for the general stress analysis**

<table>
<tr><th colspan="2">Steel grade of welded member</th><th rowspan="3">Load case</th><th>Permissible comparison value</th><th colspan="3">Permissible tensile stress for transverse loading
zul σ_{wz}
N/mm^2</th><th colspan="2">Permissible compressive stress for transverse loading
zul σ_{wd}
N/mm^2</th><th>Permissible shear stress
zul τ_w
N/mm^2</th></tr>
<tr><th rowspan="2">Symbol</th><th rowspan="2">Specified in</th><th>All types of weld</th><th>Butt weld, double bevel butt weld; special quality</th><th>Double bevel butt weld; standard quality</th><th>Fillet weld</th><th>Butt weld, double bevel butt weld</th><th>Fillet weld</th><th>All types of weld</th></tr>
<tr></tr>
<tr><td rowspan="2">**St 37*)**</td><td rowspan="2">DIN 17 100</td><td>H</td><td colspan="2">160</td><td>140</td><td>113</td><td>160</td><td>130</td><td>113</td></tr>
<tr><td>HZ</td><td colspan="2">180</td><td>160</td><td>127</td><td>180</td><td>145</td><td>127</td></tr>
<tr><td rowspan="2">**St 52-3**</td><td rowspan="2">DIN 17 100</td><td>H</td><td colspan="2">240</td><td>210</td><td>170</td><td>240</td><td>195</td><td>170</td></tr>
<tr><td>HZ</td><td colspan="2">270</td><td>240</td><td>191</td><td>270</td><td>220</td><td>191</td></tr>
<tr><td colspan="10">*) Covers all quality groups, steelmaking and casting processes.</td></tr>
</table>

Table 12. **Permissible stresses in fasteners for the general stress analysis**

<table>
<tr><th colspan="2">Type of connection</th><th colspan="2">Steel grade/ property class</th><th rowspan="2">Load case</th><th colspan="2">Permissible shear stress
zul τ_a
N/mm^2</th><th colspan="2">Permissible bolt or rivet bearing stress
zul σ_l
N/mm^2</th><th>Permissible tensile stress
zul σ_z
N/mm^2</th></tr>
<tr><th>Fastener</th><th>Joint</th><th></th><th>Specified in</th><th colspan="2"></th><th colspan="2"></th><th></th></tr>
<tr><td rowspan="8">Rivets</td><td rowspan="4">Single shear</td><td rowspan="2">USt 36</td><td rowspan="2">DIN 17 111</td><td>H</td><td rowspan="4">$0{,}6 \cdot \text{zul}\ \sigma_d$</td><td>84</td><td rowspan="4">$1{,}5 \cdot \text{zul}\ \sigma_d$</td><td>210</td><td rowspan="2">(30)</td></tr>
<tr><td>HZ</td><td>96</td><td>240</td></tr>
<tr><td rowspan="2">RSt 44-2</td><td rowspan="2">DIN 17 111</td><td>H</td><td>126</td><td>315</td><td rowspan="2">(45)</td></tr>
<tr><td>HZ</td><td>144</td><td>360</td></tr>
<tr><td rowspan="4">Multiple shear</td><td rowspan="2">USt 36</td><td rowspan="2">DIN 17 111</td><td>H</td><td rowspan="4">$0{,}8 \cdot \text{zul}\ \sigma_d$</td><td>113</td><td rowspan="4">$2 \cdot \text{zul}\ \sigma_d$</td><td>280</td><td rowspan="2">(30)</td></tr>
<tr><td>HZ</td><td>128</td><td>320</td></tr>
<tr><td rowspan="2">RSt 44-2</td><td rowspan="2">DIN 17 111</td><td>H</td><td>168</td><td>420</td><td rowspan="2">(45)</td></tr>
<tr><td>HZ</td><td>192</td><td>480</td></tr>
<tr><td rowspan="8">Fit bolts</td><td rowspan="4">Single shear</td><td rowspan="2">4.6</td><td rowspan="2">DIN 267 Part 3</td><td>H</td><td rowspan="4">$0{,}6 \cdot \text{zul}\ \sigma_d$</td><td>84</td><td rowspan="4">$1{,}5 \cdot \text{zul}\ \sigma_d$</td><td>210</td><td>100</td></tr>
<tr><td>HZ</td><td>96</td><td>240</td><td>110</td></tr>
<tr><td rowspan="2">5.6</td><td rowspan="2">DIN 267 Part 3</td><td>H</td><td>126</td><td>315</td><td>140</td></tr>
<tr><td>HZ</td><td>144</td><td>360</td><td>154</td></tr>
<tr><td rowspan="4">Multiple shear</td><td rowspan="2">4.6</td><td rowspan="2">DIN 267 Part 3</td><td>H</td><td rowspan="4">$0{,}8 \cdot \text{zul}\ \sigma_d$</td><td>112</td><td rowspan="4">$2 \cdot \text{zul}\ \sigma_d$</td><td>280</td><td>100</td></tr>
<tr><td>HZ</td><td>128</td><td>320</td><td>110</td></tr>
<tr><td rowspan="2">5.6</td><td rowspan="2">DIN 267 Part 3</td><td>H</td><td>168</td><td>420</td><td>140</td></tr>
<tr><td>HZ</td><td>192</td><td>480</td><td>154</td></tr>
<tr><td rowspan="4">Non-fit bolts</td><td rowspan="4"></td><td rowspan="2">4.6</td><td rowspan="2">DIN 267 Part 3</td><td>H</td><td rowspan="4">–</td><td>70</td><td rowspan="4">–</td><td>160</td><td>100</td></tr>
<tr><td>HZ</td><td>80</td><td>180</td><td>110</td></tr>
<tr><td rowspan="2">5.6</td><td rowspan="2">DIN 267 Part 3</td><td>H</td><td>70</td><td>160</td><td>140</td></tr>
<tr><td>HZ</td><td>80</td><td>180</td><td>154</td></tr>
<tr><td colspan="3" rowspan="2">Diameter to be considered for</td><td colspan="2">rivets</td><td colspan="5">Diameter of hole</td></tr>
<tr><td colspan="2">bolts</td><td colspan="4">Diameter of unthreaded shank</td><td>Minor thread diameter</td></tr>
<tr><td colspan="10">The tensile stress values for rivets given in brackets are permitted for exceptional cases only.</td></tr>
</table>

7 Verification and analyses

7.1 General

The verification and analyses described in subclauses 7.2, 7.3 and 7.4 shall be carried out individually for the load-bearing members and for the principal connections and joints. No such verification need be made for design purposes in respect of subordinate components such as walkways, stairways, platforms, hand rails and cabins.

The overall stresses governed by the type of crane, load case and verification shall not exceed the permissible stresses in each case, and the safety factors shall not be less than the values specified.

In the special cases listed in table 9, the permissible stresses in accordance with tables 10 to 12 may be exceeded, and the factors of safety against bulging may be below those specified in DIN 4114 Part 1 and Part 2 and in table 13. Where several special cases occur simultaneously, the total amount of the maximum permissible stresses or the minimum factors of safety shall be limited to the greater of the values allowed for one of such special cases, provided however that the percentage allowed for each individual special cases is not exceeded.

7.2 General stress analysis

7.2.1 Load cases and permissible stresses

The general stress analysis in respect of safety against attaining the yield point shall be carried out separately for load cases H and HZ, using the permissible stresses listed in tables 10 to 12. As regards load case HS, the stresses of load case HZ multiplied by a factor of 1,1 may be used.

