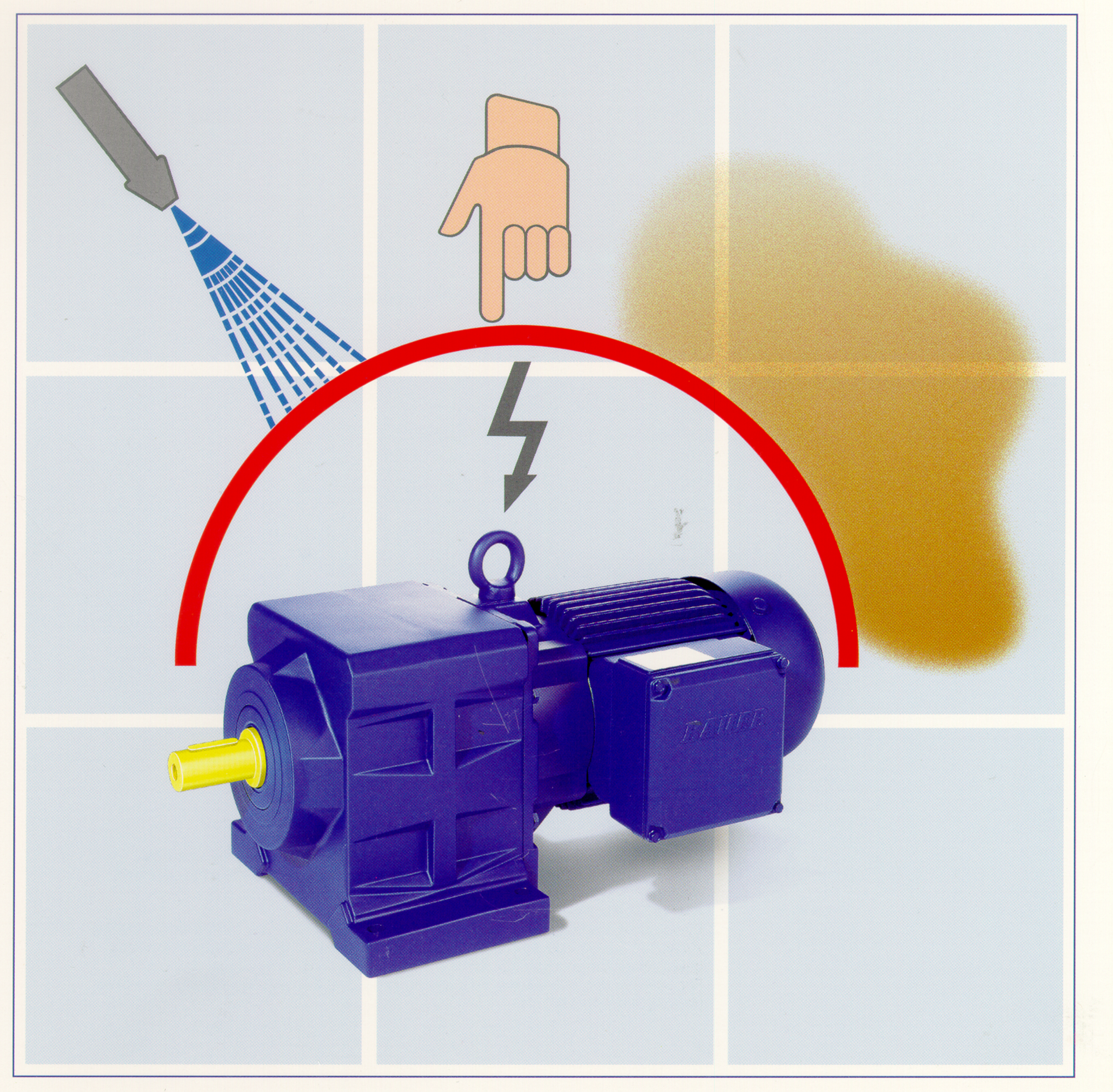
Electronic Publication EP 101 E

IP degrees of protection



BAUER geared motors

IP degrees of protection

EP 101 E

Obering. H. Greiner

Table of contents

1 Degrees of protection and drive technology
2 European standard EN 60529
3 IP Code
4 IP Codes for electrical machines
5 Testing for protection against ingress of foreign objects
6 Testing for protection against water
7 Supplementary letters
8 Example of testing for water protection
9 Special enclosure according to IP66
10 Dust-proofing test
11 Variation of testing conditions in dust-proofing tests
12 Protection against access
13 Condensation
14 Humidity – Tropical conditions – Termites
15 Dust explosion protection
16 IP degree of protection and types of protection
17 PTB report on testing the degree of protection
18 Terminal box construction
19 Corrosion protection
20 Impact resistance
21 International application of the IP Code
22 Degrees of protection in North America
23 Outdoor installation
24 Origin of the IP Code
25 Symbols
26 Proof of effectiveness of IP65

Bibliography
Index of keywords

BAUER geared motors

1 Degrees of protection and drive technology

The commonly used principle of individual electric motor drives has resulted in the motor being included in the overall design of a machine and thus becoming more and more exposed to the ambient influences that arise during operation.
This is particularly true of geared motors whose low shaft speed can be exactly matched to the final speed, thereby permitting ***direct installation*** without intermediate speed reducing elements. Where the speed reduction is obtained by a belt, the high speed drive motor may be mounted from the ceiling (Fig. 1.2), but if a directly coupled geared motor is used it will be in close proximity to the work area of the driven machine (Fig. 1.1) and may be exposed to greater amounts of dust and moisture. It is, however, in just such more adverse environmental conditions that the enclosed reduction gearing offers decisive advantages over any open form of speed reduction.
Such applications have created the need to adapt the design and its degree of protection of the geared motor from the beginning to be able to withstand the adverse ambient influences, so that even under such difficult conditions it will work reliably and without special maintenance requirements.

Fig. 1.1 Direct drive of a drying drum driven be three-phase geared motors

Fig. 1.2 Indirect drive of a wet drum grinder in a ceramics factory with standard motor and two-stage V-belt reduction

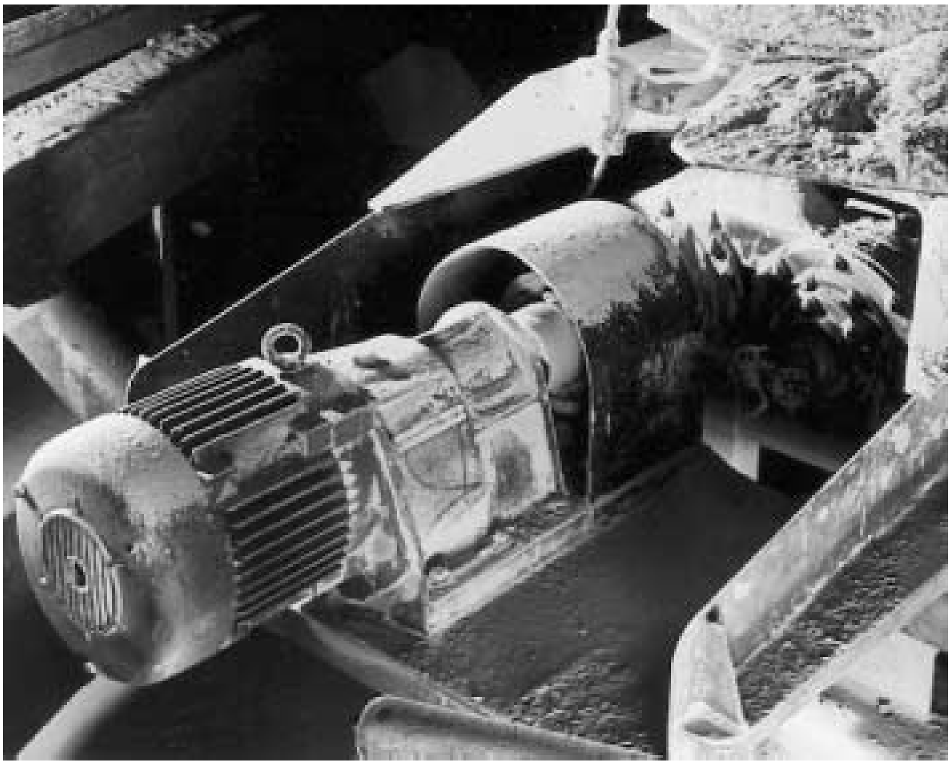


Fig. 1.3 Direct drive of a screw conveyor for cement

2 European standard EN 60529

The European standard is the evolution of a coding system that was introduced for the first time in 1934 in Germany [11]. It was first introduced into various national standards and then into international recommendations as well (see Section 18).

2.1 Numeration

A special explanation follows to provide greater clarity of the numbering system:
Due to the complicated structure of DIN, DKE and VDE and the interests of the publishers responsible for the marketing of standards (VDE and Beuth) made it necessary to establish a designation as »DIN VDE 0470, Part 1« for the first edition.
The numerical series VDE 0470 concerned itself only with testing units and testing methods; Part 1 in the edition 12.84 applied to the jointed test finger. Users of these standards will hardly expect a basic standard under this numerical series such as the determination for the degrees of IP protection.
Beginning with the 2nd edition the number is DIN EN 60529 (VDE 0470, Part 1).
Consumers, designers, authors of technical instructions and catalogs were well advised to use the designation »European standard EN 60529« from the beginning [6].

2.1.1 Designation of new standards

International Standard IEC 60529 2nd edition: 1989 + A1: 1999
European Standard EN 60529: 1991 + A1: 2000
German Standard DIN EN 60529 (VDE 0470, Part 1): 2000

2.1.2 Revised national standards

DIN 57470 Part 1/VDE 0470 Part 1/12.84
DIN 40 050/07.80
DIN 40 052/07.80
DIN 40 053 Part 1/07.80
DIN 40 053 Part 2/07.80
DIN 40 053 Part 3/07.80
DIN 40 053 Part 4/07.80
DIN VDE 0470-1 (EN 60529): 1992

2.1.3 Revised international standards

IEC 529, 1st edition (1976)
HD 365 (harmonizing document based on IEC 529, 1st edition)

2.2 Fundamental changes

The primary focus of the revision of the IEC 60529 was the clarification of fundamental determinations that had been interpreted differently in some cases as they were transferred into almost 25 national standards (Fig. 2.2.1):

- ☐ Designation with the first code number 2 (IP2X) requires testing with the jointed test finger **and** the 12.5 mm sphere. Opening widths that are larger than 12.5 mm are therefore not permitted with this degree of protection.

- ☐ In order to clarify that the jointed test finger with a diameter of 12 mm can penetrate an enclosure in its entire length of 80 mm, the nominal diameter of the sphere was changed from 12 to 12.5 mm. According to previous determinations this type of penetration with the same nominal diameters was possible only within the different tolerance zone positions. It was therefore not clear whether the use of both access probes was required.

- ☐ The original dimension specified in IEC 144 [1] (with a sphere diameter of 12.5 mm) was again included.

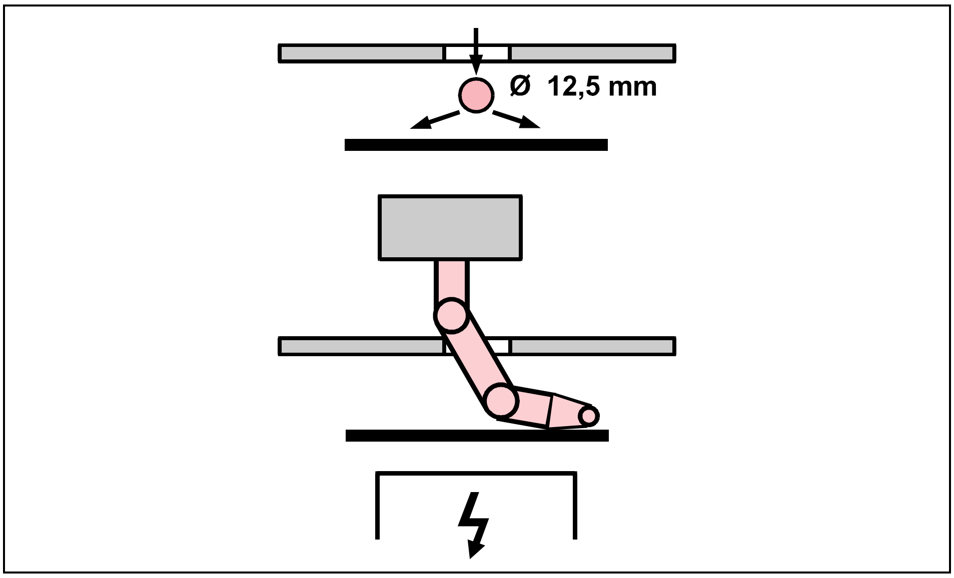


Fig. 2.2.1 One of the questions to be clarified by IEC/TC70:
IP2X, IP1X or IP1XB?

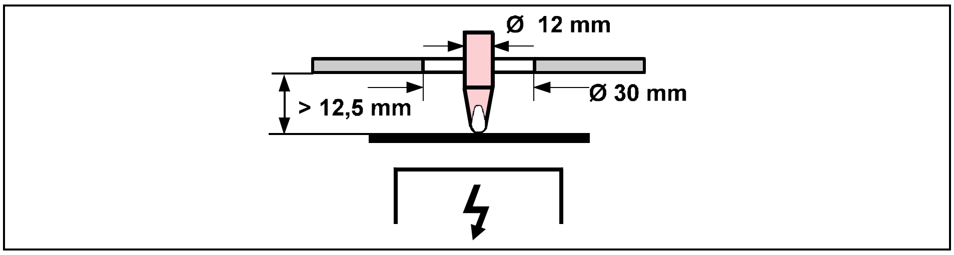


Fig. 2.2.2 Example of high degree of protection against access (finger protection) and low protection against ingress of foreign objects:
Designation with 2-digit code: IP1X
with 3-digit code: P1XB

New specifications were established in the revision of IEC 60529 for probes to test the protection against contact with tools, wire or other objects. It was also clearly defined that the selected dimensions was simply a matter of »convention«.
A length of 100 mm was established for the active part of the probe that penetrates the enclosure. The spherical »stop face« is designed to simulate the angled joints of the finger holding the »tool« (see Section 3.3.2.4).
The expansion of the IP Code is laid out so that there are no essential changes for the design and testing of machines in the consistent application of earlier specifications, reflecting an urgent request from various technical sectors and national committees.

On the other hand the ACOS proposal is taken into account, which specifies that the IEC/TC70 standard for protection against direct contact through enclosures has a pilot function.
Based on a request by the technical committees for the household appliances industry (IEC/TC61) a deviation was made from the previous principle for the designation of protection against the ingress of water, in which the indication of a specific degree of protection necessarily always included compliance with all the lower degrees of protection. The single exception involves the transition from protection against water jets (IPX5 and IPX6) to protection against immersion (IPX7 and IPX8).
The national committee 212 »Degrees of protection« has resolved to retain the term »Gehäuse« – the translation used for decades in standards and practice for the term »enclosure« – and to add the newly specified term »Umhüllung« in parentheses in Section 2.3.12 of DIN VDE 0100 Part 200.
Additional changes and supplements that merit note include:

2.3 Additional changes

- ☐ Empty enclosures and testing of the same are included in the scope of application. A separate standard (EN 60439-6) is in preparation.
- ☐ Since machinery for high-voltage use of up to 72.5 kV is also included in these applications, the approach to hazardous live parts is also included in the protection against direct contact.
- ☐ The scale of the degrees of protection against access covers protection against accidental contact with the back of the hand, but not protection against intentional contact with an extended hand.
- ☐ The criteria for evaluation of a »harmful effect« of dust or water during the test for degree of protection have been expanded and made more precise wherever possible.
- ☐ At the request of the household appliance sector (IEC/TC61) oscillating tubes with a radius of up to 1600 mm are now permissible for tests for spraying and splashing water (IP3X and IP4X). The water throughput rate was defined to result in an approximately equally high stress per unit area (Fig. 6.1).
- ☐ A more complete Annex A is designed to clarify the use of test probes and list the criteria for test evaluation.
- ☐ Annex B lists specifications that must be made by the Technical Committees in their product standards.

In the revision of IEC 60529 the attempt was made to eliminate ambiguities in the original version and to expand its application to the widest possible range of electrical machines.
Due consideration was given to the parallel, higher level work being carried out on a new overall concept for »protection against electric shock« in IEC/TC64.

2.4 Summary

Several ambiguities in the first editions of the IEC 60529, the expansion of the range of application to include household appliances, and installation and new requirements for protection against access have made it necessary to revise the specifications for the degree of IP protection.
The old IP Code can continue to be used unchanged for machines that are designated strictly according to the earlier specifications.

The IP Code is a part of the basic knowledge of every electrician and finds daily application to many types of machinery.

Users should know that the IP Code remains »downward compatible«, even after revision and within the framework of a European standard.

2.5 Electrical machines

The standards for the degree of protection of electrical machines are based on the higher ranking determinations of IEC 60529, and also contain additional requirements:

International:
IEC 60034-5, 4th edition 12.2000
Rotating electrical machines
Part 5: Degrees of protection provided by integral design of rotating electrical machines (IP Code) – Classification

National:
DIN VDE 0530 Part 5, 2nd edition 04.1988
EN 60034, Part 5
Rotating electrical machines
Part 5: Classification of degrees of protection by enclosures for rotating machines
In preparation: DIN EN 60034-5 (VDE 0530 Part 5)

See Section 4 for conformances and deviations from the higher European standard EN 5029 as it applies to all types of machinery

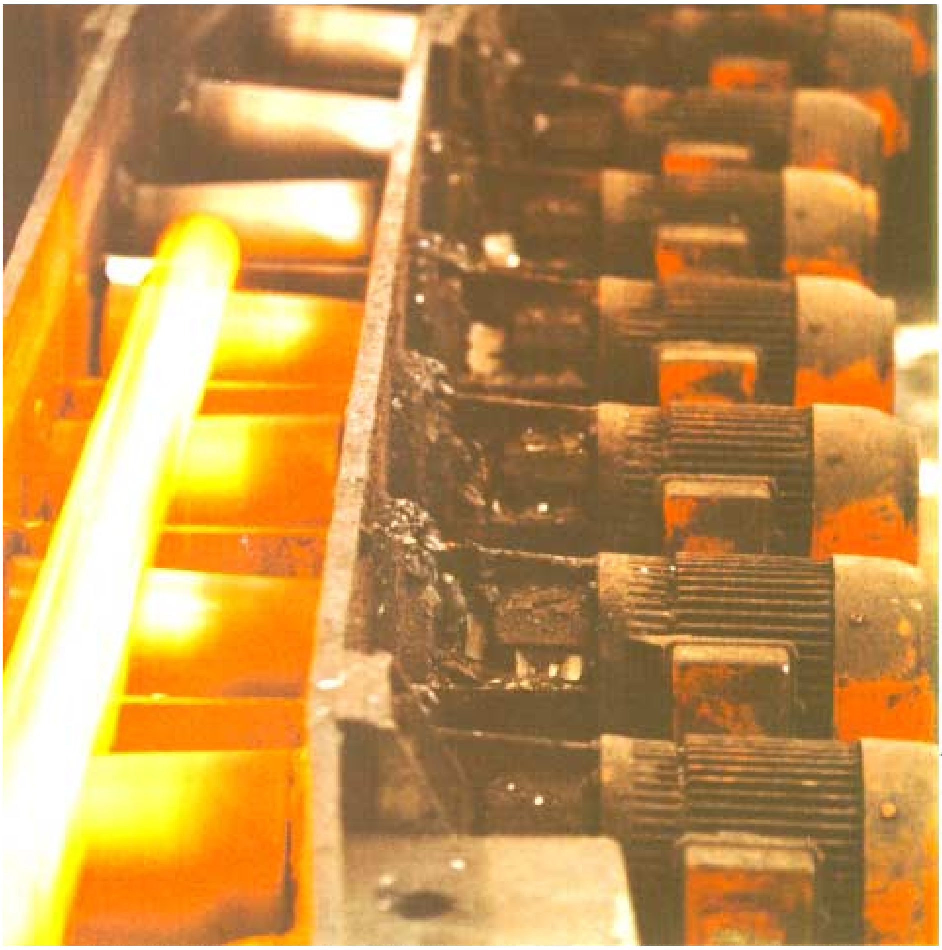


Fig. 2.5 Roller table geared motors in the direct range of conductive scaling dust

3 IP Code

The degree of protection provided by an enclosure is indicated by an alphanumeric code (IP Code).
The following notes apply to the status specified in EN 60529.