The values in the "zul σ_z" column are also permitted in respect of compressive stresses in the immediate vicinity of points of introduction of forces.

Welds shall exhibit a tensile strength and a yield strength not less than those of the steel of which the welded components are made. Longitudinal stresses shall remain within the permissible stresses in members specified in table 10.

The permissible tensile stresses in welds for transverse loading may only be used if the plates required for the transmission of the tensile forces, which are thereby stressed transversely in their rolling plane, are suitable for this purpose (see table 24, test method associated with letter symbol D).

See clause 9 for permissible tensile forces on prestressed bolts.

In normal cases, the following fasteners shall be used:

for members made of ST 37 steel, USt 36 rivets and bolts of property class 4.6;

for members made of St 52 steel, RSt 44-2 rivets and bolts of property class 5.6.

If the above rules are followed, the specified bolt or rivet bearing stresses shall also apply for members.

7.2.2 Combined stresses

Where states of combined plane stresses exist, the comparison stress shall be verified in addition for members as specified in table 10, paying attention to the plus or minus signs, as follows:

$$\sigma_v = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \cdot \sigma_y + 3 \cdot \tau^2} \leqq \text{zul } \sigma_z$$

for welds as specified in table 11, the comparison value shall be verified as follows:

$$\sigma_v = \sqrt{\bar{\sigma}_x^2 + \bar{\sigma}_y^2 - \bar{\sigma}_x \cdot \bar{\sigma}_y + 2 \cdot \tau^2} \leqq \text{zul } \sigma_z$$

(continued on page 14)

Table 9. **Permissible deviations for stresses and factors of safety against bulging**

No.	Special case	Permitted plus deviation, in %	Permitted minus deviation, in %
1	Deviations from design loads, in total	3 % of permissible stresses	3 % of safety factors
2	Unintentional changes in the support conditions	10 % of permissible stresses	6 % of safety factors
3	Construction conditions	10 % of permissible stresses for load case HZ	6 % of safety factors for load case HZ

Table 10. **Permissible stresses in members for the general stress analysis and the verification of stability**

Steel grade of member: Symbol	Steel grade of member: Specified in	Load case	Permissible comparison stress / Permissible tensile stress zul σ_z N/mm²	Permissible compressive stress zul σ_d N/mm²	Permissible shear stress zul τ N/mm²
St 37*)	DIN 17100	H	160	140	92
		HZ	180	160	104
St 52-3	DIN 17100	H	240	210	138
		HZ	270	240	156

*) Covers all quality groups, steelmaking and casting processes.

In the verification carried out in accordance with DIN 4114 Part 1 and Part 2, the values specified in the "zul σ_d" column above shall always be entered in the calculation for "zul σ".

Table 8. **Characteristic values of steel grades used for the calculation**

Steel grade: Brief designation	Steel grade: Specified in	Characteristic values: Yield stress σ_S N/mm²	Characteristic values: Modulus of elasticity (tension, compression) E N/mm²	Characteristic values: Shear modulus G N/mm²	α_T $\frac{mm}{mm \cdot K}$
Structural steel St 37*)	DIN 17 100	240	210 000	81 000	
Tube steel St 35*)	DIN 1629 Parts 1 and 3				$12 \cdot 10^{-6}$
Structural steel St 52-3	DIN 17 100	360			$12 \cdot 10^{-6}$
Rail steel with a tensile strength of not less than 600 N/mm²					
*) Covers all quality groups, steelmaking and casting processes.					

See DIN 15 018 Part 2 for selection of quality groups, steelmaking and casting processes of the steels.

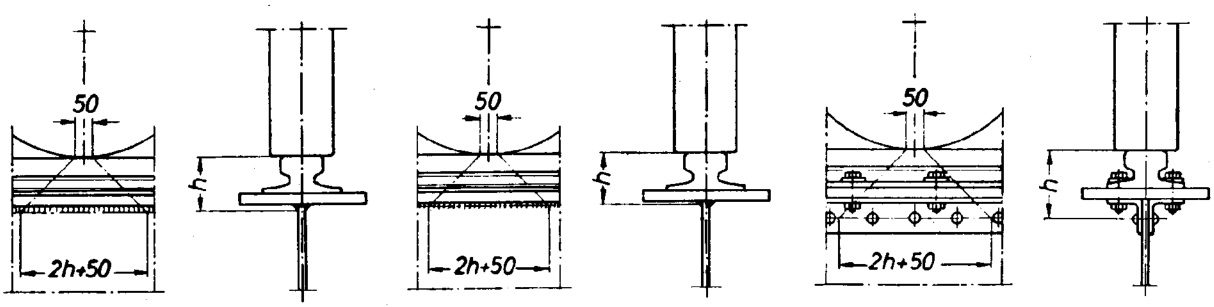
6.9 Longitudinal distribution of wheel loads

The local stresses in the rail, rail foot, flanges, double fillet welds or web rivets and webs of rail bearing beams which arise from wheel loads acting normally and transversely to the rail shall be determined in accordance with the rail and flange system.

Unless a more accurate calculation is made, the individual wheel load may be distributed uniformly in the direction of the rail over a length of ($2\,h$ + 50 mm), on condition that the rail is directly supported on the flange as illustrated in figure 7. The height h, related to the top edge of the rail, shall be entered as follows for the purpose of analysing

the web: as the distance to the bottom edge of the fillet weld or of the flange boss (see figure 7 a);
the fillet weld: as the distance to the centroidal axis of the fillet weld (see figure 7 b);
the web rivets: as the distance to the centre line of the rivets (see figure 7 c).

Dimensions are given in mm.



a) web b) fillet weld c) web rivets

Figure 7. Height h for the analysis

If the rail rests on an elastic support, the transverse and the longitudinal distribution of the bearing pressure under the rail shall be taken into consideration in their most unfavourable pattern in each case for the calculation of the rail bearing beam and of the rail.

Table 7. **Load cases**

Types of load			Symbol	Normal load cases									Special load cases						
4.1 Main loads	4.1.1 Self weight		G	$\varphi \cdot G$				$\varphi \cdot G$			G	$\varphi \cdot G$	G	G	$\varphi \cdot G$				G
	4.1.4.1 Self weight factor		φ	$\varphi \cdot Gm$				$\varphi \cdot Gm$			Gm	$\varphi \cdot Gm$	–	$\varphi \cdot Gm$	–				–
	4.1.2 Loads arising from bulk materials in bins and on continuous conveyors		Gm																
	4.1.3 Lifted load		P	$\psi \cdot P$				–			–	$\varphi \cdot P$	P	P	–				–
	4.1.4.2 Nominal load spectrum factor		ψ									–	–	–	–				–
	4.1.4.3 Dropping or sudden setting down of useful loads		$-0{,}25 \cdot \psi \cdot P$	–				$-0{,}25 \cdot \psi \cdot P$			–	–	–	–	–				–
	4.1.3 Lifted load without effect of useful load		Po								Po	–	–	–	–				–
	4.1.5 Inertia forces arising from driving mechanisms	Trolley travel	Ka	Ka	–	–	–	Ka	–	–	–	–	–	–	Ka	–	–	–	–
		Crane travel	Kr	–	Kr	–	–	–	Kr	–	–	–	–	–	–	Kr	–	–	–
		Slewing	Dr	Dr	Dr	Dr	Dr	Dr	Dr	Dr	–	–	–	–	–	–	Dr	–	–
		Luffing	Wp	–	–	Wp	–	–	–	Wp	–	–	–	–	–	–	–	Wp	–
	4.1.6 Centrifugal forces		Z	–	–	–	Z	–	–	–	–	–	–	–	–	–	Z	–	–
4.2 Additional loads	4.2.1 Wind load, with crane	in service	Wi	Wi				Wi			–	Wi	–	–	–				–
		out of service	Wa	–				–			Wa	–	–	–	–				–
	4.2.2 Forces arising from skewing		S	–				–			–	S	–	–	–				–
4.3 Special loads	4.3.1 Tilting force arising in crane trolleys with positive guidance of the lifted load		Ki	–				–			–	–	Ki	–	–				–
	4.3.2 Buffer forces		Pu	–				–			–	–	–	Pu	–				–
	4.3.3 Test loads	Small	Pk	–				–			–	–	–	–	$\frac{1+\psi}{2} \cdot Pk$				–
		Large	Pg	–				–			–	–	–	–	–				Pg

The wind loads shall always be entered in the calculation at their full value. Acceleration forces and deceleration forces acting simultaneously with wind loads shall only be entered in the calculation to an extent which ensures that the driving forces specified in subclause 4.1.5 are not exceeded.

Impact from bulk material as specified in subclause 4.1.7, thermal effects as specified in subclause 4.2.3, snow loads as specified in subclause 4.2.4, loads on walkways etc. as specified in subclause 4.2.5 need only be taken into consideration in special cases.

In the case of tower cranes and of portal slewing cranes, a verification of the energy absorption capacity of the buffers and of the effect of the buffer forces on the supporting structure may be dispensed with, on condition that the rated travelling speed is less than 40 m/min, and that reliably operating limit switches are installed in addition to the buffer stops.

4.3.3 Test loads

In the case of cranes for which a verification of stability is required in accordance with DIN 15019 Part 1 or Part 2, the small and large test loads respectively which are specified in the above-mentioned standards shall be used as the basis for the stress analysis.

In the case of cranes which do not require a verification of stability to be carried out, the test loads are obtained by multiplying the lifted load P by the following factors:

small test load: $Pk = 1{,}25 \cdot P$;

large test load: $Pg = 1{,}33 \cdot P$,
for lifting classes H 1 and H 2;

(subject to particular agreement): $Pg = 1{,}50 \cdot P$,
for lifting classes H 3 and H 4.

For the stress analysis, the small test load shall be multiplied by $\frac{1 + \psi}{2}$.

The design loads used in the stress analysis with the crane subjected to the test load are based on the following procedure.

If the crane is loaded with the small test load, all the permissible motions shall be carried out individually with the load situated in the most unfavourable position; however, due care should be observed during the test. A new motion shall only be initiated after the oscillations arising from the previous motion have ceased completely.

If the crane is loaded with the large test load, then the small test load shall first be raised to a short distance from the floor. Thereafter, the remainder of the load (making it up to the large test load) shall be attached with all due care, so as to avoid any oscillations if possible.

Testing with test load Pk or Pg shall be carried out in the absence of wind.

5 Load cases

The main loads, additional loads and special loads specified in clause 4 are classified into load cases H, HZ and HS in table 7.

All the loads in one column of the zones framed in thick black lines under the heading "normal load cases" taken together constitute load case H. All the loads in a column under the heading "normal load cases" taken together constitute load case HZ.

6 Calculation

6.1 General

The calculations shall conform to the generally accepted rules of statics, dynamics and to the science of the strength of materials.

In cases where additional tests are carried out to determine stresses within the framework of the design loads specified in clauses 4 and 5, the test results may be used as the basis for the calculation, using the same safety factors.

All references to systems, dimensions and cross sections made on drawings shall coincide with those made in the calculations. Deviations are permitted if the safety of all components concerned is increased thereby beyond any doubt.

6.2 Alignment of craneway

Unless the crane operator has specified anything to the contrary, the calculation shall be made on the assumption that the craneway has been carefully laid and that it has been properly aligned both vertically and horizontally.

6.3 Imposed loads (live loads)

Imposed loads shall be entered in the calculation of the members concerned at the most unfavourable positions, values and directions.

6.4 Materials

The materials used shall be specified. Materials other than the steel grades specified in table 8 may be used on condition that their mechanical properties, their chemical composition and if applicable their weldability are guaranteed by the manufacturer of the material concerned.

In the general stress analysis and the verification of service strength, the permissible stresses and the stability criteria may be derived, at equal ratio at best, from the dangerous limit states (guaranteed yield stress or 0,2 % proof stress, service strength at 90 % survival expectancy, buckling, collapsing, bulging), as in the case of the steel grades listed in table 8, by reliably reasoned calculation or tests closely reflecting actual operating conditions, for example on welded joints subjected to static loading or to loading variable with time.

6.5 Cross-sectional values and hole deductions for members and cross-sectional values for welds

The governing cross-sectional values and hole deductions for members shall be determined in accordance with DIN 18800 Part 1, March 1981 edition, subclause 3.4, and for welds they shall be determined in accordance with subclauses 7.3.1.1 and 7.3.1.2 of the same standard. The *HV-Richtlinien* are applicable to high strength bolted joints, see clause 2.

Elastic deformations, required for the calculation of statically indeterminate structures for example, shall be determined on the basis of cross-sectional values without any deduction for holes.

6.6 Tension members

Tension members, which may be subjected to compressive stresses in the case of slight deviations from the design loads originally planned, shall exhibit a slenderness ratio λ not exceeding 250 and shall be capable of absorbing a reasonable compressive force.

6.7 Determination of stresses

The stresses shall be determined for the individual load cases in accordance with clause 5 and table 7 on the basis of the cross-sectional values given in subclause 6.5.

In the case of fillet welds subjected to compressive loading in the direction normal to the weld, such as between web plate and flange plate, no allowance shall be made for contact between the members to be joined.

6.8 Connections and joints

In the areas of force diversions and cut-outs, the stress patterns which are disturbed thereby shall be verified, unless adequate structural measures have been taken to allow for such disturbances.

The individual parts of a member etc. shall each be separately connected or jointed and covered.

Where in composite members a stress resultant is passed on by a system of welds, rivets and bolts, it shall be possible for this stress resultant to be distributed unambiguously and proportionally among the individual parts of the cross section, and to be transmitted by only one type of connection to each part of the cross section.

Angle cleats shall be connected with the structure either taking 1,5 times the value of the applicable proportion of the stress resultant for one leg and the given value itself for the other leg, or taking 1,25 times the value for both legs. Welded-on lug plates shall be connected with the structure taking 1,5 times the value of the applicable proportion of the stress resultant.