3.1 Arrangement

IP 2 3 C M

Code letters
(International Protection)

First characteristic numeral
(numerals 0 to 6, or letter X)

Second characteristic numeral
(numerals 0 to 8, or letter X)

Additional letter (optional)
(letters A, B, C, D)

Supplementary letter (optional)
(letters H, M, S, W)

If the specification of a characteristic numeral is not required, it shall be replaced by the letter »X« (»XX« if both numerals are omitted). Additional letters and/or supplementary letters may be omitted without replacement. If more than one supplementary letter is used, alphabetical order should be applied.
If an enclosure provides different degrees of protection for different intended mounting arrangements, the relevant degrees of protection shall be indicated by the manufacturer in the instructions for the respective mounting arrangements.

3.2 Definitions

Element	Numerals or letters	Definition for the protection of equipment	Definition for the protection of persons
Characteristic numerals	**IP**	-	-
First characteristic numeral		Against ingress of solid foreign objects	Against access to hazardous parts with
	0	(unprotected)	(unprotected)
	1	≥ 50 mm diameter	back of the hand
	2	≥ 12.5 mm diameter	finger
	3	≥ 2.5 mm diameter	tool
	4	≥ 1.0 mm diameter	wire
	5	dust-protected	wire
	6	dust-tight	wire
Second characteristic numeral		Against ingress of water with harmful effects	
	0	(unprotected)	-
	1	vertically dripping	-
	2	dripping (15° tilted)	-
	3	spraying	-
	4	splashing	-
	5	jetting	-
	6	powerful jetting	-
	7	temporary immersion	-
	8	continuous immersion	-
Additional letter (optional)			Against access to hazardous parts with
	A	-	back of the hand
	B	-	finger
	C	-	tool
	D	-	wire
Supplementary letter (optional)		Supplementary information specific to:	
	H	High-voltage apparatus	-
	M	Motion during water test	-
	S	Stationary during water test	-
	W	Weather conditions	-

3.3 Optional additional letter for contact protection

In the first version of IEC 60529 and in DIN 40050, attaining a high degree of protection against access was associated with a small opening width or, in other words, a high degree of protection against the ingress of foreign objects. This specification was an unnecessary impediment for apparatus to be used in clean rooms that require large ventilation openings and which are access-proof on account of the sufficient distances to the internal live parts.

The new version of IEC 60529 and EN 60529 now makes it possible to indicate the degree of protection against access by distances or barriers by using an additional letter (A, B, C or D). The additional letter can be used as an option when the access protection is greater than indicated by the first numeral, or when information on protection against the ingress of foreign objects is not desired. The individual standards committees have the right to decide whether they wish to utilize this extension of the code for degree of IP protection in their product standards.
The national and international committees responsible for the degrees of protection of electrical machines have rejected the introduction of this additional letter in their product standard (EN 60034-5 (DIN VDE 0530 Part 5) and in IEC 60034-5): ***Access protection for electrical machines is achieved primarily by limiting the opening widths and can therefore be described with the first code number of an IP Code using two numerals.***
Few other sectors have taken advantage of this option. The minimum requirement for protection against direct access, however, is defined with the new IP Code (e.g. IPXXB) in basic safety regulations. The following section explains this expansion of the IP Code.

The additional letter indicates the degree of protection for persons with regard to access to hazardous parts.

Additional letters are only used:

- ❑ if the actual protection against access to hazardous parts is greater than the protection specified by the first code number, or
- ❑ if only the protection against access to hazardous parts is specified and the first code number is replaced with an X.

This higher degree of protection could be provided by guards, suitable shape of openings or distances inside the enclosure.

Additional letter	Degree of protection Brief description	Definition
A	Protected against access with the back of the hand	The access probe, sphere of 50 mm diameter, must have adequate clearance from hazardous parts
B	Protected against access with a finger	The jointed test finger of 12 mm diameter, 80 mm length, must have adequate clearance from hazardous parts
C	Protected against access with a tool	The access probe of 2.5 mm diameter, 100 mm length, must have adequate clearance from hazardous parts
D	Protected against access with a wire	The access probe of 1.0 mm diameter, 100 mm length, must have adequate clearance from hazardous parts

Table 3.3 Degrees of protection against access to hazardous parts indicated by the additional letters

3.3.1 Test probes

Access probes have been newly defined in IEC 60529 and EN 60529. They form part of a system of test proves described fully in DIN IEC 61032 / VDE 0470 Part 2 [7] comprising a total of 18 selected variants from the IEC standards.

- ❑ IP Code probes
  - access probes
  - object probes

- ❑ Other probes
  - for protection against hazardous active and mechanical parts
  - for protection against hazardous mechanical parts
  - for protection against hot or incandescent internal parts.

The access probes listed below are used in the IP Code:

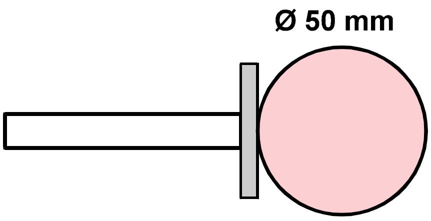
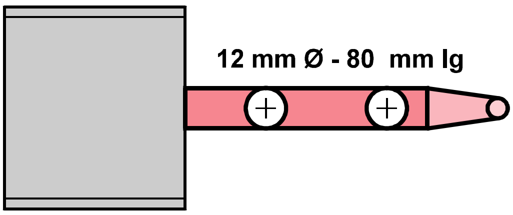
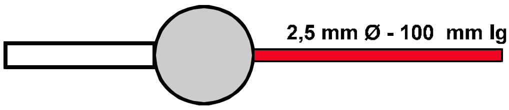
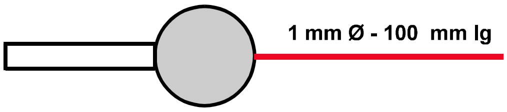
Protection against access with	Access probe	Explanation
Back of the hand		The plate between the sphere and the handle is not a stop but is provided to protect the tester
Finger		The »jointed test finger« has two joints. For the purposes of the IP test it is only to be used up to the first stop face measuring 50 mm x 20 mm, and 80 mm along its length
Tool		The »stop face« takes the form of a 35 mm ∅ sphere. It is intended to simulate the knuckle when the tool or wire is held in the hand
Wire		

Fig. 3.3.1 Access probes for testing the protection against access in the IP system

3.3.2 Testing for protection against access

While the first code number generally describes protection offered by restricting the opening widths in the enclosure, the additional letters describe »protection provided by distances or barriers«. The following table explains the test using access probes:

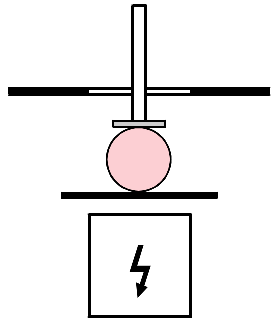
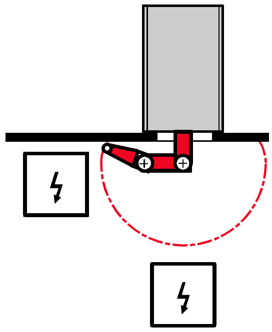
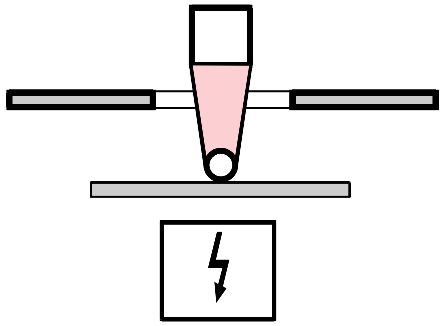
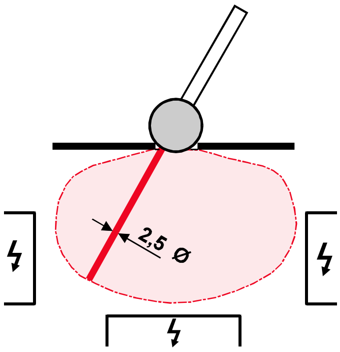
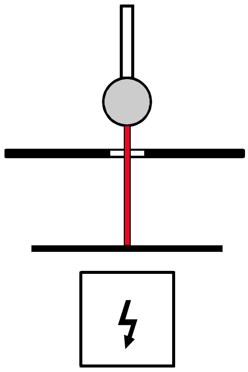
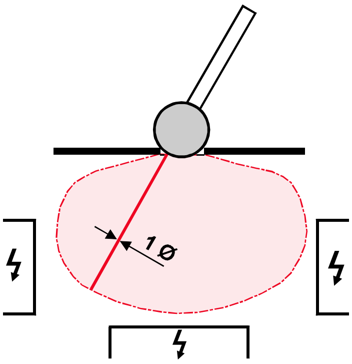
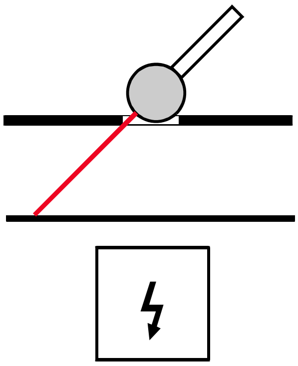
IP Code	Protection against access by	
	Distance	Barrier
IPXXA	-	
IPXXB		
IPXXC		
IPXXD		

Fig. 3.3.2 Use of access probes to test the degree of protection against access in accordance with the additional letters in the IP Code

4 IP codes for electrical machines

The following deviations and supplements have been established for the general specifications for electrical machines, etc. in IEC 60034-5 [4] and the German standard on which it was based.

4.1 Frequently used degrees of protection

From the very large number of possible degrees of protection against contact and ingress of water, a series of typical combinations have established themselves in practice. The following table gives a survey of the most frequently used degrees of protection (see Annex A on DIN VDE 0530, Part 5 / EN 60034, Part 5 : 1988).

Second numeral ⇒	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
First numeral ⇓									
0									
1			IP12						
2		IP21	IP22	IP23					
3									
4					IP44				
5					IP54	IP55			

For decades the relevant standards committees were of the opinion that electrical machines from serial production – such as standard motors – could not be designed to be completely dust-tight with the degree of protection IP6X. For this reason the degree of protection IP55 is shown in the above table as the highest "common" degree of protection. Manufacturers of special machines with the degree of protection IP65 therefore had to use the standard EN 60529, which applied to all types of apparatus.
This restriction is omitted in the new 2000 edition of the IEC 60034-5. Table 2 contains the degree of protection IP6X "dust-tight" and Table 4 shows the corresponding testing conditions [4].

4.2 Protection against contact with external fans

The blades and spokes of fans outside the enclosure (external fans) must be protected against direct contact by means of guards complying with the following requirements:

Protection of machine:	IP1X	IP2X to IP5X
Test of fan guard:	50 mm sphere	Finger test

For the test, the rotor is slowly rotated by hand. Smooth rotating shafts and similar parts are not considered dangerous. In certain applications (such as agricultural or domestic appliances) more extensive precautions against accidental contact may be required.
Under intended use according to DIN 31000/VDE 1000 »General principles for the safety design of technical products« the following degrees of protection against contact and hazard from moving parts are standard:

- IP0X for use in closed areas for electrical operations
  (the degree of protection IP 0X is not permissible for hazardous moving parts; these must be protected against unintentional contact).

- IP1X for use in electrical operation areas
- IP2X in all other cases.

Fig. 4.2
Fan cowl of a three-phase motor.
A 12 mm mesh size is sufficient on the inlet grill in accordance with the degree of protection IP2X.
A mesh size of 8 x 8 mm is usually provided.

The standards or other technical codes of practice pertaining to certain applications contain more extensive requirements or specify the measure to be taken to prevent a particular type of hazard.
Installation regulations, such as standards in the DIN VDE 0100 series, specify the measures to be taken to prevent a particular type of hazard (example: by additional covers, barriers or guards, or the installation in an enclosure).

4.3 Ranking the degrees of protection

Up to the revision of IEC 60529 : 1989 [3] the self-explanatory principle – that higher degrees of protection include the lower degrees of protection – applied. In unclear cases it was necessary to carry out the test with the requirements for both the high and the lower degree of protection.
At the insistence of the IEC TC61 (household appliances sector) this clear concept collapsed in the high degrees of water protection because the transition demanded by ACOS (Advisory Committee of Safety) from the formerly used "droplet marking" to the "IP Code" was made to depend on this concession. The manufacturers of electrical toothbrushes wanted to designate their products as "suitable for temporary immersion IPX7" – in the event, for example, that the toothbrush should fall into the sink for a brief period of time. Because the unit did not pass the test with powerful water jets (IPX6), an exemption regulation was required, which was pushed through by the strong lobby of the IEC TC61 in ACOS.
From the point of view of the electrical engineering industry it is unfortunate that an electric toothbrush can have the same identifying marking as an industrial submergible pump, and that a relevant safety-related classification system that has been in use for decades has been undermined.
The TC2 of the IEC would have had the opportunity to rectify the regulations in the product standard IEC 60034-5 : 2000, but did not pursue the German proposal.

Following Clause 6 of IEC 60529 it would have been possible to have achieved formal and objective clarity with the following recommendation:

Up to the second code number 6 the designation indicates that the requirements for all the lower code numbers have also been met.
In general, rotating electrical machines for “various” applications should be designated in accordance with the last column and must meet the requirements both for the test with water jets as well as temporary or continuous submersion.

The enclosure fulfills the test for			
Water jets, second code number	*Temporary/ continuous immersion, second code number*	*Designation and marking*	*Scope of application*
5	*7*	*IP X5/IP X7*	*various*
6	*7*	*IP X6/IP X7*	*various*
5	*8*	*IP X5/IP X8*	*various*
6	*8*	*IP X6/IP X8*	*various*

Unfortunately this clarification has been lost due to the disregard of IEC 60529.

4.4 Evaluation criteria according to the dust-proofing test IP5X

In Section 13.5.2 of IEC 60529 the following was established in the acceptance conditions for the first code number:
""The protection is satisfactory if, on inspection, talcum powder has not accumulated in a quantity or location such that, as ***with any other kind af dust,*** it could interfere with the correct operation of the equipment or impair safety. Except for special cases to be clearly specified in the relevant product standard, no dust shall deposit where it could lead to tracking along the creepage distances."
In IEC 60034-5, Table 4, Numeral 5 the relevant passage states:
"The protection is satistactory if, on inspection, talcum powder has not accumulated in a quantity or location such that, as with any kind of ordinary dust (i.e. ***dust that is not conductive, combustible, explosive or chemically corrosive***), it could interfere with the correct operation ot the machine."

The strict interpretation of this non-practice-oriented specification in the product standard for applications similar to those shown in Fig. 2.5 reveals that a dust-protected motor (according to IP5X) does not exhibit the necessary degree of operational safety. For ***dust explosion protection*** there is the technical and formal problem that the degree of protection IP5X according to IEC 60034-5 does not meet the requirements. The necessary steps have already been taken in the draft to IEC 61241-1 for dust-explosion-protected electrical machines. Here, a test and evaluation according to IEC 60529 (not IEC 60034-5) is also explicitly required for electrical machines which are "dust-protected IP5X" or "dust-tight IP6X".

4.5 Limitations of the IP degree of protection

External influences such as corrosive solvents (cutting lubricants or coolants), vermin, solar radiation and icing are expressly excluded from the scope of application of IEC 60529. Regarding the water protection tests Clause 6 also states: "The tests for the second characteristic numeral are carried out with fresh water. The actual protection may not be satisfactory if cleaning operations with high pressure and/or solvents are used."
There were good reasons to explicitly point out these limitations of the IP protection: if an idle external fan is blocked by frozen snow, remedy is possible only through the use of an additional protective roof or space heater.
In the processing of foodstuffs and increasingly in the hobby sector as well, high-pressure cleaning units are being used whose water jets far exceed the impact as defined as in "powerful water jets" IPX6.
The TC2 of IEC would have been well advised to have also shown these limitations in the product standard IEC 60034-5 : 2000 and helped avoid unnecessary discussions between manufacturers and users.