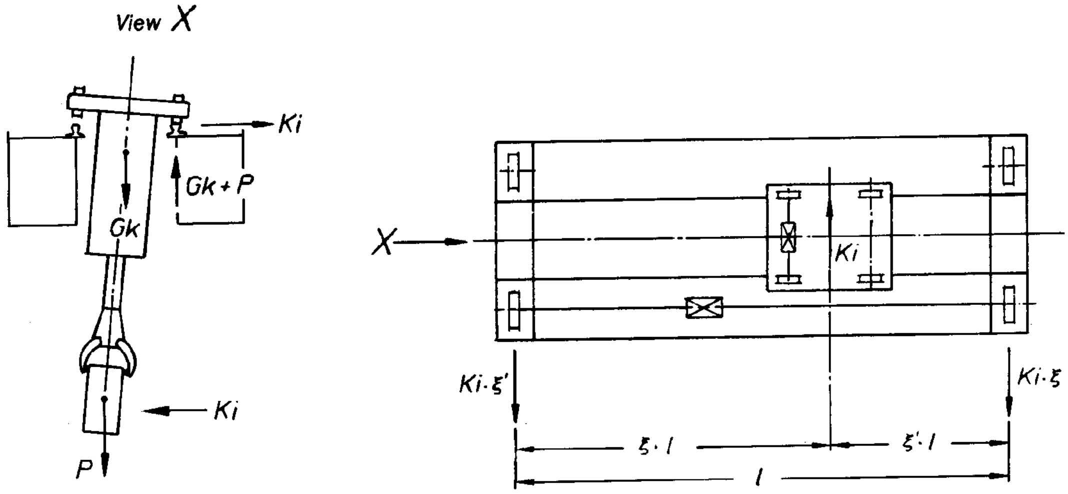


Figure 6. Example of the distribution of forces due to tilting of a crane trolley with positive guidance of the lifted load in the direction of crane travel

4.2.4 Snow loads

Snow loads need only be considered in special cases, and when they are, DIN 1055 Part 5 shall be observed.

4.2.5 Loads on walkways, stairways, platforms and hand rails

In the case of walkways, stairways and platforms, a moving concentrated load shall be entered in the calculation in addition to the self weights, and this shall be

3000 N to allow for persons carrying loads,

1500 N to allow for persons not carrying loads.

As regards hand rails, a moving horizontal concentrated load acting outwardly or inwardly shall be assumed, amounting to

300 N to allow for persons carrying loads,

150 N to allow for persons not carrying loads.

The above-mentioned concentrated loads need not be taken into account in respect of any member stressed by lifted loads in accordance with subclause 4.1.3, such as the main girders of crane bridges.

4.3 Special loads

4.3.1 Tilting force arising in crane trolleys with positive guidance of the lifted load

The force due to the tilting of crane trolleys with positive guidance of the lifted load shall be determined from the tilting conditions without regard for the factors described in subclause 4.1.4, as a horizontal load Ki acting at floor level or obstacle level, and in the direction of trolley or crane travel. The trolley shall be assumed to be located in the most unfavourable position for this purpose. Unless a more accurate calculation is made, Ki shall be distributed proportionally between both sides of the craneway without considering any inertia force effects or any skidding of the driven track wheels (see figure 6). The value of Ki may be limited to ¼ of the sum of the self weight of the trolley G_K plus the lifted load P.

If there is an operational possibility of the tilted trolley tilting back again to its normal position due to the sudden yielding of the obstacle, then the forces arising from such an occurrence shall be taken into account.

4.3.2 Buffer forces

As regards this special load case, it is assumed that in normal operation cranes or trolleys collide with one another or collide against buffer stops only on rare occasions. The buffer forces Pu due to cranes or trolleys crashing against stops or colliding with one another shall be limited by buffers or by similar energy absorbing means. The required energy absorption capacity of the buffers and the maximum buffer forces Pu shall be determined on the basis of 85 % of the rated travelling speed of cranes and 100 % of the rated travelling speed of trolleys.

In cases where automatic devices for slowing down the motion are installed, the required energy absorption capacity of the buffers and the maximum buffer forces Pu may be computed on the basis of the highest travelling speed likely to arise in such a case, but this shall be not less than 70 % of the rated speed.

Furthermore, the kinetic energy released on the collision of two cranes characterized by the moving masses m_1 and m_2 and by the amounts $|v_{F1}|$ and $|v_{F2}|$ of the maximum travelling speed shall be determined by the following equation:

$$E = \frac{m_1 \cdot m_2 \cdot (|v_{F1}| + |v_{F2}|)^2}{2\,(m_1 + m_2)}$$

For the verification of the buffers and of the strength of the supporting structure, the forces arising from the moving masses of the self weights and of the positively guided lifted loads situated in the most unfavourable position, if applicable, shall be entered in the calculation in each case, but the factors mentioned in subclause 4.1.4 shall not be used. Loads suspended from carrying means and freely oscillating loads need not be considered. An appropriate substitute mass shall be entered in the calculation in lieu of that of the rotating parts of the running gear. The buffer forces shall be distributed in accordance with the buffer characteristics and the possible movements of the supporting structure. In this connection, the resistances to motion due to the frictional contact between track wheels and rails may be allowed for by means of a factor $f = 0{,}20$.

In the case of cranes or trolleys with or without useful load, no negative wheel loads may result from 1,1 times the buffer force and from the self weights and lifted loads previously mentioned. Unless a more accurate stress analysis is carried out, the buffer forces shall be multiplied by an oscillation coefficient in accordance with table 6 for the stress analysis, depending on the shape of the area beneath the buffer characteristic.

Table 6. **Oscillation coefficients for simplified computation**

Area beneath the buffer characteristic, approximating a	Oscillation coefficient in respect of collision with	
	crane	trolley
triangle	1,25	1,35
square	1,50	1,60