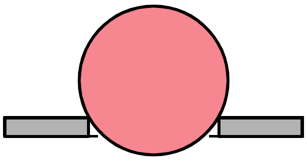
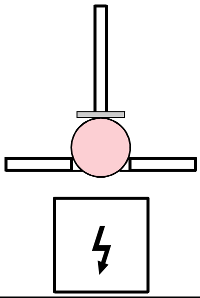
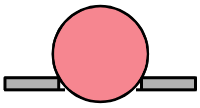
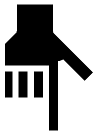
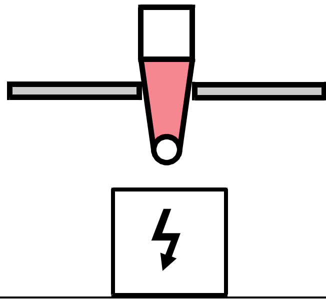
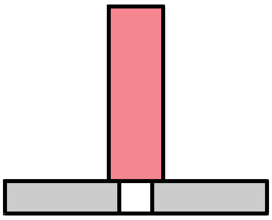
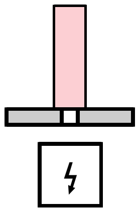
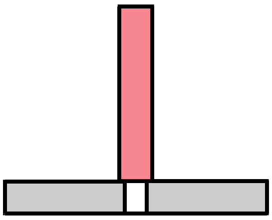
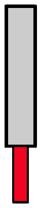
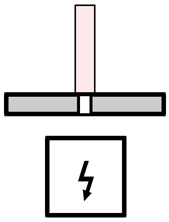
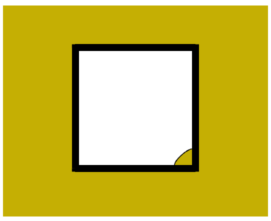
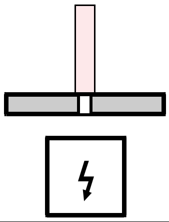
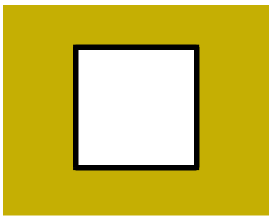
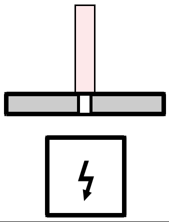
PROTECTION AGAINST INGRESS OF FOREIGN OBJECTS First characteristic numeral				
Degree of protection	**Protection of machines against penetration by solid foreign objects**		**Protection of persons against access to hazardous parts**	
IP1X	**≥ 50 mm ∅**		**Back of hand** 	
IP2X	**≥ 12.5 mm ∅**		**Finger** 	
IP3X	**≥ 2.5 mm ∅**		**Tool** 	
IP4X	**≥ 1.0 mm ∅**		**Wire** 	
IP5X	**dust-protected**			
IP6X	**dust-tight**			

Fig. 5 Requirements for the first characteristic numerals IP1X to IP6X
Protection against ingress of foreign objects

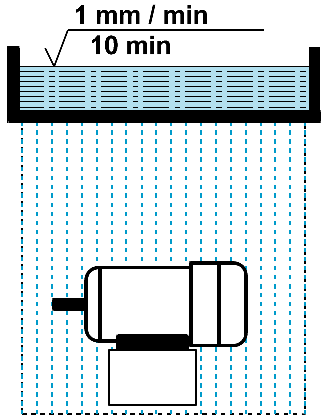
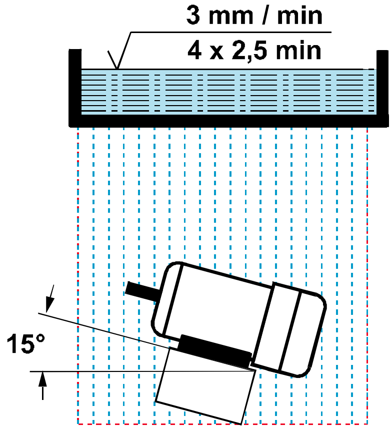
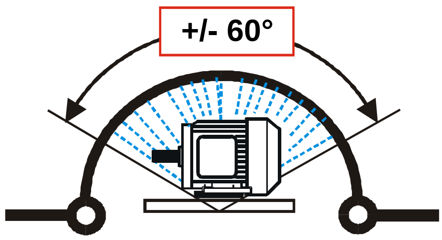
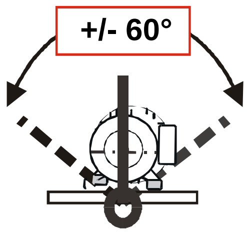
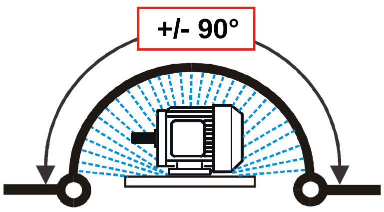
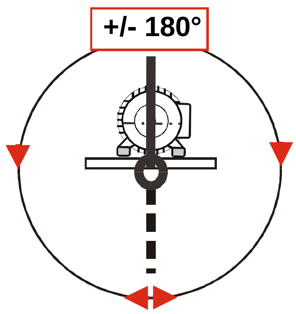
PROTECTION AGAINST INGRESS OF WATER Second characteristic numeral		
Degree of protection	**Protection against**	**Principle of test**
IPX1	**Dripping water**	
PX2	**Dripping water at 15° tilting**	
IPX3	**Spraying water**	  0.07 l/min per hole
IPX4	**Splashing water**	 0.07 l/min per hole 

Fig. 6.1 Requirements for second code number IPX1 to IPX4
Protection against water (dripping water ... splashing water)

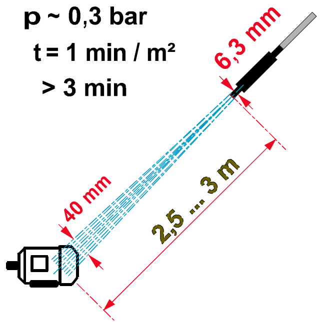
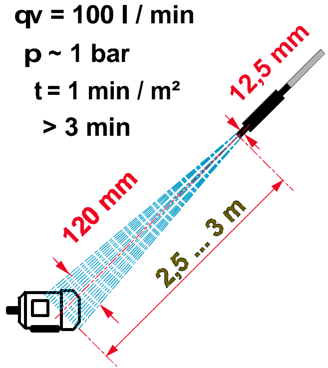
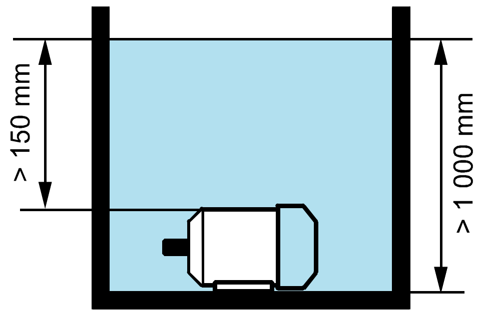
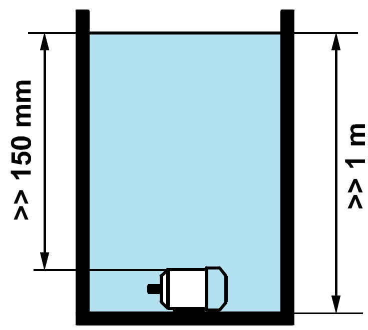
PROTECTION AGAINST WATER Second characterstic numeral		
Degree of protection	**Protection against**	**Principle of test**
IPX5	**Water jets**	**qv = 12,5 l / min** **p ~ 0,3 bar** **t = 1 min / m²** **> 3 min** 
IPX6	**Powerful water jets**	**qv = 100 l / min** **p ~ 1 bar** **t = 1 min / m²** **> 3 min** 
IPX7	**Temporary immersion in water**	*t* = 30 min 
IPX8	**Continuous immersion in water**	***t*** = ∞ IPX8 > IPX7 

Fig. 6.2 Requirements for the second code number IPX5 to IPX8
Protection against water (water jets ... submersion)

7 Supplementary letters

The supplementary letters »M, S and W« have been included in the standard for electrical machines. For reasons of clarification IEC 60034-5 : 2000 is quoted here:
"Additional information may be provided by a supplementary letter following the second characteristic numeral. If more than one letter is used, alphabetic sequence shall apply."

7.1 Letters S and M

For special applications such as open, enclosed-ventilated (ODP) machines on board a ship when the air inlet and outlet openings must be shut during idle periods, a letter may be placed after the code numbers. This letter indicates whether protection against the harmful effects due to the ingress of water with the machine at standstill (letter S) or with an machine in motion (letter M) has been proven or tested. In such a case the degree of protection for both operating states of the machine must be specified (e.g. P55S / IP20M). If the supplementary letters are omitted, the degree of protection has been met for all specified applications.

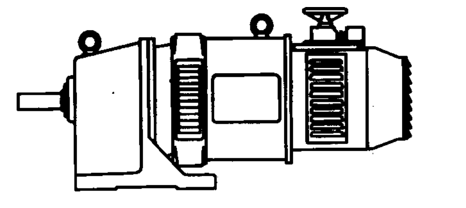


Fig 7.1.1
IP20M – operation in harbor

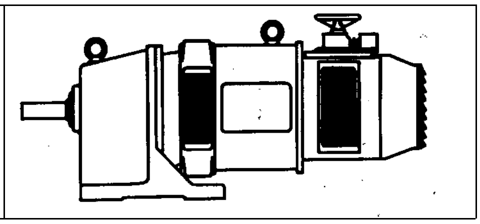


Fig 7.1.2
IP55S – travel on high seas

7.2 Letter W

The letter »W« may be used to indicate open, enclosed-ventilated machines installed for use under defined weather conditions and with additional protective measures or equipment.
In the second edition of IEC 60034-5 : 1968 the letter »W« had been used with the same meaning directly after the IP code letters.

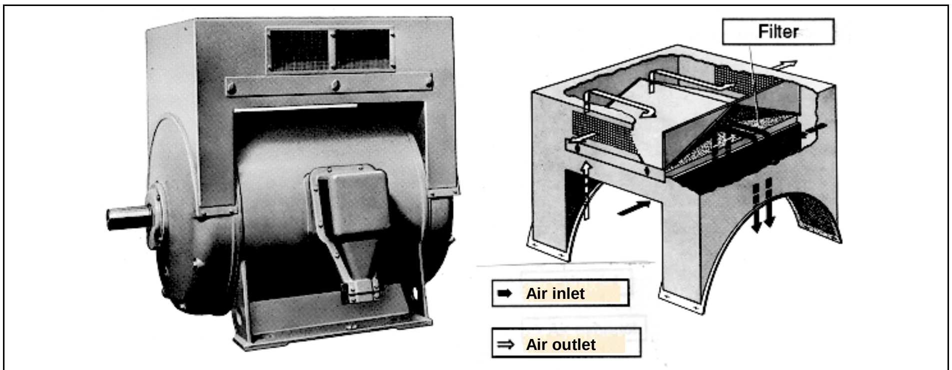


Fig 7.2 Open, enclosed-ventilated machine with special air flow – »weather protection« (Source: SIEMENS)

7.3 Requirements and tests

The degree of protection W is intended for air-cooled open machines with open circuit cooling, that is, machines with cooling Systems designated by ICOX to IC3X according to IEC 60034-6.Weather-protected machines shall be so designed that the ingress of rain, snow and airborne particles into the electrical parts is reduced.
Other measures providing weather protection (such as encapsulated windings or total enclosure) are not designated by W.

Machines with degree of protection W shall have ventilation passages constructed such that:

a) at both intake and discharge, high-velocity air and airborne particles are prevented from entering the internal passages leading directly to the electrical parts of the machine;

b) the air intake path, by baffling or use of separate housings, provides at least three abrupt changes in the direction of the air intake, each of which is at least 90°;

c) the air intake path provides an area of average velocity not exceeding 3 m/s, enabling any particles to settle. Removable or otherwise easy to clean filters or any other arrangement for the separation of particles may be provided instead of a settling chamber.

The protection of the machine against contact, foreign objects and water shall comply with the conditions and tests specified for the stated degree of protection.

The design of the terminal box shall ensure a degree of protection of at least IP54.

If necessary, arrangements to provide protection against icing, moisture, corrosion or other abnormal conditions shall be made by agreement (e.g. by using anti-condensation heating).
For the verification of weather protection W, a study of drawings is generally sufficient.

Note is made here of the fact that British manufacturers in particular have used the letter »W« on totally encloded fan-cooled (TEFC) standard motors to indicate »outdoor installation«. This does not correspond with the purpose of the standard.

8 Examples of testing for water protection

The different testing conditions used for electrical machines to test for degrees of water protection IPX4 and IPX5 are compared below.

8.1 Degree of protection IP X4

This degree of protection is a part of the standard degree of protection IP 44 and IP 54 for three-phase cage motors operating in the normal range.

8.1.1 Testing conditions

Testing for the second code number 4 with oscillating tube or spray nozzle
The test must be carried out with the oscillating tube, assuming that the size and form of the machine is designed so that the radius of the oscillating tube does not exceed 1 m. If this condition cannot be met, a hand-held spray nozzle must be used.

a) Conditions for the oscillating tube:
The oscillating tube has spray openings arranged over the entire 180° of the half-circle. The overall flow rate is set using the value specified in the table and measured with a flowmeter.
The tube can be swiveled at an angle of almost 360°, or 180° on both sides from the vertical. The time for a complete testing period (2 x 360°) is approximately 12 seconds.
The testing time is 10 minutes.
The support for the machine to be tested must be perforated in order to prevent it from functioning as a deflection plate. The enclosure is sprayed from all directions by swiveling the tube over its entire range of movement.

b) Conditions for the spray nozzle:
The cover provided with the counterweight must be removed from the spray nozzle and the enclosure sprayed from all directions.
The water throughput rate and the spraying time for each unit area are specified in the standard.

Total delivery rate q_V under IPX3 and IPX4 testing conditions
Average delivery rate per hole q_{V1} = 0.07 l/min

Tube radius	IPX3		IP X4	
mm	Number of open openings N[1)]	Total delivery rate % l/min	Number of open openings N[1)]	Total delivery rate % l/min
200	8	0,56	12	0.84
400	16	1.1	25	1.8
600	25	1.8	37	2.6
800	33	2.3	50	3.5
1000	41	2.9	62	4.3

1) Depending on the actual arrangement of the openings (if spacing is defined) the number of open openings N may be increased by 1.

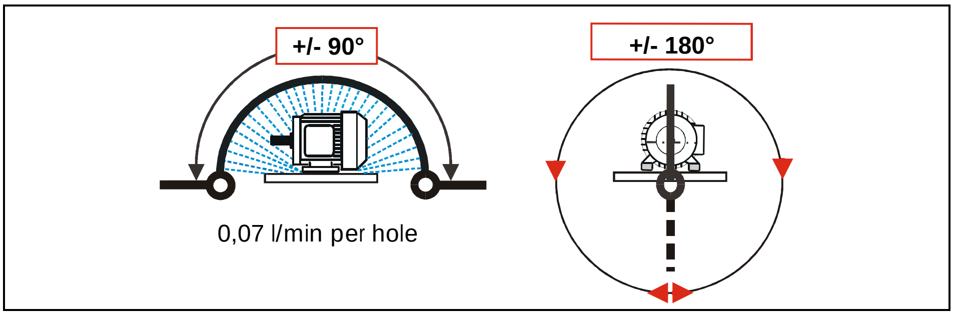


Fig. 8.1.1.1 Illustration of testing with oscillating tube

Fig. 8.1.1.2 Oscillating tube for testing the degree of protection against »water spray«

8.2 Degree of protection IPX5

This degree of protection is a part of the degrees of protection IP55 and IP65 infrequently offered in catalogs.

8.2.1 Testing conditions

The test is carried out by spraying the motor with water from all directions from a standard nozzle.
The following conditions must be met:

- Internal diameter of nozzle: 6.3 mm
- Delivery rate: 12.5 l/min ± 5%
- Water pressure: Adjust to specified delivery rate
- Core of main water stream: circle with approx. diameter of 40 mm at distances of 2.5 m from the nozzle
- Test duration per m² surface area of enclosure: 1 min
- Minimum duration: 3 min
- Distance from nozzle to enclosure surface: between 2.5 m and 3 m.

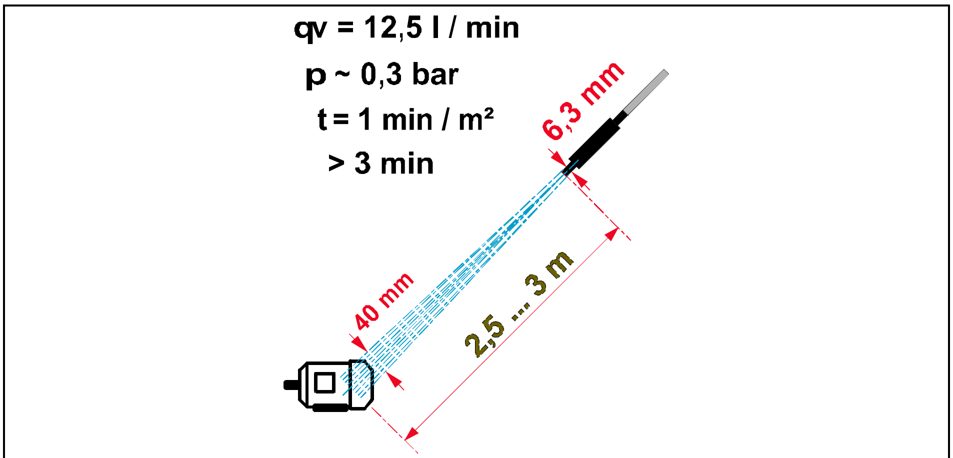


Fig. 8.2.1 Illustration of the water jet test for the degree of protection IP X5

Fig. 8.2.2 Test arrangement for the degree of water protection IP X5 "Water jet"

Fig. 8.2.3 Effect of water during the water jet test IPX5

Fig. 8.2.4 Effect of water during the water jet test IP X6 »Powerful water jets«

9 Special protection according to IP66

The IP65 enclosure provides a particularly high degree of protection for electrical machines against adverse environmental conditions as shown in comparisons in the previous sections. Such motors can, without further protection, be installed in the open since normal rain will not penetrate into the housing. In such situations particularly careful sealing of the cable entry into the terminal box, the fixing of the readily available cover over the inlets in the case of vertical mounting, and regular repainting of the outside is recommended. There are also applications that make further measures to seal the machine necessary and achieve protection to IP66 requirements. These additional measures are recommended where the motor may be flooded for a short time (as, for example, on the deck of ship, in cellars subject to flooding), when continuously sprayed (as in cooling towers) or where frequently hosed down (as in car wash installations, breweries, milk treatment plants or transport installations for saltwater fish). This very high degree of protection requires a number of measures that must be carried out in the factory according to very detailed manufacturing schedules.

9.1 High degrees of water protection in accordance with installation regulations

Protection against the effects of water is defined in the installation regulations for many applications by the specification of a minimum degree of IP protection.

For example, high degrees of protection are stipulated in the following zones:

IPX5 **Protection against water jets**
Workshop pits cleaned with water jets
Showers (Zones 1, 2 and 3)
Car washes
Meat processing plants (where machine parts are hosed directly)
Cheese ripening rooms
Sewage treatment plants

IPX6 **Protection against powerful water jets**
Exposed decks on ships

IPX7 **Protection against temporary immersion**
Dairies
Saunas (spraying area)
Slaughterhouses
Swimming pools (where subjected to hosing)
Washrooms

A full list of requirements for each operating area can be found in the guideline »Standards and degrees of protection for electrical installations« by K. Nowak, a valuable and comprehensive reference work for day-to-day practice.