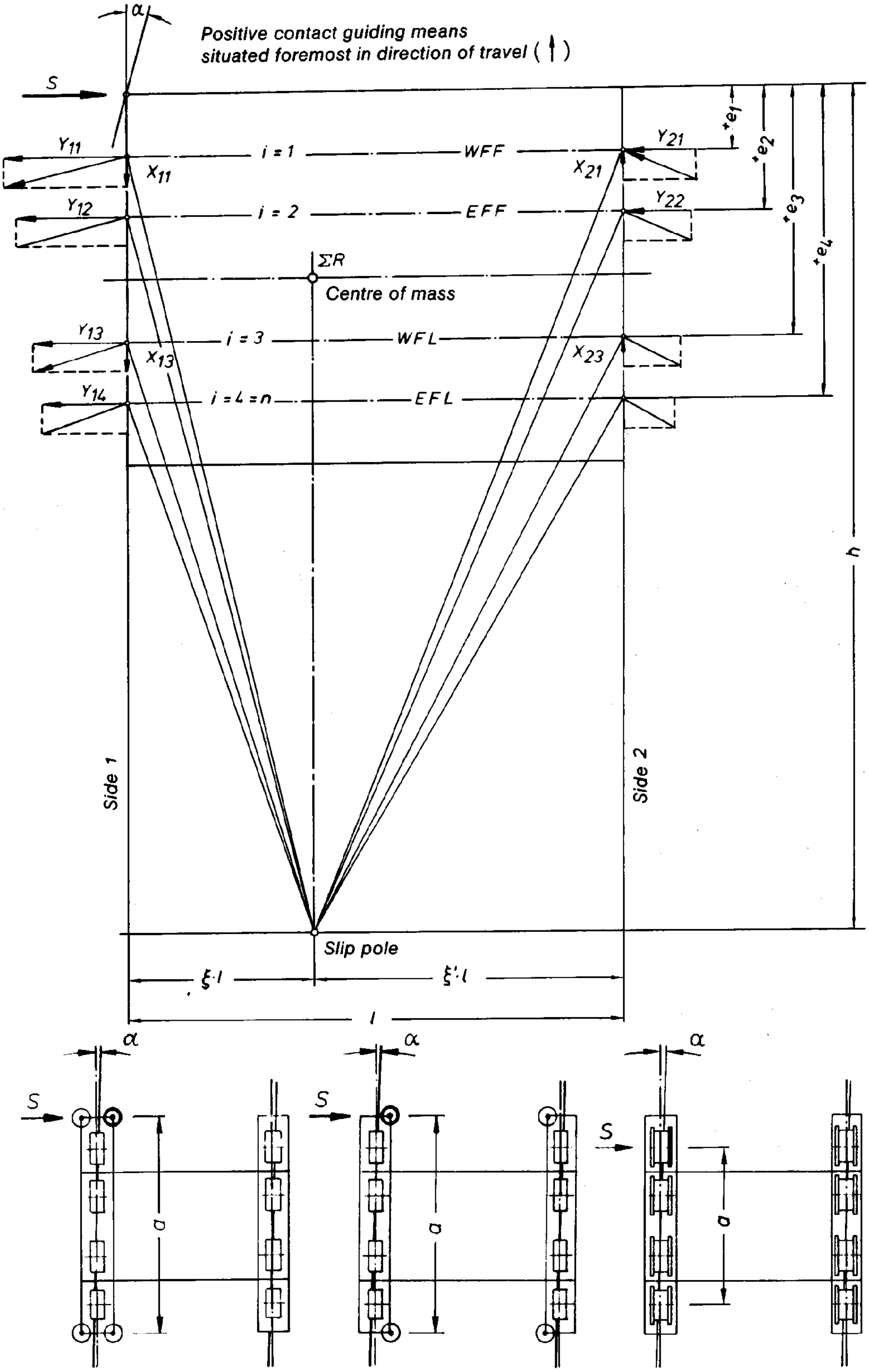


Figure 5. Dimensions and forces due to skewing of a crane with four pairs of track wheels representing different system characteristics

4.2.3 Thermal effects

Thermal effects shall only be taken into consideration in special cases. When this is the case for cranes installed outdoors at an assumed ambient installation temperature of +10 °C, temperature variations of ±35 K shall be assumed for the calculation, or in the case of non-uniform temperature rises in individual members, temperature variations of ±15 K shall be assumed.

In the case of cranes operating in hot environments, the assumed values shall correspond to the local conditions, e.g. for cranes in foundries and pit furnace shops.

A linear expansion coefficient in accordance with table 8 shall be entered in the calculations.

Table 3. **Coefficient of frictional contact f as a function of the skew angle α**

α‰	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	6,0	7,0	8,0	9,0	10,0	12,5	15,0	>15,0
f	0,094	0,118	0,139	0,158	0,175	0,190	0,203	0,214	0,233	0,248	0,259	0,268	0,275	0,287	0,293	0,300

For cranes out of service, the wind load shall be entered in the calculation at the dynamic pressures specified in DIN 1055 Part 4.

4.2.2 Forces arising from skewing

When a crane skews at a skew angle α, a positive contact force S, dependent on the running gear and supporting structure, is generated on the front guiding means or group of guiding means (front in the direction of travel); these guiding means may consist of a wheel flange or of a guide roller, and as a result of force S, a group of forces $X_{1\,i}$, $Y_{1\,i}$ and $X_{2\,i}$, $Y_{2\,i}$, which are connected by friction, acting in the contact areas of the track wheels is generated.

The distribution of the force S resulting from the skewing of cranes with flanged track wheels is similar to that described in subclause 4.1.5, figure 4.

For cranes with a total of n pairs of track wheels arranged each on an axis i, and of which m are speed-synchronized, and whose wheel loads $R_{1\,i}$ on side 1 and $R_{2\,i}$ on side 2 are of equal magnitude respectively for each side, and assuming the usual tolerances for track wheel diameter, axial parallelism of track wheel bores and position of the runway, with a linearized frictional contact relationship applying equally to longitudinal and transverse slip, the following applies:

$$f = 0{,}30 \cdot (1 - e^{-0{,}25 \cdot \alpha})$$

where

e = 2,71828 (basis of the natural logarithms) and skew angle α to be entered in ‰.

$$S = \lambda \cdot f \cdot \Sigma R$$

$$X_{1\,i} = \lambda_{1\,ix} \cdot f \cdot \Sigma R \qquad X_{2\,i} = \lambda_{2\,ix} \cdot f \cdot \Sigma R$$

$$Y_{1\,i} = \lambda_{1\,iy} \cdot f \cdot \Sigma R \qquad Y_{2\,i} = \lambda_{2\,iy} \cdot f \cdot \Sigma R$$

where

ΣR is the sum of all wheel loads arising from self weights and lifted load, excluding the factors mentioned in subclause 4.1.4;

$\alpha = \alpha_F + \alpha_v + \alpha_0 \geqq 15$‰, skew angle resulting from the sum of all the possible displacements transversely to the runway, related to the distance a of the positive guiding means when the crane is askew;

α_F is the skew angle resulting from 75% of the track clearance between straight rail and positive guiding means, but not less than from 5 mm in the case of guide rollers and not less than from 10 mm in the case of wheel flanges;

α_v is the skew angle resulting from abrasive wear of not less than 3% of the rail head width in the case of guide rollers, and not less than 10% of the rail head width in the case of wheel flanges;

α_0 = 1 ‰ skew angle resulting from tolerances of the crane and craneway.

Other values of the skew angle α shall be agreed.

Factors λ, $\lambda_{1\,ix}$, $\lambda_{1\,iy}$ and $\lambda_{2\,ix}$, $\lambda_{2\,iy}$ for the calculation of forces S, $X_{1\,i}$, $Y_{1\,i}$, $X_{2\,i}$, $Y_{2\,i}$ and of the position h of the slip pole are determined in accordance with tables 4 and 5 by the dimensions of the crane according to figure 5, by the position of the overall centre of mass due to the self weights and to the lifted loads, and by the running gear system and structure system as defined by the following symbols:

W = pair of track wheels speed-synchronized by a mechanical or electrical shaft;

E = pair of track wheels individually supported on bearings or individually driven;

F = fixed bearing of track wheel and supporting structure: lateral displaceability;

L = movable bearing of track wheel or supporting structure: lateral displaceability.

Table 4. **Position h of the slip pole and factor λ for the calculation of the positive contact force S**

System	h	λ
FF	$\dfrac{m \cdot \xi \cdot \xi' \cdot l^2 + \Sigma e_i^2}{\Sigma e_i}$	$1 - \dfrac{\Sigma e_i}{n \cdot h}$
FL	$\dfrac{m \cdot \xi \cdot l^2 + \Sigma e_i^2}{\Sigma e_i}$	$\xi' \left(1 - \dfrac{\Sigma e_i}{n \cdot h}\right)$

Table 5. **Factors $\lambda_{1\,ix}$, $\lambda_{1\,iy}$ and $\lambda_{2\,ix}$, $\lambda_{2\,iy}$ for the calculation of the frictional forces, $X_{1\,i}$, $Y_{1\,i}$ and $X_{2\,i}$, $Y_{2\,i}$**

System	$\lambda_{1\,ix}$	$\lambda_{1\,iy}$	$\lambda_{2\,ix}$	$\lambda_{2\,iy}$
WFF	$\dfrac{\xi \cdot \xi'}{n} \cdot \dfrac{l}{h}$	$\dfrac{\xi'}{n}\left(1 - \dfrac{e_i}{h}\right)$	$\dfrac{\xi \cdot \xi'}{n} \cdot \dfrac{l}{h}$	$\dfrac{\xi}{n}\left(1 - \dfrac{e_i}{h}\right)$
EFF	0	$\dfrac{\xi'}{n}\left(1 - \dfrac{e_i}{h}\right)$	0	$\dfrac{\xi}{n}\left(1 - \dfrac{e_i}{h}\right)$
WFL	$\dfrac{\xi \cdot \xi'}{n} \cdot \dfrac{l}{h}$	$\dfrac{\xi'}{n}\left(1 - \dfrac{e_i}{h}\right)$	$\dfrac{\xi \cdot \xi'}{n} \cdot \dfrac{l}{h}$	0
EFL	0	$\dfrac{\xi'}{n}\left(1 - \dfrac{e_i}{h}\right)$	0	0

based on the condition that the driving forces acting on the crane are practically free from backlash.