It is striking that protection against ***powerful*** water jets (IPX6) appears ***in the standards*** to be reserved exclusively for use on ships.
This can perhaps be attributed to earlier editions of DIN 40050 in which the ***degree of protection IPX4S*** was contained as ***»protection against temporary flooding = protection against heavy seas«***.
In actuality there are a series of applications in which this high level of water protection

- ☐ offers a higher degree of technical safety compared to IPX5
- ☐ permits a much more economical solution than IPX7.

This section shows the opportunities and limitations for the degree of protection IPX6.

9.2 Standard testing conditions

The standard testing conditions are discussed in Sections 3 and 6. They are sufficient under normal conditions and have been shown to be effective in practice.

Fig. 9.2.1 Test arrangement for the degree of water protection IPX6 "Powerful water jet"

Fig. 9.2.2 Effect of water jet during test for IPX6

9.3 Stricter testing conditions

In the case of adverse conditions, especially with regard long-term wear, the user is recommended to consider actual experience as a precautionary measure when selecting operating equipment. The manufacturer is well advised not to view a single passing of a standardized test as a guarantee of long-term effectiveness. Most water tests for the IP Code last only ***10 minutes.*** One year has ***8760 hours.***

The following illustrations show factory-specific testing methods in which the water pressure, water quantity and time period were increased beyond the specifications of the standard.
Experience has shown that no other degree of severity can replace a sufficiently long testing period.

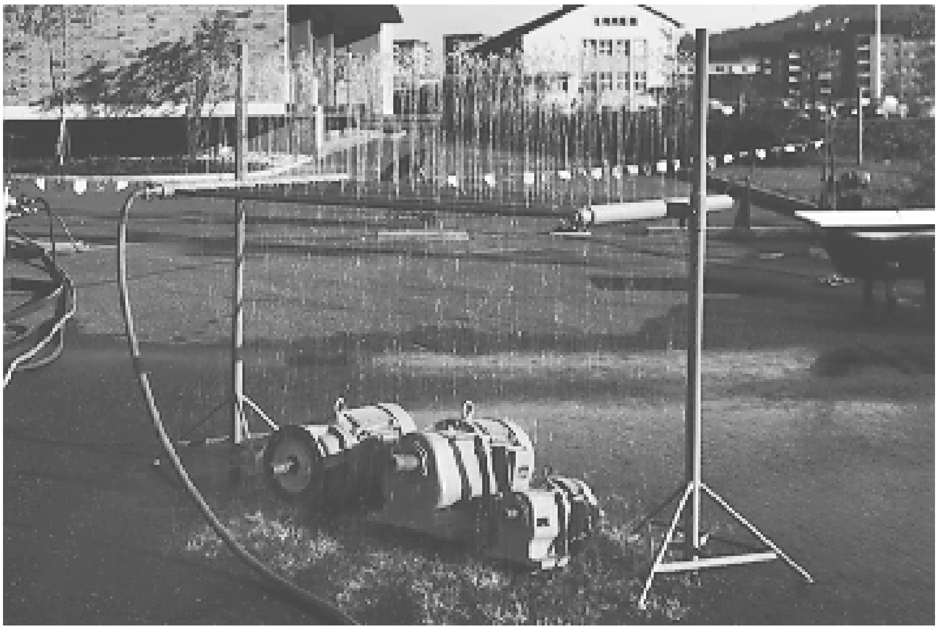
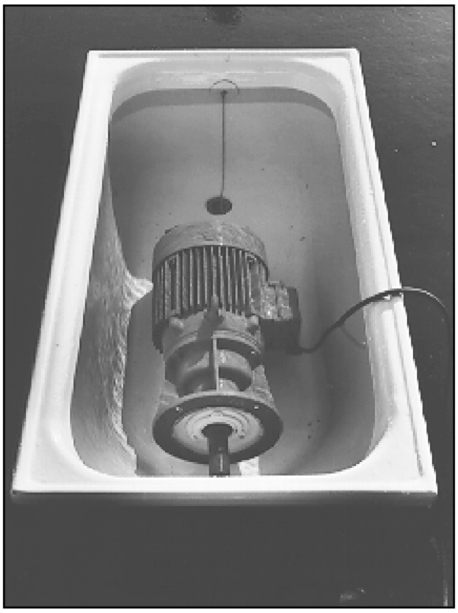


Fig. 9.3.1 Increased severity test of motors with IP66 by long-term spraying



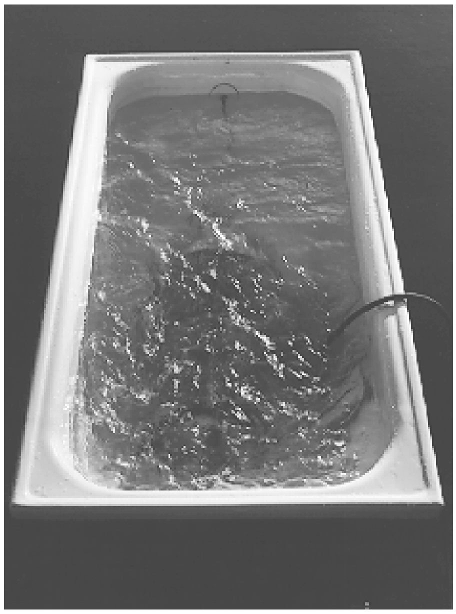


Fig. 9.3.2 Increased severity test of motors with IP66 protection by intermittent immersion

Fig. 9.3.3 to 9.3.5 Increased severity test of IP66 protected motors with a water jet from a 25 mm diameter nozzle and pressure corresponding to 8 m head

Fig. 9.3.6 Increased severity test of IP66 protected motors with a 25 mm diameter jet and pressure equivalent to an 8 m head

9.4 Applications for the special degree of protection IP66

There are a number of applications that make further measures to seal the machine necessary and achieve protection to IP66 requirements. These additional measures are recommended where the motor may be flooded for a short time (as, for example, on the deck of ship, in cellars subject to flooding), when continuously sprayed (as in cooling towers) or where frequently hosed down (as in car wash installations, breweries, mild treatment plants or transport installations for sea saltwater fish). This very high degree of protection requires a number of measures that must be carried out in the factory according to very detailed manufacturing schedules.

9.4.1 Cooling tower fans

Cooling towers are used to cool industrial water that has been heated during a production process and is returned to the circuit in order to save costs and spare the environment. Fig. 9.4.1.1 shows the basic principle.
It is not possible to avoid having a small percentage of the water carried along by the cooling air and escape upwards. Certain weather conditions will reveal a clearly visible »cloud« above the cooling tower.
This water wets the drive for the fan and constantly stresses the sealing areas.
Continuous operation under these conditions makes cooling tower drives one of the most difficult cases, and therefore presents a classic example for the degree of protection IP66.

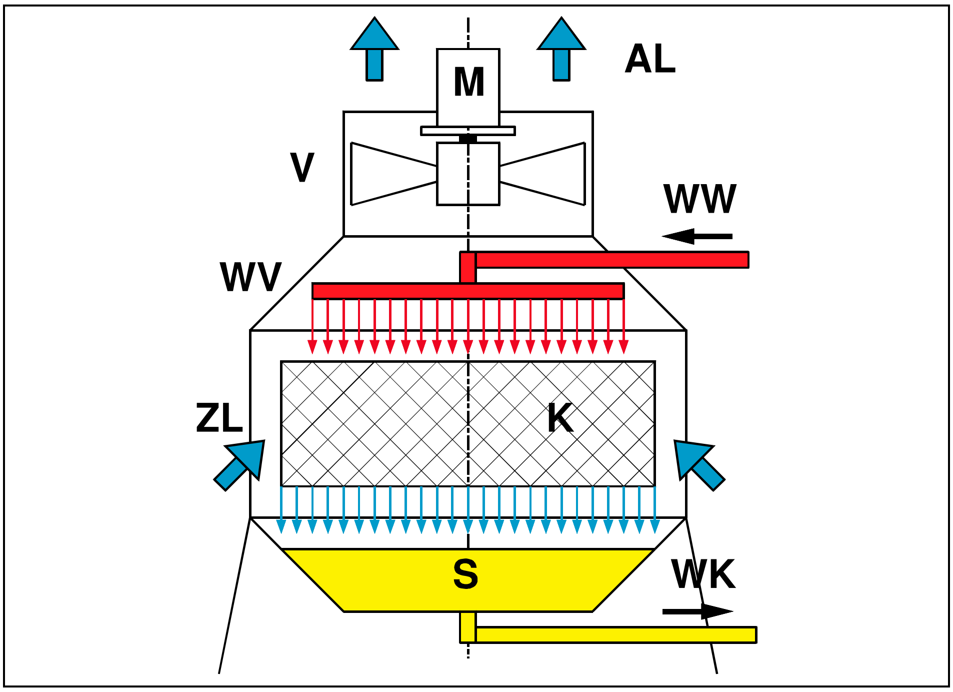


Fig. 9.4.1.1

Diagram of the function of a cooling tower

M - motor
V - fan
K - cooling components
WW - warm water
WK - cool water
ZL - inlet air
AL - exhaust air
S - collecting tank
WV - water distributor

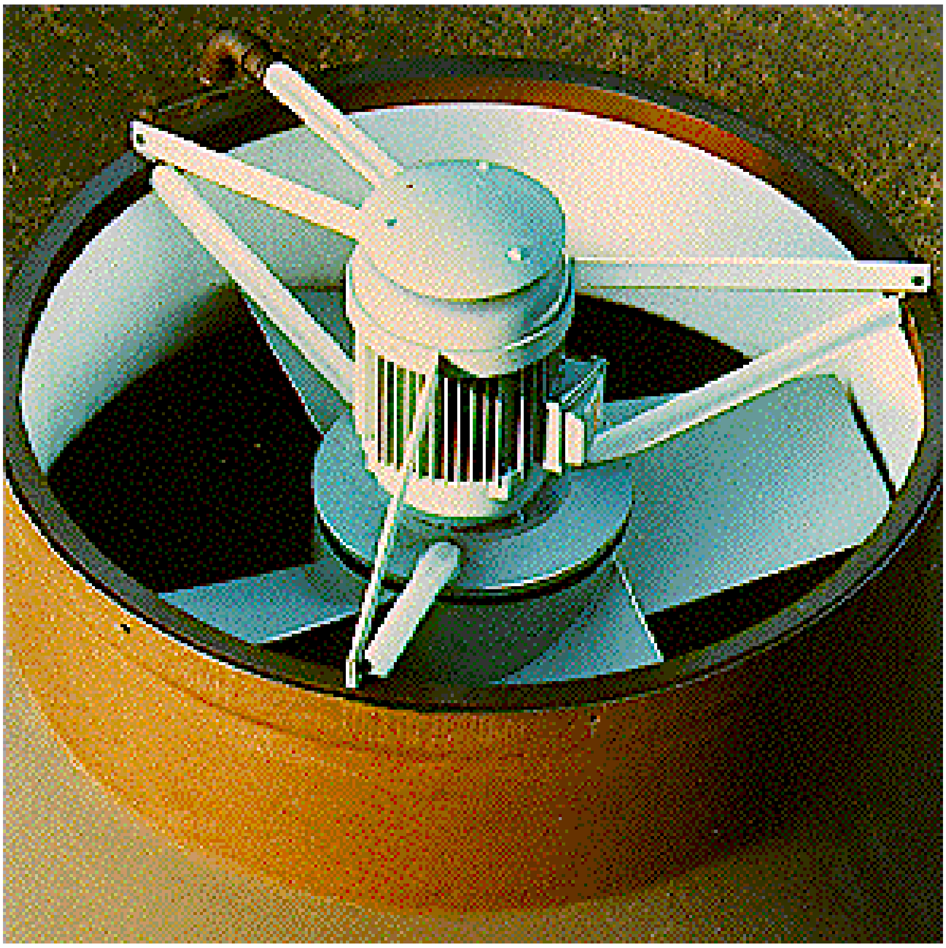


Fig. 9.4.1.2 View of a cooling tower with geared motor as the fan drive

9.4.2 Sewage treatment plants

Sewage treatment plants are often built in river plains and are consequently at risk of flooding.
Motors constructed to a special degree of protection IP66, though they provide no guarantee, have often shown a high probability of withstanding brief episodes of flooding.

Fig. 9.4.2

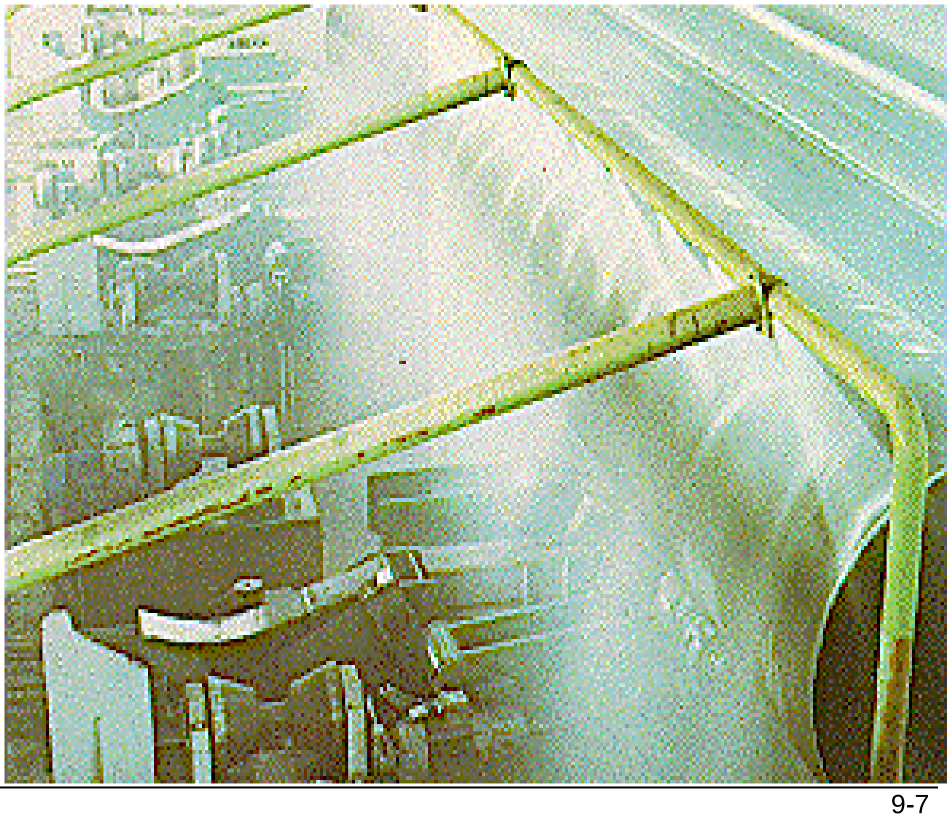
High water in a sewage treatment plant with temporary flooding of the drive motors for scraper gantries and screw conveyors

9.4.3 Steelworks

High-pressure water jets are often used for descaling large pipes and other products from steelworks.
Fig. 9.4.3 gives an indication of the conditions under which roller table motors and auxiliary drives in this area work: a case for IP66!

Fig. 9.4.3

Descaling large pipes using high-pressure water jets. Roller table motors and auxiliary drives to IP66 degree of protection

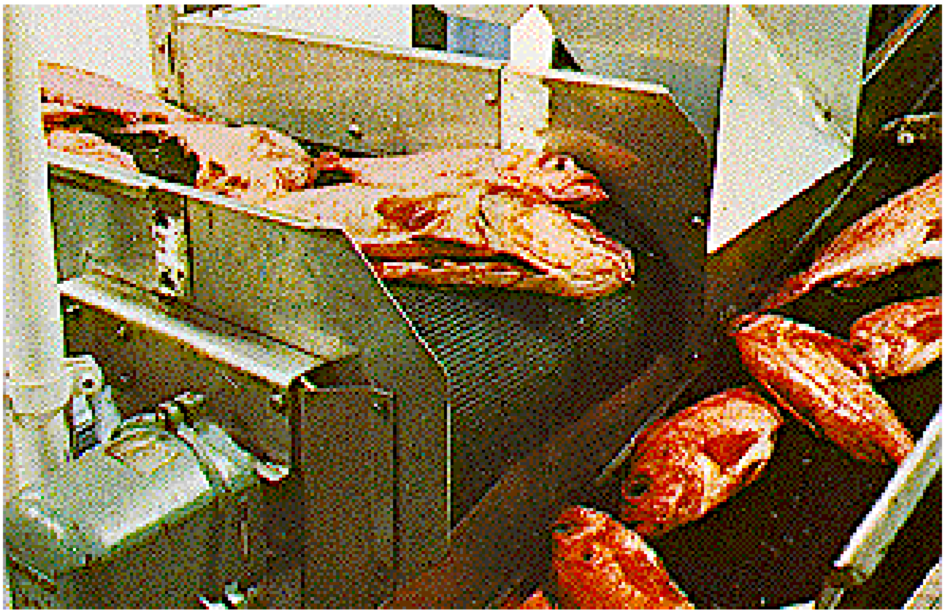


9.4.4 Fish processing plants

Equipment for processing fish – on board of fishing vessels or on land – must be cleaned regularly with powerful water jets to maintain hygienic conditions.
Gearing and drum motors to the IP66 degree of protection have been effective in these zones as well.

Fig. 9.4.4

Drum motors with special corrosion resistance IP66 in a fish processing plant



9.4.5 High-pressure cleaning and cleaning additives

High-pressure water jets (up to 10 bar) are occasionally used for applications involving the production and processing of foodstuffs (fish on deep-sea fishing vessels). Water damage is to be expected if conventional electrical machines are subjected to water jets of this type.
If chemical cleaning agents are added to the water (such as in car washes) the water is given a particularly »fine head« and can penetrate dirt and grease – even standard sealing compounds on the terminal box or the bearing flange.
EN 60529 therefore specifies the following:
"Tests for the second code number shall be carried out using fresh water. The actual protection offered may not be sufficient if cleaning processes employ high pressure and/or solvents."
Unfortunately this clarification was not included in IEC 60034-5 = EN 60034-5 (VDE 0530 Part 5).

Fig. 9.4.5

Special protective measures are recommended for electrical equipment located in the area directly affected by water in a car wash

Photo credit:
California Kleindienst Autowaschtechnik

10 Dust-proofing test

The standardized conditions of the testing method requires considerable investment. Attempts to replace the testing chamber with simpler methods (such as testing gap widths with feeler gauges or thin test wires) were unsuccessful.

10.1 Principle of the dust chamber

The dust-proofing test unit shown in Fig. 10.1.1 enables testing according to the specifications in IEC 60529.