In figures 2 and 3

$\min\,(R_{\mathrm{Ka}_1} + R_{\mathrm{Ka}_2})$

$\min R_{\mathrm{Kr}_1} + \min R_{\mathrm{Kr}_2}$

= is the determining smallest wheel load total and, respectively, the sum of the smallest wheel loads of the driven track wheels, excluding the useful load and the factors mentioned in subclause 4.1.4, required for the determination of the driving forces on the basis of the frictional contact;

l_s is the distance, measured at right angles to the direction of motion, of the resultant of the driving forces from the centre of mass S of the crane bridge, trolley and lifted load;

a is the centre-to-centre distance of the wheels or of the guide roller or groups of guide rollers for the absorption of the lateral forces, see also figure 4.

In cases where there is a considerable amount of play between structural members (hereinafter briefly referred to as members) which move relatively to one another, for example in the case of the rigid mast and the suspension gear of a stripper crane, a factor larger than 1,5 shall be used.

Where the maximum driving forces are limited by friction-type power transmission, the driving forces may be calculated from the frictional contact between the driven track wheels and the rails, using a coefficient $f = 0{,}2$. In this connection, one should proceed from the smallest wheel load total in the case of speed-synchronized driven track wheels, or from the sum of the smallest wheel loads in the case of non-speed-synchronized driven track wheels, depending on the type of driving mechanism; the factors mentioned in subclause 4.1.4 and the useful load need not be taken into consideration.

The driving forces shall always be distributed among the track wheels in accordance with the type of driving mechanism.

The inertia forces during the start-up and braking of cranes shall be entered in the calculation in each case with the trolley in the most unfavourable position for the member being analysed (see figure 3).

Where lateral forces due to inertia forces act transversely to the runway, they shall be absorbed by the rails through positive and frictional contact in accordance with the systems adopted for the supporting structure and the running gear, and in accordance with the type of guiding means used.

Unidirectional lateral forces, such as those due to inertia force effects during the start-up and braking of crane trolleys (see figure 2) shall be distributed uniformly between all the track wheels or guiding means.

Lateral forces acting in opposite directions arise if a distance l_s exists between the centre of the masses to be moved and the resultant of the driving forces. Where these forces are transmitted through the track wheels, and where there are more than two wheels per runway side, they shall be uniformly distributed between the outer wheels or outer wheel groups as shown in the examples illustrated in figure 4, namely,

where there are not more than four wheels per rail, to one outer wheel per corner,

where there are not more than eight wheels per rail, to the two outer wheels per corner,

where there are more than eight wheels per rail, to the three outer wheels per corner.

As far as the supporting structure is concerned, e.g. the bridge, trolley or balancer, the lateral forces shall, however, be distributed uniformly between all the wheels of a corner, even in the zone of the inner unloaded track wheels as shown in figure 4.

In the case of wide-span bridge cranes and portal cranes with separate driving mechanisms, whose supporting structures are not designed to compensate for resistances to motion, driving forces and inertia forces, but only for a limited elastic forward motion of one side of the running gear ahead of the other side, special devices shall be provided to ensure that the assumptions on which the design calculation is based are not exceeded.

4.1.6 Centrifugal forces

Centrifugal forces on slewing cranes shall be calculated solely on the basis of the self weight of the jib components, and, if applicable, also on the basis of the counterweights and of the lifted load, without application of the factors mentioned in subclause 4.1.4; the lifted load shall be deemed to be suspended from the tip of the jib.

4.1.7 Impact from bulk material

Impact effects on bins and transfer points due to the dropping of bulk material shall only be taken into consideration locally.

4.2 Additional loads

4.2.1 Wind loads

Wind loads shall be taken into account in accordance with DIN 1055 Part 4 in the case of cranes exposed to the wind.

For cranes in service, the wind load shall be entered in the calculation at a dynamic pressure $q = 250\,\mathrm{N/m^2}$. The wind load acting on the useful load shall be assumed at 3 % of the effect of the useful load, but at not less than 500 N, if the wind load area is not precisely known.