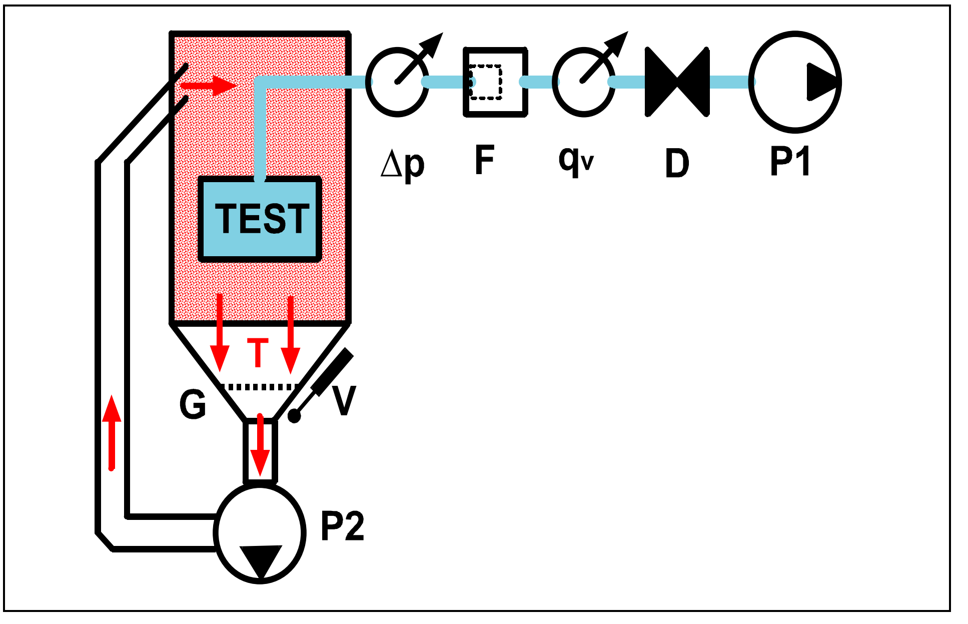


Fig. 10.1.1 Principle of testing equipment to prove dust-protection (dust chamber)

TEST	-	Test specimen
T	-	Talcum powder, max. 75 µm (2 kg/m³ of chamber)
P2	-	Dust circulation pump
V	-	Vibrator to loosen dust deposits
G	-	Guard screen
P1	-	Vacuum pump
Δp	-	Vacuum gauge (max. – 20 mbar)
F	-	Dust filter
q_v	-	Air flow meter (max. 60 $V_{test\ piece}$/h)
D	-	Throttle

Air is exhausted from the inside of the motor under test to create a vacuum equivalent to a head of – 20 mbar (vacuum), so that the dust-laden air in the test chamber is drawn through all its fissures. All joints should be tight enough to prevent the ingress of the fine talcum powder. The flake size (0.025 to 0.075 mm) and the consistency of the talcum powder is important. If the powder is too fine it will stick and seal the machine; too large a flake size will impede circulation. Heating arrangements in the test equipment enable the powder to dry and remain suspended, since prolonged storage allows it to absorb moisture.
The exhausting of air from the machine under test is intended to simulate the fluctuations in pressure that take place within an enclosed motor as it heats and cools (measurable at approx. 10 mbar).
Every time the motor heats up the air within the housing expands and is expelled – when the motor cools again the volume of air in the housing is reduced and dust-laden air is drawn into the machine, which is therefore said to "breathe". An experiment with »natural vacuum« has confirmed the considerable deposition of dust. If it is assumed that the air in the motor housing rises by 40 K (Kelvin) at rated load, then according to Charles's law the increase of volume is about 15 percent.

If there are two temperature changes per day and there are 300 working days in the year, the quantity of air passing through it can be calculated to be equivalent to 90 times the volume of air contained in the motor housing. The pressure reduction should, for the test, be adjusted so that every two hours at least 120 times the volume of air contained must pass through it. This forced throughput of air thus corresponds to normal “free breathing” during one year in operation. Whereas for a motor with an enclosure as defined by IP44 the prescribed quantity of air can be drawn through the motor with reduced pressure in the minimum time of two hours, a more thoroughly sealed motor according to IP65 will require the standard maximum test time of eight hours, even at maximum vacuum.

Fig. 10.1.2 Dust-protection testing unit according to IEC 60529, with air vacuumed from the motor. The circulation pump was not in operation for the photograph

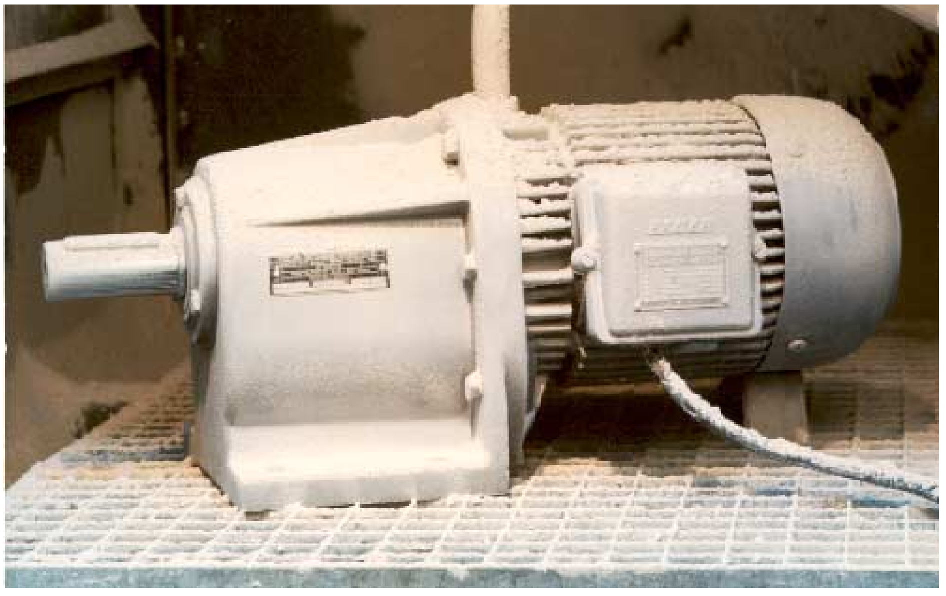


Fig. 10.1.3 Three-phase geared motor during dust-protection test

10.2 Results of the dust-proofing test

In order to meet the stringent conditions of IP6X, considerable investments in design and manufacture are necessary. On the terminal box a well-tried method of sealing consists of a cork-rubber gasket and wide, clean finished mating surface. In practice this sealing will only be effective if, after installation, the method of sealing provided by the manufacturer remains complete and undamaged. Any unused cable inlets must be sealed with the blanking off plugs provided. Where the shaft emerges from the motor a synthetic rubber or oil-soaked felt sealing ring is better than a simple greased metal-to-metal face. Figures 10.2.1 to 10.2.3 show standard production geared motor units with enclosures providing IP65 protection after dust-proofing tests. They show that that by taking suitable measures it is possible to ensure dust-tightness.

Fig. 10.2.1 Three-phase geared motor after a standard dust test.
Terminal box sealed with greased cord. Result: no dust ingress.

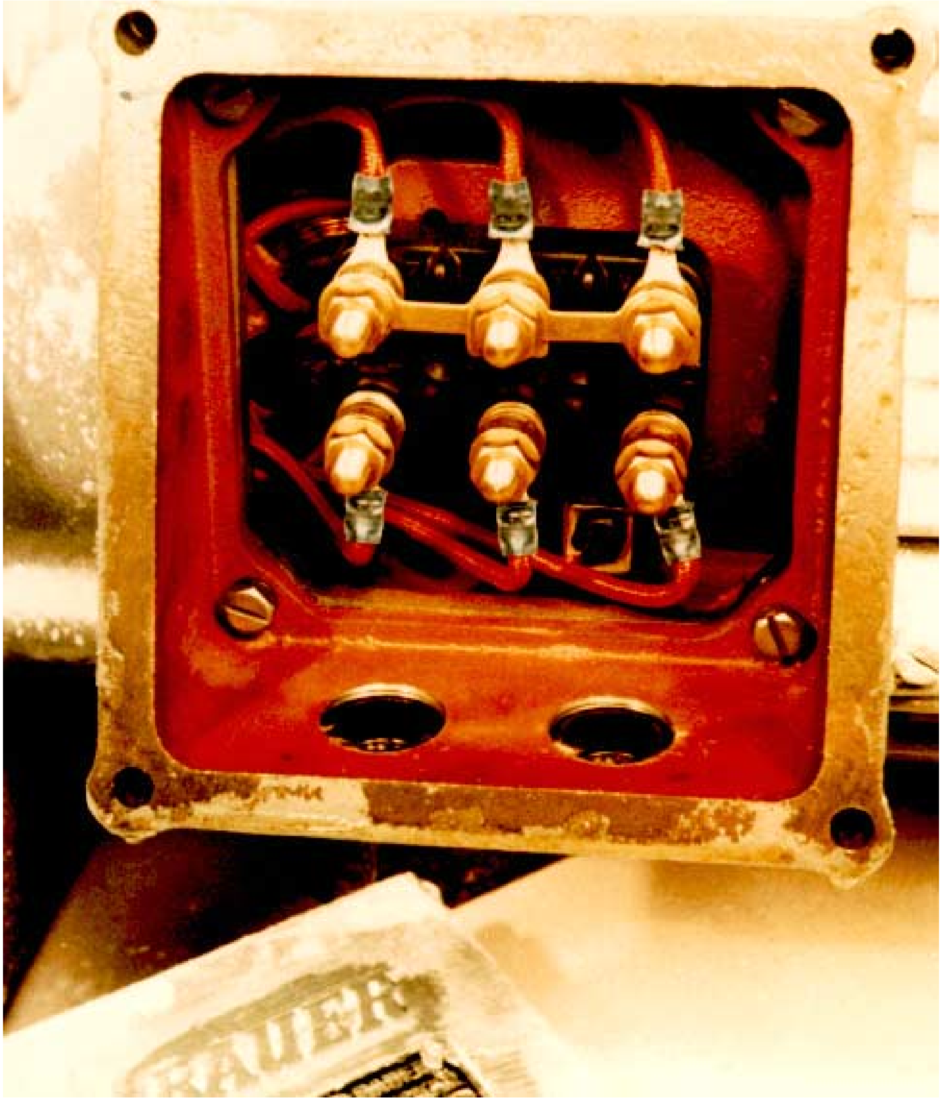


Fig. 10.2.2 Terminal box of geared motor unit with IP65 protection with mating surfaces. No dust ingress after test.

Fig. 10.2.3 Stator of geared motor after standard dust test. Motor interior is completely free of dust.

11 Variation of testing conditions in dust-proofing tests

In order to determine the influence of the width of the gaps and grain size of the powder two series of tests were carried out with some modified standard test conditions. The following illustrated account of these test leads to some interesting conclusions for actual practice.

11.1 Influence of gap width

In a simplified test arrangement as shown in Fig. 11.1.1 a stator housing was hermetically sealed at each end by special bearing caps so that the test was confined to the terminal box. Starting with the standard production version with rubber and cork seal, which – as shown in Fig. 11.1.2 – was satisfactory after the standard test time, a definite gap was set by means of feeler gauges between the metal surfaces of the terminal box and the cover, as shown in Fig. 11.1.3. Fig. 11.1.4 to 11.1.7 show the results with gap widths of 0.05, 0.1, 0.5 and 1 mm, and demonstrate that the penetration of dust is independent of gap width and is unacceptable. This is understandable since dependent on the particular specification the quantity of air (= dust throughput) is kept constant.
This set of tests shows that even the smallest gap of 50 µm is already too large to be considered for dust tightness.

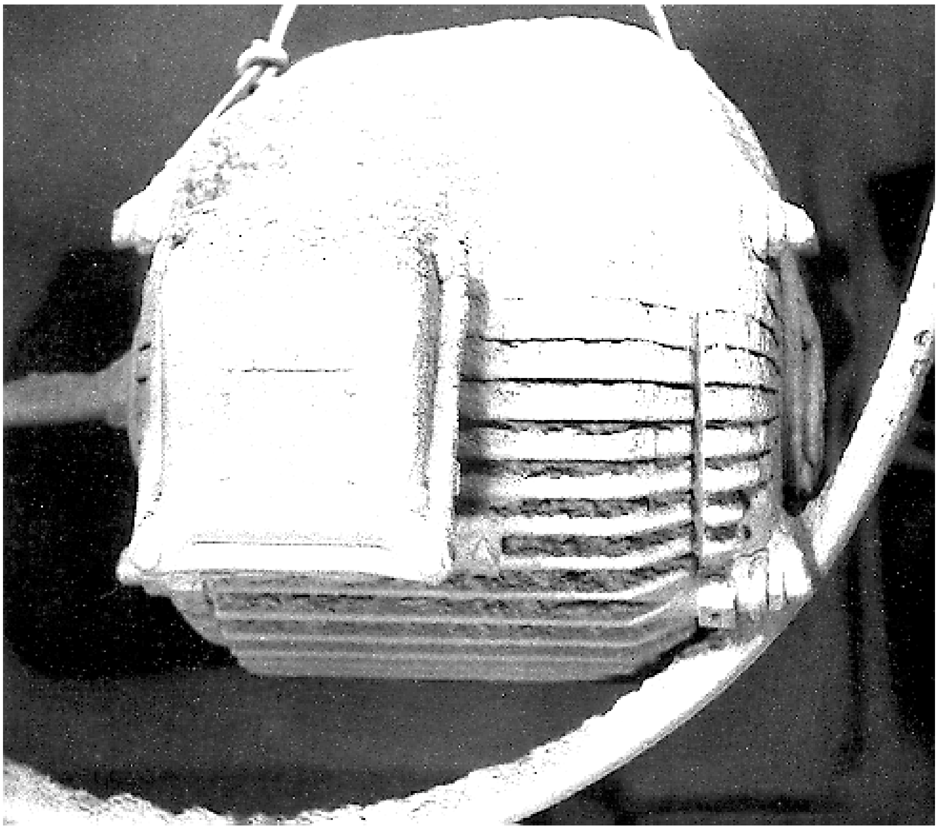


Fig. 11.1.1 Simplified test arrangement for the testing of terminal housings with different gap widths

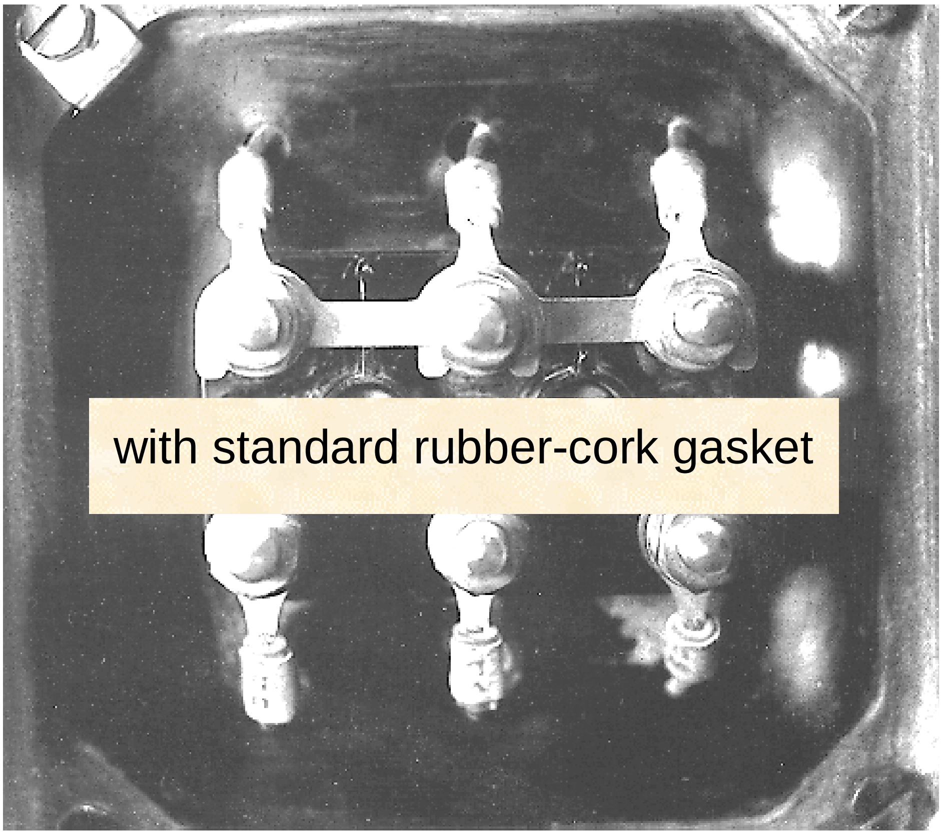


Fig. 11.1.2 Test result with standard rubber-cork gasket without gap

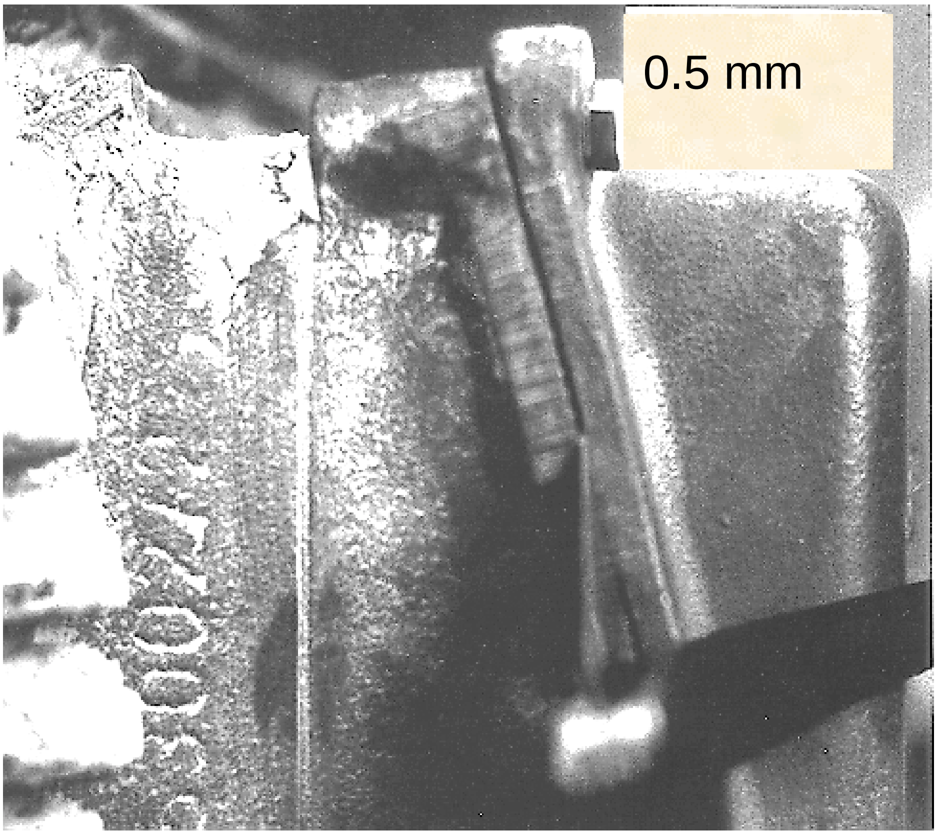


Fig. 11.1.3 Adjustment of gap width (e.g. 0.5 mm) between the blank metal surfaces of the terminal housing and cover.

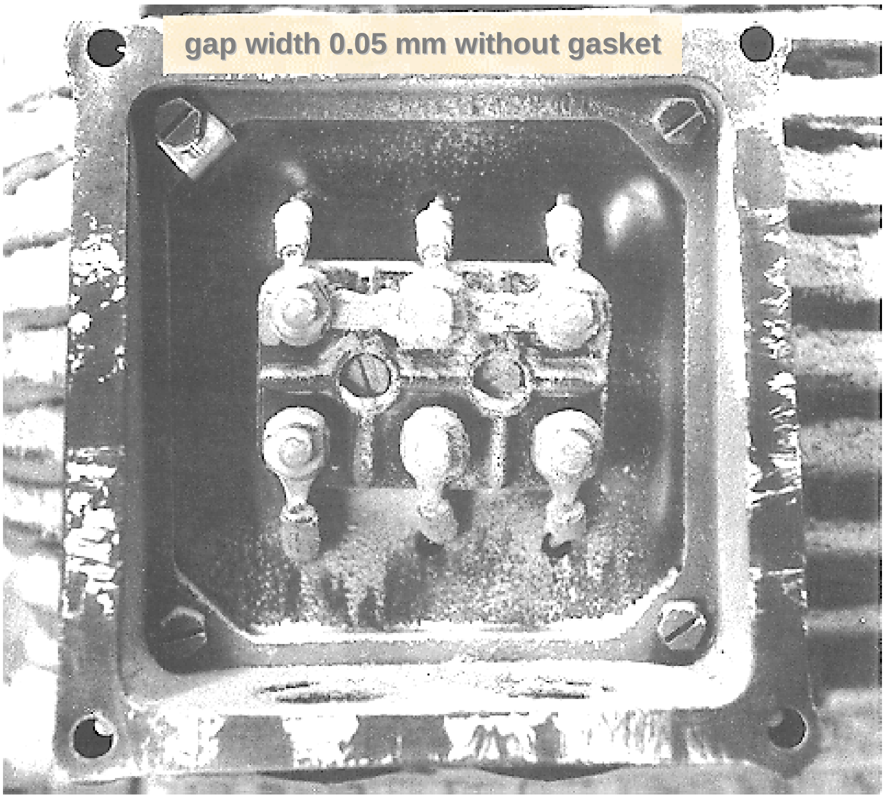


Fig. 11.1.4 Test results with a gap width of 0.05 mm
Testing time: approx. 200 minutes

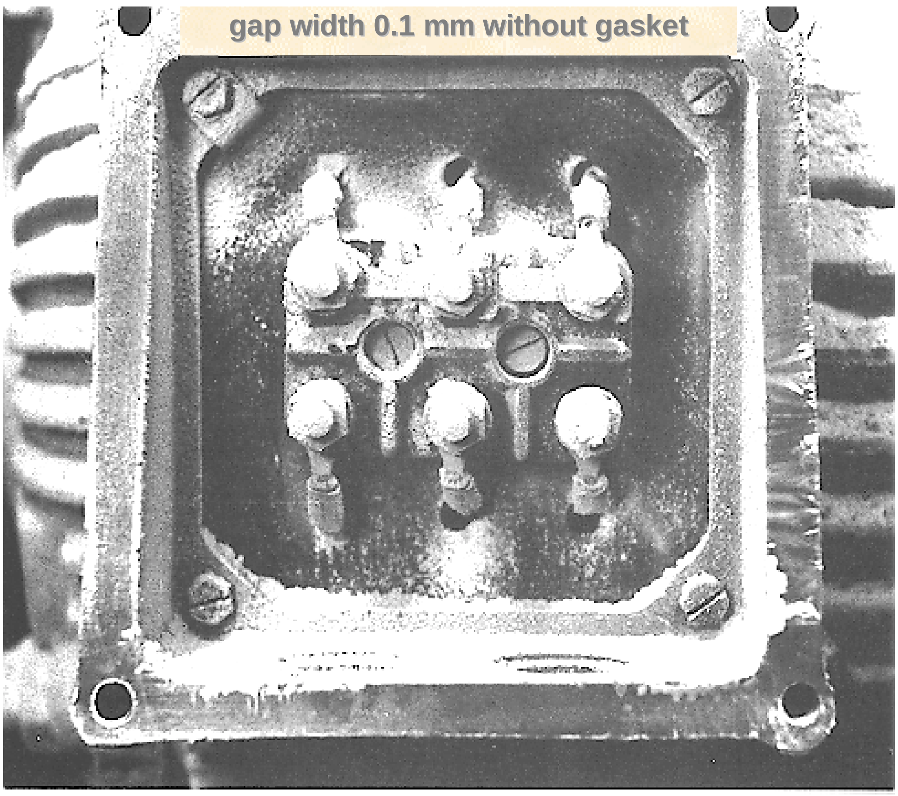


Fig. 11.1.5 Test result with a gap width of 0.1 mm
Testing time: approx. 20 minutes

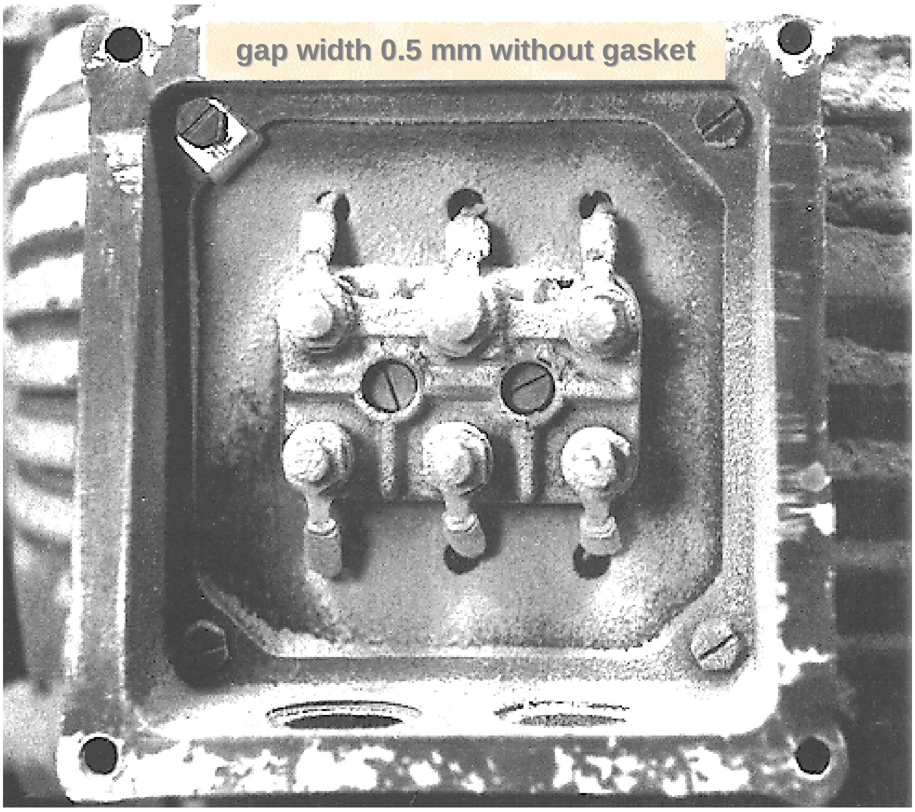


Fig. 11.1.6 Test result with a gap width of 0.5 mm
Testing time: approx. 10 minutes

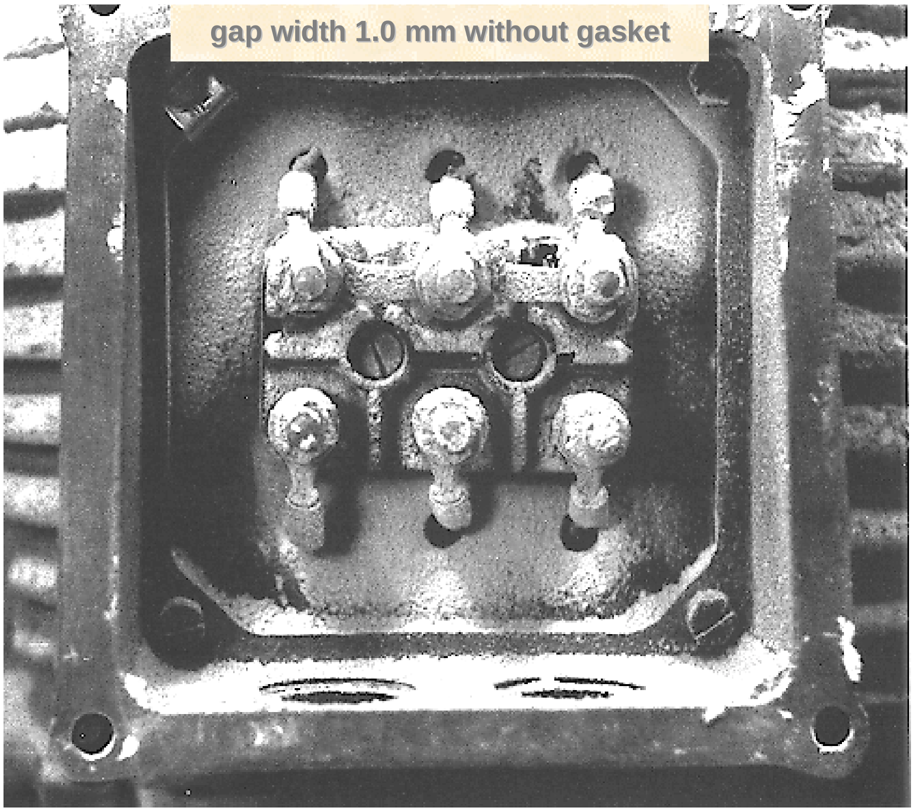


Fig. 11.1.7 Test results with a gap width of 1 mm
Testing time: approx. 10 minutes

11.2 Influence of grain size

An additional test series was conducted to investigate whether the use of especially fine powder with a grain size of 0.010 mm makes for more difficult conditions during testing and in practice.
Fig. 11.2.1 shows the method of setting up the gap of 0.05 mm on the terminal box.
When normal talcum powder with a flake size of between 0.025 and 0.075 mm was used, a relatively large deposit appeared on the terminal board as shown in the close-up photograph in Fig. 11.2.2.

Test results with extra fine powder (flake size about 0.010 mm) are shown in Fig. 11.2.3. The powdery dust obviously under the influence of electrostatic forces tends to stick and seal close gaps by itself. The standard particle size of 0.025 to 0.075 mm therefore provides realistic test conditions.

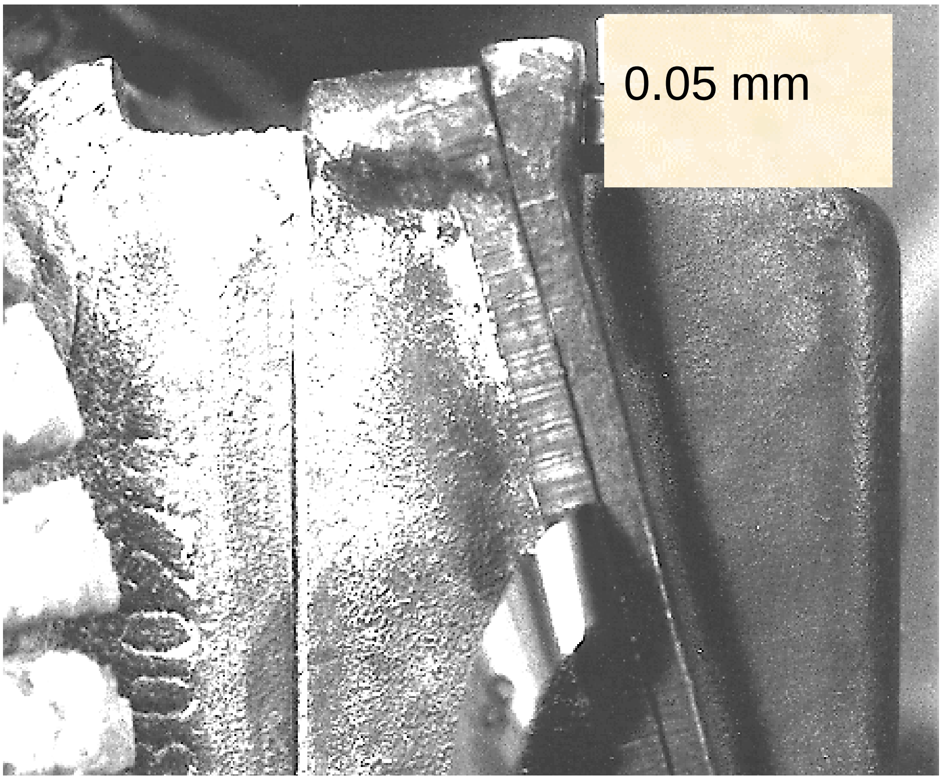


Fig. 11.2.1 Adjustment of the gap width of 0.05 mm for testing with different grain sizes.

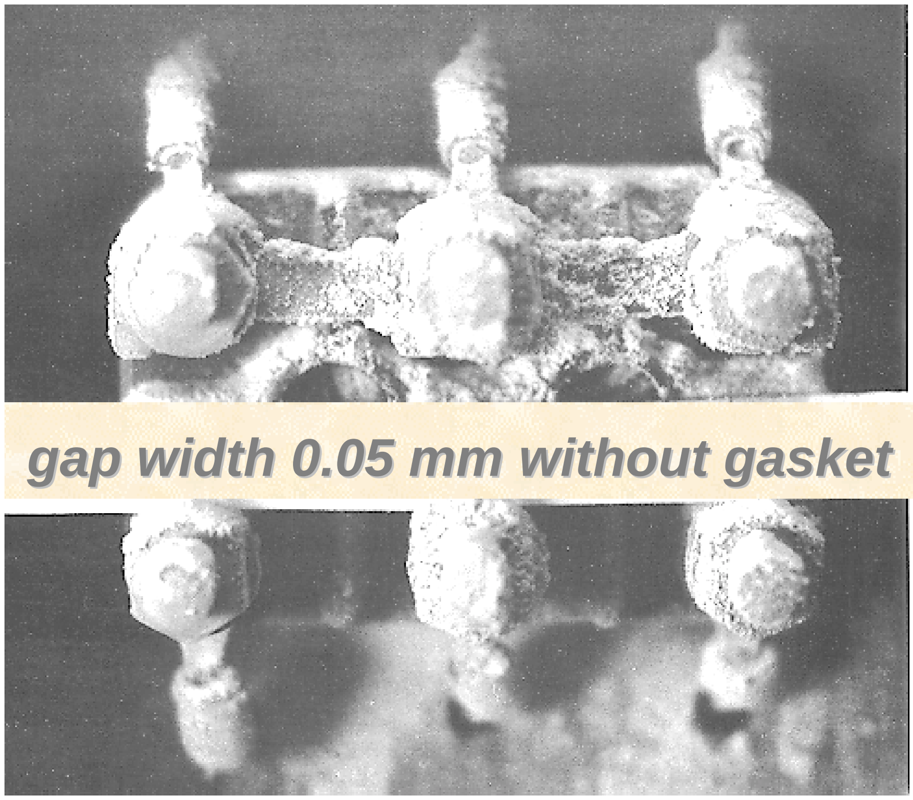


Fig. 11.2.2 Test result with normal talcum powder (grain size: 0.025 to 0.075 mm).

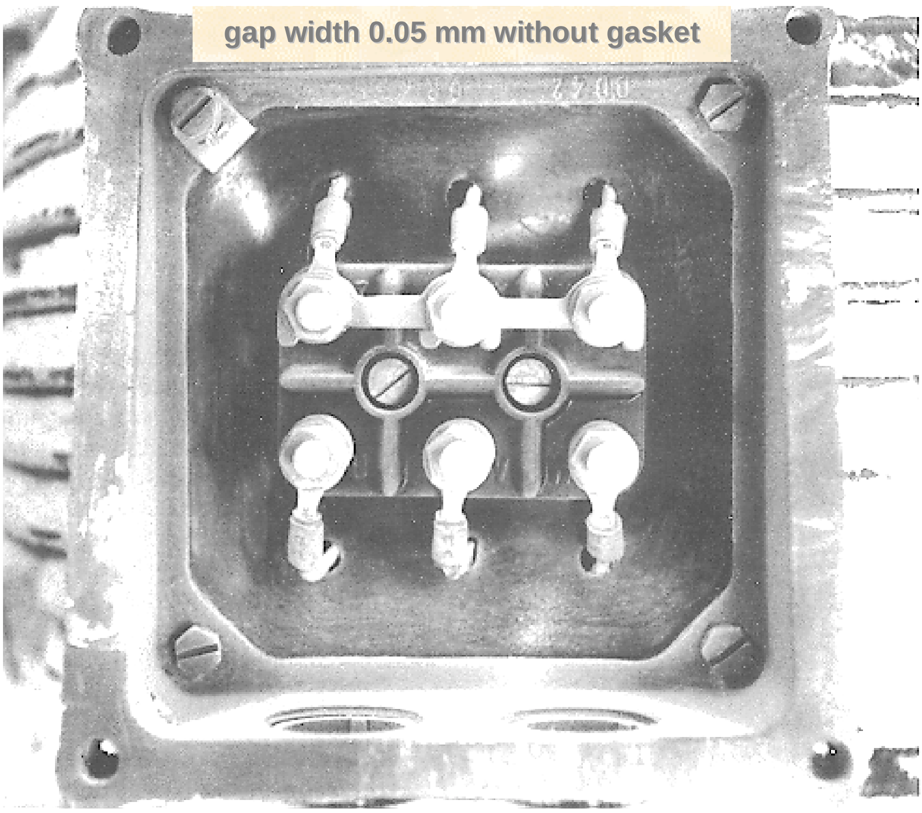


Fig. 11.2.3 Test result with very fine powder (grain size: approx. 0.010 mm).