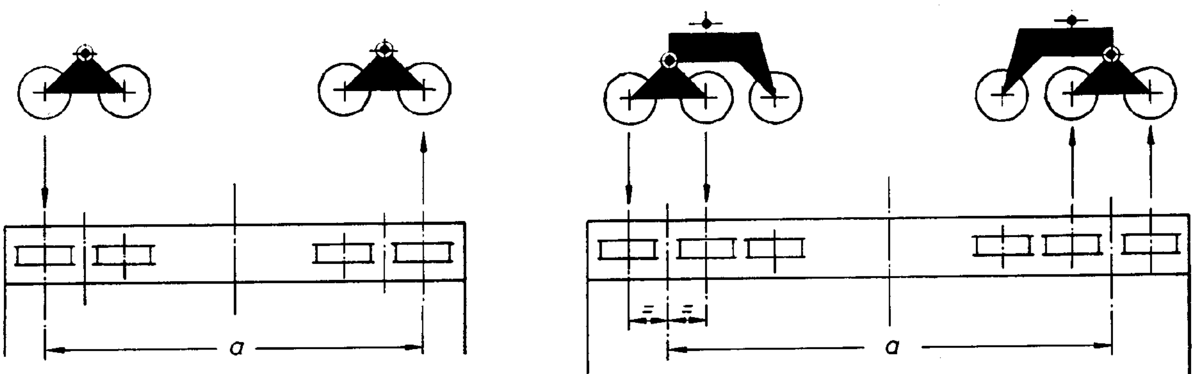


Figure 4. Distribution of lateral forces

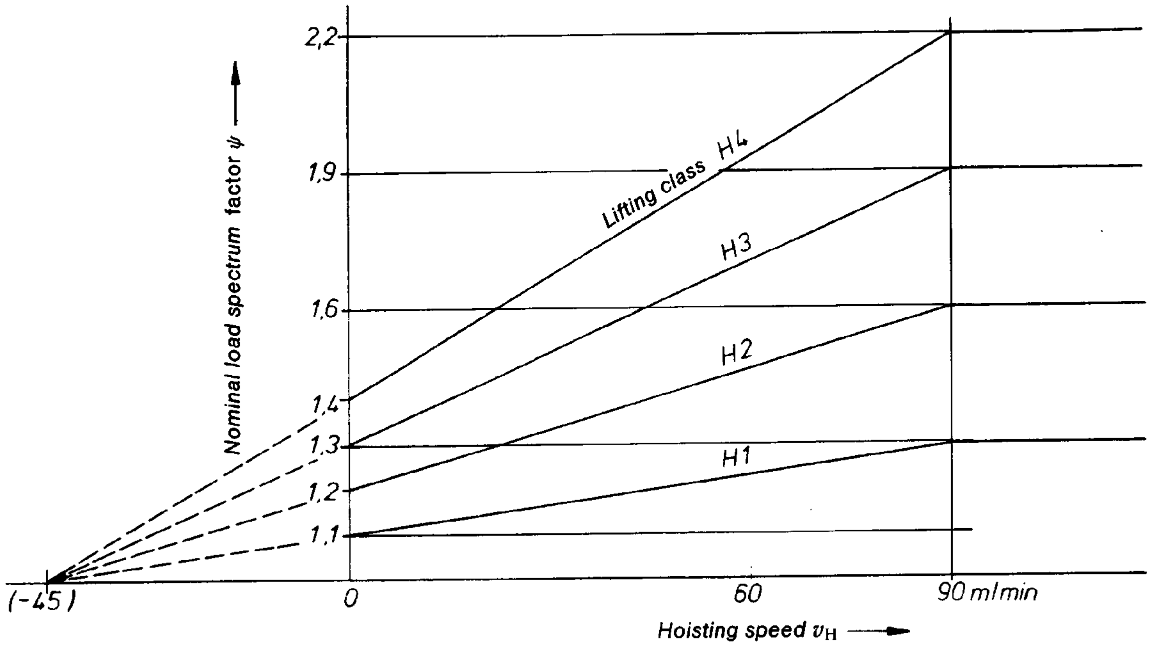


Figure 1. Lifting classes and nominal load spectrum factor ψ

Table 2. **Nominal load spectrum factor ψ**

Lifting class	Nominal load spectrum factor ψ at hoisting speed v_H, in m/min	
	Up to 90	Over 90
H 1	$1{,}1 + 0{,}0022 \cdot v_H$	1,3
H 2	$1{,}2 + 0{,}0044 \cdot v_H$	1,6
H 3	$1{,}3 + 0{,}0066 \cdot v_H$	1,9
H 4	$1{,}4 + 0{,}0088 \cdot v_H$	2,2

4.1.4.3 Dropping or sudden setting down of useful loads in the case of jib cranes

In the case of jib cranes where the dropping or sudden setting down of useful loads represents the usual operating practice, such as for cranes with magnet or grab operation, the resulting inertia force effects shall be taken into account separately. Instead of adopting a precisely computed value for this purpose, the lifted load or the stress resultants or stresses resulting therefrom may be multiplied by −0,25 times the factor ψ specified in table 2. In the case of rope controlled jibs, these negative inertia force effects are limited by the slackening of the ropes, whereby an upward movement of the jib becomes possible. The forces which arise from the subsequent falling back of the jib shall be taken into consideration.

4.1.5 Inertia forces arising from driving mechanisms

The inertia forces acting on the crane structure during acceleration and deceleration of the crane motions, such as travelling, slewing, luffing, shall be determined from the maximum driving forces arising in regular operation. In lieu of a more accurate calculation, the quasi-static forces acting on the structure and resulting from the assessment of the movement of the centre of mass of the system under the effect of the driving forces, of the resistances to motion and of the inertia forces, may be increased by a factor of 1,5 in order to take the dynamic effect into account. In this respect, loads which are not guided shall be deemed to be rigidly attached to the crane; any swinging of the loads shall be ignored. The adoption of a factor of 1,5 is furthermore

Examples of calculating the inertia forces from the frictional contact in the case of bridge cranes:

trolley travel; frictional contact
(the driven track wheels are speed-synchronized)

$$Ka = 1{,}5 \cdot 0{,}2 \cdot \min\,(R_{Ka_1} + R_{Ka_2})$$

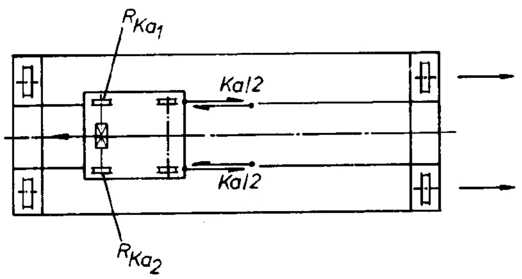


Figure 2. Inertia forces during the start-up and braking of crane trolleys with a central drive mechanism

crane travel; frictional contact
(the driven track wheels are non-speed-synchronized)

$$Kr = 1{,}5 \cdot 0{,}2\,(\min R_{Kr_1} + \min R_{Kr_2})$$

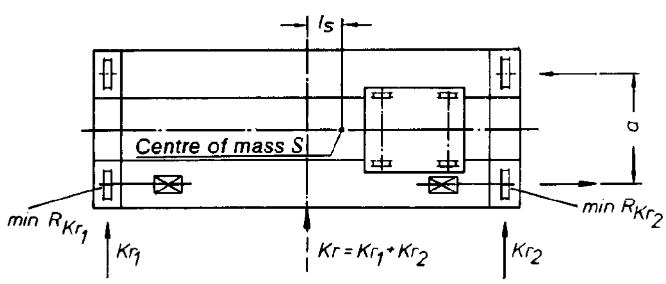


Figure 3. Inertia forces during the start-up and braking of cranes with two individual driving mechanisms ($Kr_1 = Kr_2$)

4 Design loads

The loads acting on the supporting structure are subdivided into main loads, additional loads and special loads.

The main loads comprise:
self weights;
loads arising from bulk materials in bins and on continuous conveyors;
lifted loads;
inertia forces arising from drives;
centrifugal forces;
impact from bulk material.

The additional loads comprise:
wind loads;
forces arising from skewing;
thermal effects;
snow loads;
loads on walkways, stairways, platforms and hand rails;

The special loads comprise:
tilting force arising in crane trolleys with positive guidance of the lifted load;
buffer forces;
test loads.
The above loads are grouped into load cases in clause 5.

4.1 Main loads

4.1.1 Self weights

Self weights are the masses of all the fixed and moving crane components which act permanently during operation, plus the masses of the mechanical and electrical equipment and of a proportion of the carrying means such as ropes for example, with the exception of the self weights described in subclause 4.1.3.

4.1.2 Loads arising from bulk materials in bins and on continuous conveyors

Loads arising from bulk materials in bins and on continuous conveyors shall be treated as self weights; loads of bulk materials on continuous conveyors can act either as a continuous or as a discontinuous line load.

4.1.3 Lifted loads

The lifted loads (hook loads) comprise the useful load and the self weights of members designed to carry the useful load, e.g. the bottom block, the spreader bar, the grab, the lifting magnet and also a proportion of the carrying means such as ropes.

4.1.4 Effects of vertical inertia forces

The effects of vertical inertia forces produced by the motions of the crane or of the crane components and of loads in accordance with subclauses 4.1.1 to 4.1.3 are allowed for by means of a self weight factor φ and a nominal load spectrum factor ψ.

4.1.4.1 Self weight factor φ

The self weights of moving cranes and of moving crane components in accordance with subclause 4.1.1, and the loads described in subclause 4.1.2, or the stress resultants or stresses resulting therefrom, shall be multiplied by a self weight factor φ as given in table 1 below.

In the case of cranes and crane components equipped with spring-suspended wheels running on rails, a self weight factor $\varphi = 1,1$ can be adopted for the calculation, irrespective of the travelling speed and type of runway.

Table 1. **Self weight factors φ**

Travelling speed v_F, in m/min		Self weight factor φ
Runways		
with rail joints or irregularities (road)	without rail joints or with welded and machined rail joints	
Up to 60	Up to 90	1,1
Over 60 up to 200	Over 90 up to 300	1,2
Over 200	–	≧ 1,2

Where several motions corresponding to the load cases listed in table 7 occur simultaneously at different speeds, characterized by different self weight factors φ, these factors shall be applied to the respective loads concerned.

Example:

a) Crane trolley travelling speed v = 120 m/min, φ = 1,2.
Crane travelling speed v = 30 m/min, φ = 1,1.

	Trolley travel (Ka)	Crane travel (Kr)
Multiply self weight of trolley by	$\varphi = 1,2$	$\varphi = 1,1$
Multiply self weight of crane by	$\varphi = 1,0$	$\varphi = 1,1$

b) Crane trolley travelling speed v = 30 m/min, φ = 1,1.
Crane travelling speed v = 120 m/min, φ = 1,2.

	Trolley travel (Ka)	Crane travel (Kr)
Multiply self weight of trolley by	$\varphi = 1,1$	$\varphi = 1,2$
Multiply self weight of crane by	$\varphi = 1,0$	$\varphi = 1,2$

4.1.4.2 Nominal load spectrum factor ψ and lifting classes

The lifted loads as defined in subclause 4.1.3 or the stress resultants or stresses resulting therefrom shall be multiplied by a nominal load spectrum factor ψ as given in table 2. Its value depends on the actual hoisting speed of the carrying means assumed at the commencement of the hoisting of the lifted load, and therefore on the rated hoisting speed v_H. The softer the springing of the hoisting gear, the larger the elasticity of the supporting structure, the smaller the actual hoisting speed at the commencement of the hoisting of the useful load, the smaller and steadier the acceleration and deceleration during changes in the hoisting motion, the smaller the factor ψ.

Accordingly, the cranes are classified into lifting classes H1, H2, H3 and H4, with different factors ψ as given in table 2 below. Examples of this are given in subclause 10.1. Individual self-contained parts of a crane forming integral parts of the complete unit, such as the trolley and the crane bridge or jib, the slewing unit, portal and tower, may be classified into different lifting classes within the limits defined in table 23 for the various types of crane, provided the hoisting conditions are fully known.

1 Field of application

This standard applies to the steel structures of cranes and crane equipment of any kind, and also to mobile steel structures for continuous conveyors. It does not cover craneways, excavators, ropeways, wagon tipples and mining machinery.

2 Standards and documents referred to

The following standards and documents shall be complied with unless otherwise specified in this standard.

DIN 1055 Part 4	Design loads for buildings; imposed loads, wind loads of structures unsusceptible to vibration
DIN 1055 Part 5	Design loads for buildings; imposed loads, snow load and ice load
DIN 1080 Part 1	Concepts, symbols and units used in civil engineering; principles
DIN 1080 Part 2	Concepts, symbols and units used in civil engineering; statics
DIN 1080 Part 4	Concepts, symbols and units used in civil engineering; steel construction; composite steel construction and steel girders in concrete
DIN 4114 Part 1	Steel structures; stability cases (buckling, collapsing, bulging); design principles, regulations
DIN 4114 Part 2	Steel structures; stability cases (buckling, collapsing, bulging); design principles, guidelines
DIN 4115	Lightweight and tubular steel construction in building; rules relating to approval, design and construction
DIN 8563 Part 3	Quality assurance of welding operations; fusion-welded joints in steel; requirements, evaluation groups
DIN 15001 Part 1	Cranes; terminology; classification according to type
DIN 15003	Lifting appliances; load suspending devices; loads and forces, concepts
DIN 15018 Part 2	Cranes; steel structures, principles of design and construction
DIN 15019 Part 1	Cranes; stability for cranes except non-rail mounted mobile cranes and floating cranes
DIN 15019 Part 2	Cranes; stability for non-rail mounted mobile cranes; test loading and calculation

DASt-Richtlinie (DASt Guideline) 010 *Anwendung hochfester Schrauben im Stahlbau* (Use of high strength bolts in structural steelwork) [1] [2]

Reference is also made in the text of the present standard to the following standards or to certain clauses or concepts thereof.

DIN 267 Part 3	Fasteners; technical delivery conditions; property classes for carbon steel and alloy steel bolts and screws; conversion of property classes
DIN 1626 Part 1	Welded carbon and low alloy steel pipes for supply purposes, process plant and tanks; general specifications, survey, recommendations for use
DIN 1626 Part 2	Welded carbon and low alloy steel pipes for supply purposes, process plant and tanks; pipes for general use (commercial quality); technical delivery conditions
DIN 1626 Part 3	Welded carbon and low alloy steel pipes for supply purposes, process plant and tanks; pipes subject to special requirements; technical delivery conditions
DIN 1626 Part 4	Welded carbon and low alloy steel pipes for supply purposes, process plant and tanks; high performance pipes; technical delivery conditions
DIN 1629 Part 1	Seamless carbon steel tubes for supply purposes, process plant and tanks; survey, technical delivery conditions; general data
DIN 1629 Part 3	Seamless carbon steel tubes for supply purposes, process plant and tanks; tubes subject to special requirements; technical delivery conditions
DIN 2310 Part 1	Thermal cutting; concepts and nomenclature
DIN 2310 Part 3	Thermal cutting; oxygen cutting; bases of process, quality, dimensional deviations
DIN 4132	Craneways; steel structures; principles of calculation, design and construction
DIN 6914	Hexagon bolts with large widths across flats for high strength friction grip bolting in steel structures[3]
DIN 6915	Hexagon nuts with large widths across flats for high strength friction grip bolting in steel structures
DIN 6916	Round washers for high strength friction grip bolting in steel structures
DIN 6917	Square washers for high strength friction grip bolting of I sections in steel structures
DIN 6918	Square washers for high strength friction grip bolting of channels in steel structures
DIN 17100	Steels for general structural purposes; quality specifications
DIN 17111	Low carbon steels for bolts, nuts and rivets; technical delivery conditions
DIN 18800 Part 1	Steel structures; design and construction

3 Details to be given for design purposes

The following information shall be given for design purposes:

type of crane and method of operation;

assumed total number of all load cycles or operating cycles;

loadbearing systems reflecting the actual service conditions as closely as possible, including outline drawings and main dimensions;

design loads;

lifting classes and loading groups to be considered;

materials of individual members and connections or joints;

shapes, dimensions and static cross-sectional values of all loadbearing members;

verification and analyses relating to said members and to the principal connections or joints.

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[1] Referred to as *HV-Richtlinien* (HV Guidelines) in this standard.

[2] Published by *Stahlbau-Verlag*, Köln.

[3] Referred to as high strength friction grip bolts in this standard.

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Cranes
Steel structures
Verification and analyses

DIN 15 018 Part 1

Krane; Grundsätze für Stahltragwerke; Berechnung

Supersedes April 1974 edition.

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

Dimensions in mm

DIN 15 018 Part 1 and Part 2 have been published following an abridged procedure as specified in DIN 820 Part 4, in the form of corrected editions. This method of proceeding, as well as the corrections that have now been made, were notified and explained in the *DIN-Mitteilungen* (DIN News) 61, 1982, volume No. 8, pages 496 to 498.

It would have been inadvisable to revise the content of the standard at the present time, in view of the general approval which has greeted its publication, and mainly because of the current discussions on the national basic standards relating to steel structures (DIN 18 800); furthermore, the efforts of ISO/TC 96 to achieve an internationally approved ruling with regard to the loads and load combinations which are to be assumed for the verification by calculation of the performance characteristics of cranes, had to be borne in mind.

The principal corrections, including those which have arisen from the processing of the comments received, are described in the Explanatory notes.

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Translation
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