12 Protection against access

»Protection against access to hazardous parts« is an important aspect of occupational safety. This protection is described by the »IP Code« for electrical apparatus, covering all types of electrical equipment from electrical sockets to motors, clothes irons and lamps.
Based on the proven IP degrees of protection according to DIN 40050 and »downward compatible« to the same, an extended »IP Code« has been introduced by standards International IEC 60529 and European EN 60529 .

It is significant that the original standard DIN VDE 50 [11] (see Section 24) was created only for electrical machines, that this electrical apparatus has an important placement in the standard, and that specialists in the electrical machines industry have consistently played an essential role in the evolution of this safety standard:
In today's power engineering sector electric motors have been integrated in machinery to be easily accessible for operating personnel and must therefore be well protected against access to hazardous parts.
»Hazardous« parts are the ***rotating parts*** as well as the electrical connections subject to voltage.

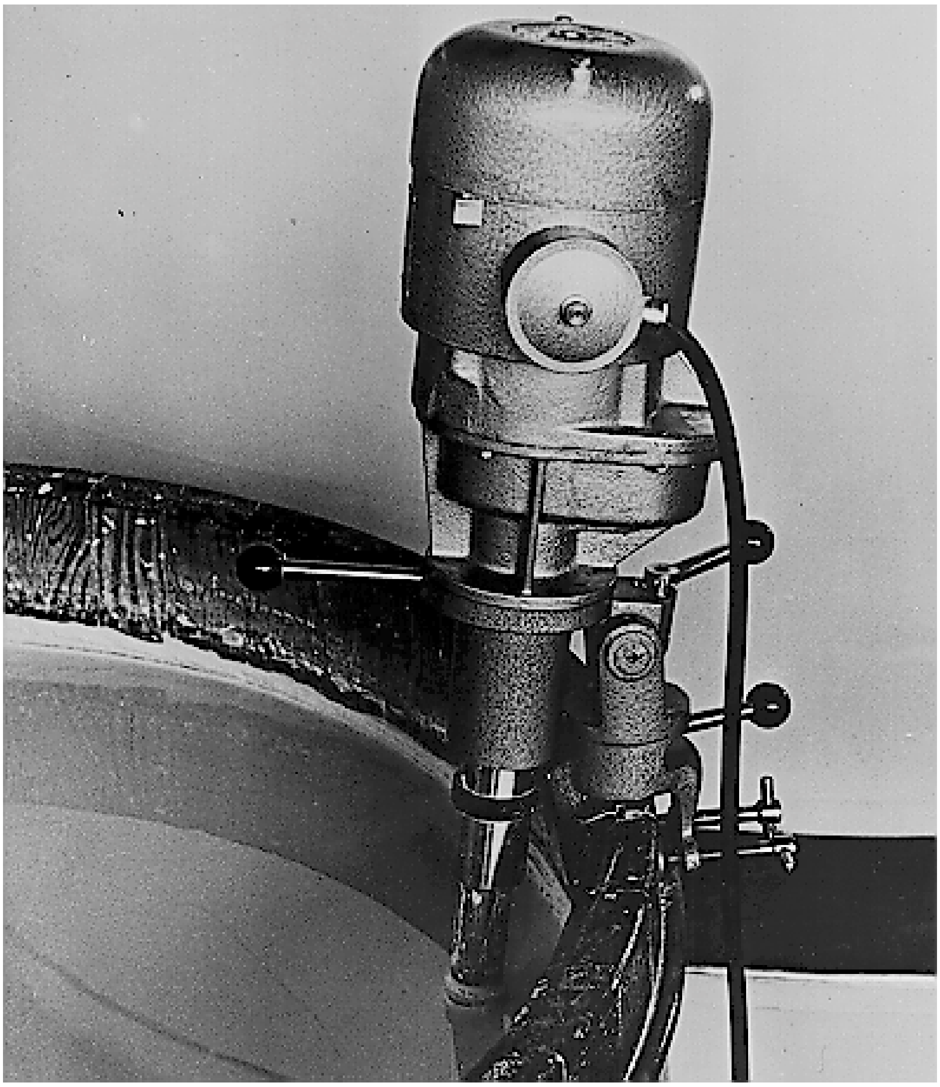


Fig. 12 Geared motor for driving a »clamp-on agitator« with direct access for operating personnel

12.1 Terminology

This standard applies to machines with a rated voltage of up to 72.5 kV. This has made it necessary to include »approach to live parts« in the examination.
The well-known term »direct access« in the standards for installing low-voltage systems has had to be replaced by a limited system of new definitions within the scope of the IP degrees of protection:

12.1.1 Hazardous parts

Parts that are dangerous to approach or touch.

Hazardous live parts

Live parts that under certain external influences can induce an electric shock (see supplement to IEC 60536).

Hazardous mechanical parts

Moving parts, with the exception of smooth rotating shafts, that are dangerous to touch.

12.1.2 Protection by an enclosure against access to hazardous parts

Persons are to be protected against:

- access to hazardous live parts (low-voltage)
- access to hazardous mechanical parts
- approach within sufficient clearance to hazardous high-voltage live parts inside an enclosure.

Note: This degree of protection can be achieved
- by means of the enclosure itself
- by means of covers as a part of the enclosure or clearances within the enclosure.

12.1.3 Sufficient clearance as protection against access to hazardous parts

A distance determined to prevent access or approach to a hazardous part.

12.1.4 Access probe

A test probe that in a defined manner simulates a body part, or a tool or other object held by a person, in order to determine sufficient clearance from hazardous parts.

The clause »... in a defined manner ... « is intended to express that this is a ***convention*** that cannot cover every conceivable case that may occur in actual practice (finger length, tool dimensions).

12.2 Theory and practical application

A great deal of time has been spent in the national and international standards committees on the question of whether the standardized »access probes« are truly representative for actual practice.
This can of course not be stated with »absolute certainty«:

- ☐ Many people have fingers that are longer than the »standardized« 80 mm.
- ☐ Many screwdrivers are longer than the »standardized« 100 mm and thinner than 2.5 mm.
- ☐ Many wires are longer than the »standardized« 100 mm and thinner than 1 mm.

The lengthy discussions on the tolerance of the conical part – the »fingertip« of the testing finger, and the effect of this tolerancing on the penetration depth and the test result – also appear to be of theoretical interest at the most, and are of less interest in the practical sphere.
The effectiveness of the testing equipment whose basic design has been a part of the German VDE specifications, in conjunction with many other additional measures for protection against access, is demonstrated by the overall downward trend of electrical accidents.

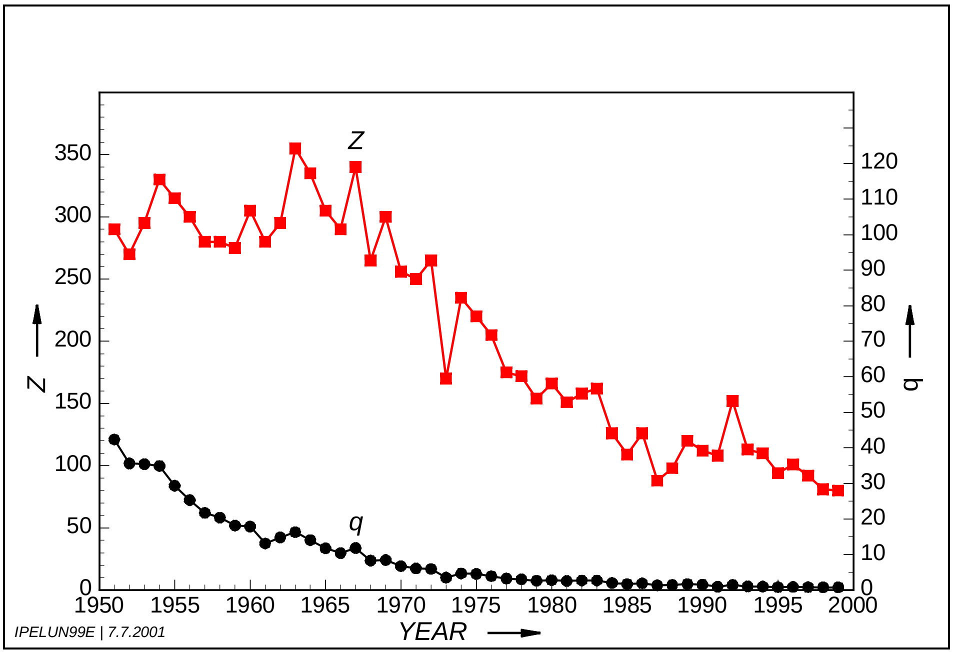


Fig. 12.2.1 Fatal electrical accidents in Germany 1950 - 1999 according to DKE information (B. Schröder; "Harmonisierung kontra Sicherheit?")
Z – number of accidents
q – relative death rate based on the number of inhabitants and electrical energy consumption

It is important that the electrical machines continue to be built and tested according to minimum requirements for access protection and that the requirements for the testing equipment are designed to be simple and easy to use. The number of joints in the »jointed test finger« and the tolerances on the »fingertip« are examples for this fundamental and theoretical discussion. Fig. 12.2.2 shows the problem concerning a conical test probe whose penetration depth »*b*« becomes increasingly dependent on the tolerance of the diameters »d« and »*D*« as the width/diameter of the cone decreases. In the practical example of the test finger according to Fig. 3.3.1 the penetration depth tolerance can fluctuate by around Δb = 1 mm.

Fig. 12.2.3 should make these relationships clear.
Instead of limiting the tolerance, as some circles have demanded, designers of enclosures should be made aware of the fact that an adequate safety clearance from the minimum requirements of this standard must be observed. Annex A of DIN EN 61032 (VDE 0470 Part 2) : 1998 [7] therefore states:

"Test probes are a proven and established means of determining the protection of electrical machines with regard to access to hazardous parts.

Small limiting deviations are desirable in view of the compatibility and reproducibility of the test results. Large limiting deviations, however, are necessary in view of the economical manufacture of the probes and wear owing to their frequent use.

It is important that both the designers of electrical machines with hazardous parts and the users of test probes are aware of these facts and of the natural limitations in the use of the test probes.

In principle the relevant dimensions of electrical equipment (such as openings or clearances) should be designed to ensure that a wide safety margin is provided between the hazardous parts and the test probe, with the largest limiting deviations applying to the probe."

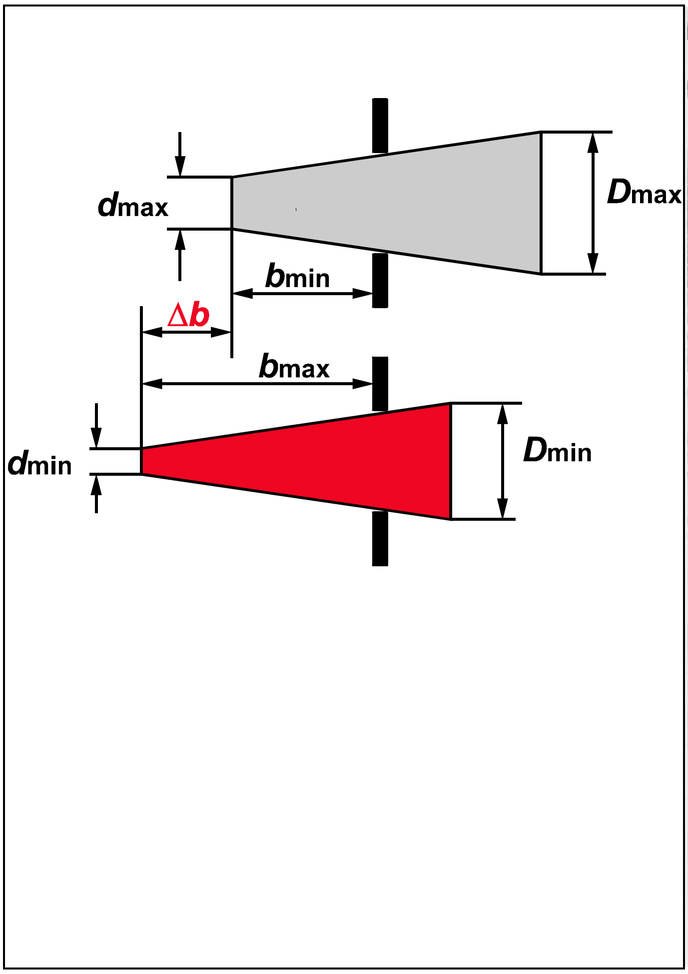


Fig. 12.2.2
Relationship of the penetration depth »*b*« on the tolerance of the diameter of a conical test probe

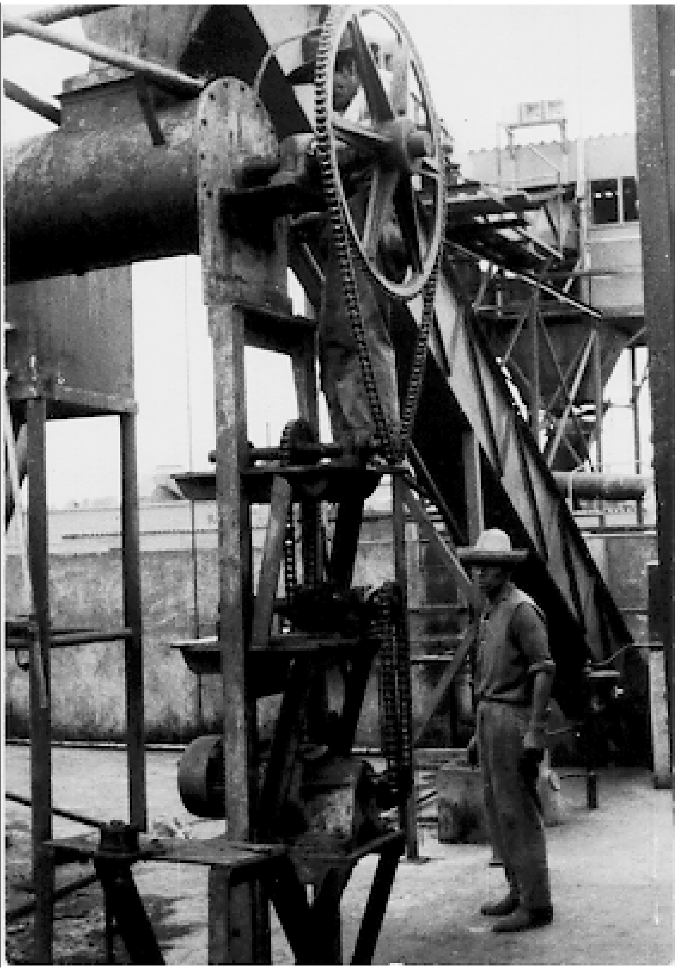


Fig. 12.2.3
Exposed chain transmission on a geared motor in a fish meal factory in Peru

12.3 Protection against access by child fingers

The principle that only ***»instructed persons«*** work with ***industrial*** machinery, such as electric motors, currently applies. Protection against access is therefore based on an adult's finger (see Table 3.3.1).
Ventilation openings on an electric motor may, therefore, be slots or round/square holes up to a width of 12 mm. As an opening width of only 8 x 8 mm was previously permissible for explosion-proof motors, most were designed uniformly with a mesh size of 8 mm (see Fig. 4.2).

Motors with these types of fan cowls are increasingly to be found in »lay applications« such as drive for high-pressure jets, hedge trimmers and concrete mixers.
Fig. 12.3.1 shows that protection against ***intentional contact by children*** is not guaranteed by the standardized safety distances devised on the basis of an adult finger.

- »IEC 60529« line:
  Penetration depth of the test finger according to EN 60529.
- »EN 294, Tab. 5« lines;
  Safety clearances specified in the new European standard EN 294 behind slot widths »e« for persons 3 years old and older [9].
- »UL« line:
  Penetration depths that were determined by »Underwriters Laboratories« during tests with 100 children between the ages of 3 and 10 (upper limit).

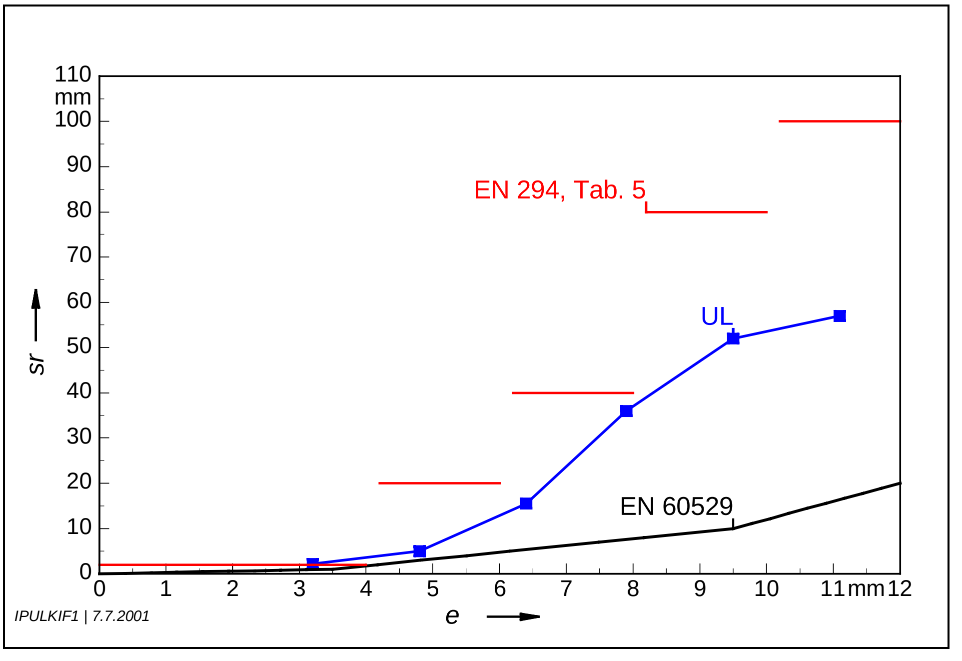


Fig. 12.3.1 Comparison of safety clearances and penetration depths

EN 60529	Test finger for IP2X or IPXXB
EN 294	European standard [9]
UL	Test of the Underwriters Laboratories with children between the ages of 3 - 10 years (max. required clearance)

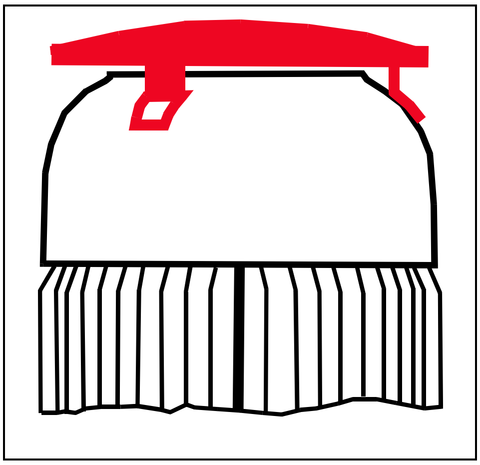
e - slot width
sr - penetration depth

Reference had been made in subclause 4.3 of the standard on the degree of protection of electrical machines (EN 60034-5 : 1986) to the external fan cowl in terms of the hazard posed to children:
"In certain applications, such as agricultural or domestic appliances, more extensive precautions against accidental or deliberate contact may be required."

Fig. 12.3.2 shows how »more extensive precautions« may appear.

Fig. 12.3.2

Additional guard for increased protection against access to the fan cowl of a surface-ventilated closed electric motor



At the instigation of the ACOS (Advisory Committee on Safety) work is currently underway in the international standards committee TC 70 to determine the dimensions of a standardized child's test finger. Following appropriate expansion of the standards governing the affected electrical machines this will then be used to test the degree of protection offered against access by children.

Summary
The manufacturer must be informed of increased requirements on the degree of protection against access to the external fan of an electric motor that go beyond standardized »finger safety«.
The responsibility to provide protection against access to the free shaft and transmission components fitted to it (couplings, belt pulleys, chain wheels) rests solely with the designer or installer of the machinery. This also applies where a »second shaft extension« is fitted to the fan side of the motor.

13 Condensation

Condensation is often cited as the cause of damage to winding resulting from water or humidity.
It is worth analyzing the processes critically to gain an objective insight into the causes.

13.1 Physical process

The processes that cause the formation of condensation are best explained using the simplified »Humidity status graph« in accordance with DIN IEC 60721-2-1.

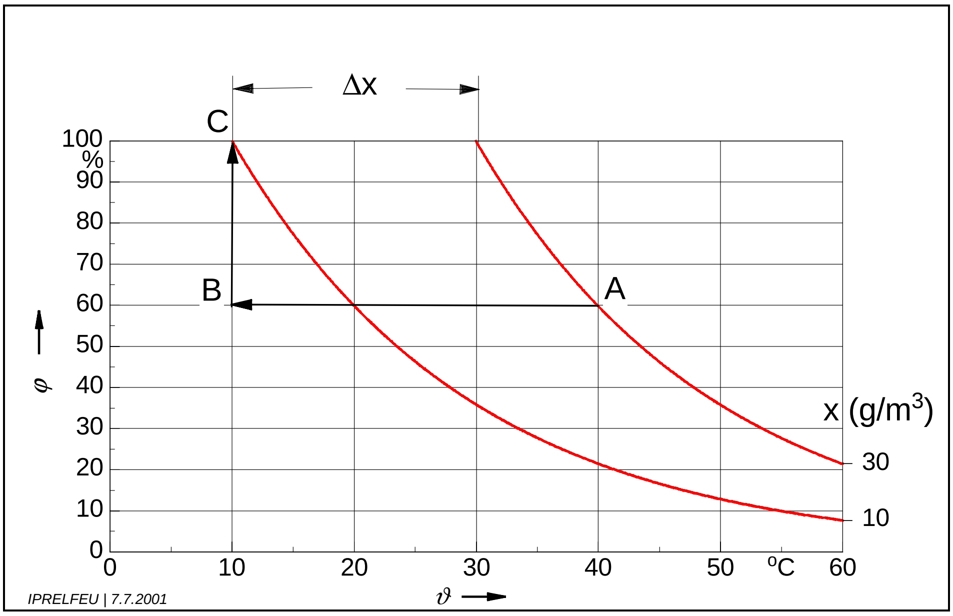


Fig. 13.1 Simplified humidity status graph in accordance with IEC 60721-2-1

x	-	Absolute humidity (water vapor content)
φ	-	Relative humidity
ϑ	-	Temperature

The curves on the graph (reduced to two for clarity) show the stable condition of humid air. An ***»absolute humidity x«*** of 30 g/m³, for example, may be present as vapor in air at 60 °C. The air holds little water in this state; the ***»relative humidity φ«*** (as a proportion of maximum saturation) is approximately 20%.
The 100% saturation point is only reached at a temperature of 30 °C. The total volume of water can no longer be held in the air at lower temperature so a portion of the vapor condenses out as ***»condensation«*** (dew).
Let air with an absolute humidity of x = 30 g/m³ and a temperature of 40 °C be present in a closed enclosure that is not airtight (point »A« in the diagram). The relative humidity is φ = 60%. If the container and its contents are suddenly cooled to 10 °C (point »B«), the air will only be able to hold a humidity of 10 g/m³ at point »C« (φ = 100 %). The »saturation deficit« Δx = 30 - 10 = 20 g/m³ is released in the form of condensation and precipitates mainly on the cold surfaces of the enclosure (inner walls).

13.2 Quantity of condensate

Absolute humidity fluctuates in nature. In other words, the weight of water (g) per volume of air (m³) varies between approximately 5 g/m³ (in northern Europe) and 30 g/m³ (at the equator). These figures indicate that the amount of condensation is never very high, even in extreme cases. The diagram provides guide values for the free volume of air (*V*) in motors with a shaft height range *AH* of 71 to 200 mm and the maximum water content of 600 mg (0.6 g) for an overall size of 200. Only a fraction of this water can form condensation.

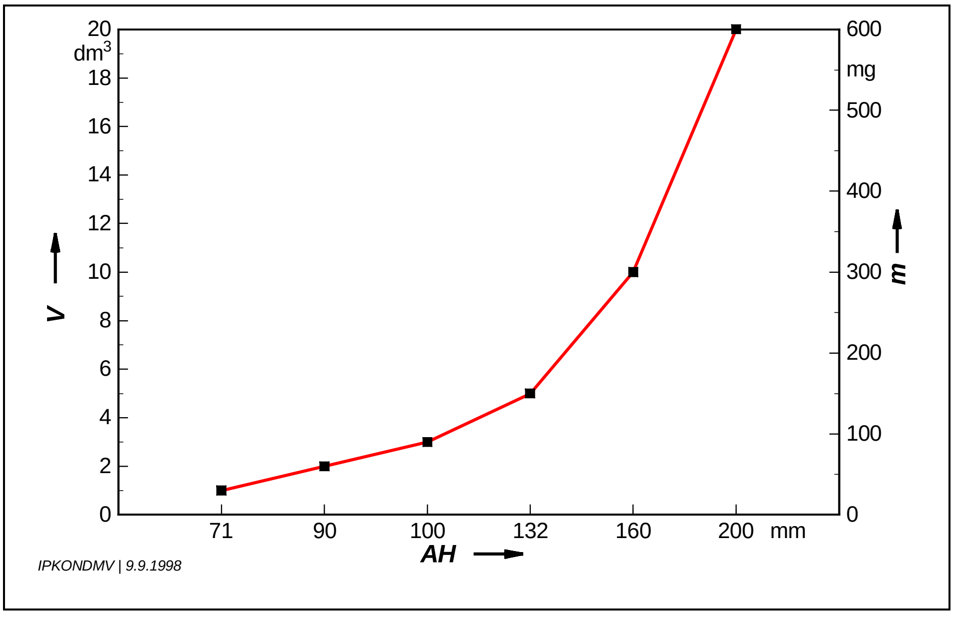


Fig. 13.2 Guide values for the free volume of air (*V*) and the maximum water content (*m*) in motors with shaft heights (*AH*) 71 to 200 mm

Even under repeated heating and cooling it is physically impossible for condensation to form in such quantities that the winding components are »under water«.

As a consequence, this also means that condensate drain holes are superfluous.

13.3 Size and location of condensate drain holes

Motor manufacturers have given great consideration to the correct location of condensate drain holes in the past. The relevant instructions in their operating instructions speak volumes.

- ☐ The condensate drain hole should be small enough to prevent penetration of dust and external water: maximum 8 mm in accordance with DIN 40050; as previously applicable, Sample Sheet 1 dated 1963.
- ☐ It must be large enough to prevent blockage caused by rust and dirt: at least 4 to 6 mm.
- ☐ It should be located at the lowest point: no simple requirement for different installation and, above all, for vertical configurations. The notion that water will seep from the upper winding chamber through the slots and the air gap to the lower end winding, where it will drain without causing damage, is just as incomprehensible as the effect of a hole in the top end of the laminated core (Fig. 13.3).
- ☐ Seal plugs were introduced because open condensate drain holes clearly cause more damage than they prevent. These ranged from grub screws (which rusted solid), plastic bungs (which are so inaccessible that they can never be opened) to valves which are supposed to operate yet another electrical lockout device for the motor (German patent).
- ☐ Flameproof configurations were required for »flameproof enclosure« type explosion protection.

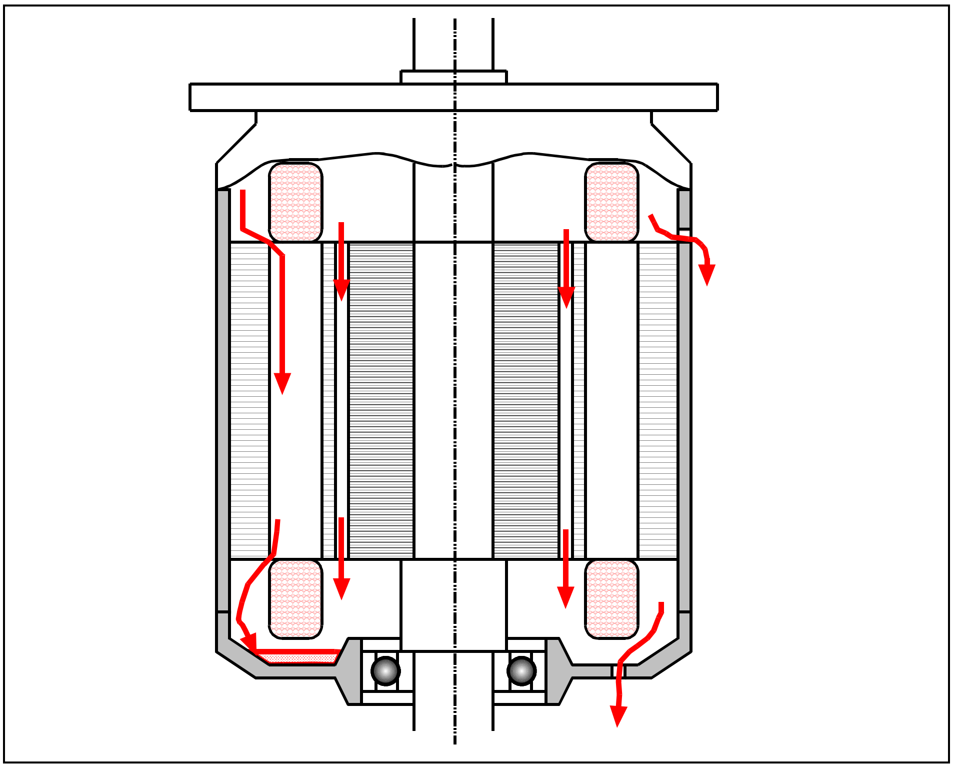


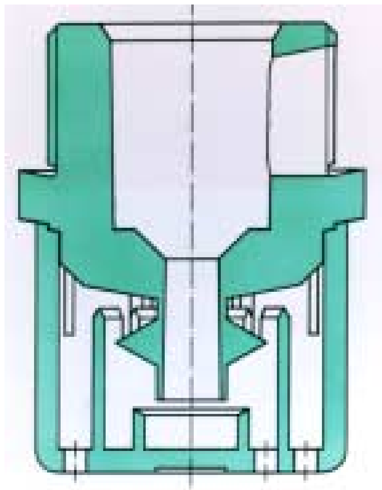
Fig. 13.3 Schematic diagram of a machine in V3 configuration with theoretical paths (through the drain holes provided) and actual paths through the slots and air gap

13.4 Protection against condensation

The problems debated so hotly in the past were discussed in such detail in the previous section in order to throw greater light on the position held today.

- ☐ Condensation can ***never be eliminated entirely***.
- ☐ Initially the condensation forms a film of moisture on all parts – including the winding – and only in extreme cases does it collect in such quantities that it can be drained off.
  Moisture-resistant, ***non-hygroscopic insulating materials*** and paints are more important than drain holes.
- ☐ ***Adequate distances*** must be provided, especially in areas where water may collect.
- ☐ ***Stator standstill heating is advisable*** in extreme cases to prevent sudden and excessive temperature differences. Special heater coils are fitted to medium and small motors for this purpose. The stator winding on smaller machines is usually supplied with single-phase current at approximately 20% of the rated voltage.
- ☐ An »air-conditioning connection« is commercially available for special cases (see Fig. 13.4.2).
  It acts as a ***breathing aid*** to reduce vacuum pressures, suction water, and the collection of condensation.
  It offers a high degree of IP protection against dust, infiltration water and access as a ***drain hole*** for penetrating water.

Decades of experience show that condensate drain holes can safely be omitted provided that these basic principles are followed. Today, condensate drain holes are usually only supplied as an option, whereas a survey conducted in 1963 showed that more than 80% of all closed (TEFC) three-phase motors produced in Germany were fitted with condensate drain holes.

	
Fig. 13.4.1 Crowding between the end winding and bearing bracket give rise to flashovers in the presence of condensation. A drain hole would not help in these circumstances.	Fig. 13.4.2 Air-conditioning connection with Pg 16 / Pg 21 and M 25 / M 32 threads Manufactured by STAHL Schaltgeräte GmbH

13.5 Discrimination between condensation, external water

Winding damage caused by water or humidity should not be attributed prematurely to condensation.
The overriding majority of such instances of damage can be traced to infiltration water. If rust starts to form on fittings, bearing flanges, inward projecting threads or contact surfaces of the terminal box, this is a clear indication of infiltration water – especially when combined with corresponding operating conditions (such as outdoor installation).
It is a less known fact that new winding can generate water the first time the motor is started if hygroscopic insulating materials were used (for the lamination insulation, for example). Dissertation research resulted in astonishing quantities of condensation, which decreased considerably upon each subsequent warm-up sequence and were not repeated, even after prolonged exposure to humidity.

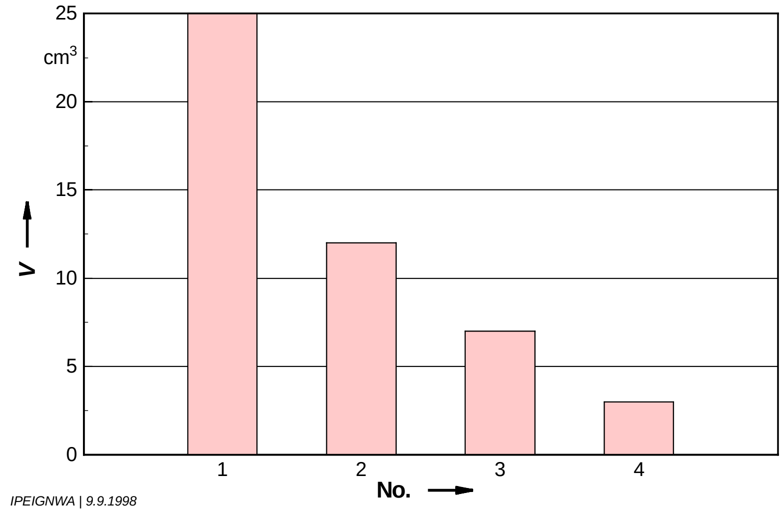


Fig. 13.5 Quantity of fluid (*V*) generated in a three-phase motor with a shaft height of 132 for the first four warm-up sequences after manufacture

14 Humidity Tropical conditions Termites

This section is designed to show that a high IP Code can provide additional but not the sole means of protection. This is also indicated by the standard EN 60529, which ***excludes the following influences from its scope***:

- ☐ Corrosion
- ☐ Mold
- ☐ Vermin
- ☐ Solar radiation
- ☐ Humidity (i.e. formed by condensation).

14.1 Humidity

Ambient air always holds a certain amount of water in the form of vapor. »Absolute humidity« fluctuates in nature. In other words, the weight of water (g) per volume of air (m³) varies between approximately 5 g/m³ (in northern Europe) and 30 g/m³ (at the equator). The warmer the air, the more moisture it can hold. Absolute humidity is particularly high in »hothouse« climates. (Relative humidity and condensation are discussed in Section 13.)
Humidity is taken on by absorbent (hygroscopic) materials. Even modern, highly-finished laminated fiberboard absorbs up to 15% of its weight in water (see Fig. 14.1.1).

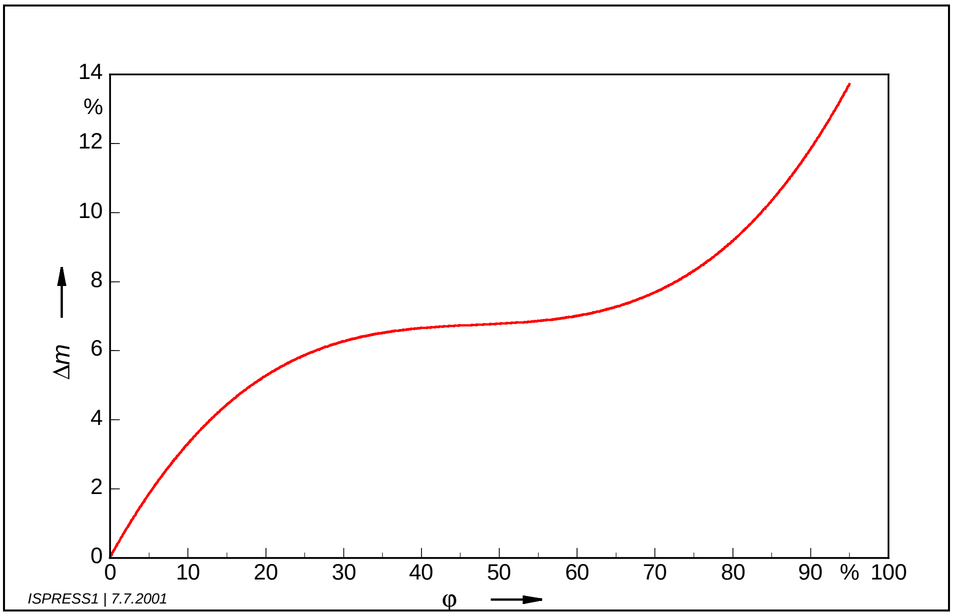


Fig. 14.1.1 Water absorption (Δm) as a percentage of weight of laminated fiberboard when stored in air with different relative humidities (φ)

Prolonged exposure of Class A and E insulating materials (paper, laminated fiberboard, cotton, silk, asbestos) to high humidity levels showed a decrease in the insulating properties of the materials which can often result in the failure of the winding. If one compares the breakdown strength of laminated fiberboard commonly used today and modern films, the basic difference becomes most noticeable in the ***absolute level*** but is less clear as a function of the relative humidity (Fig. 14.1.2; note logarithmic scale).

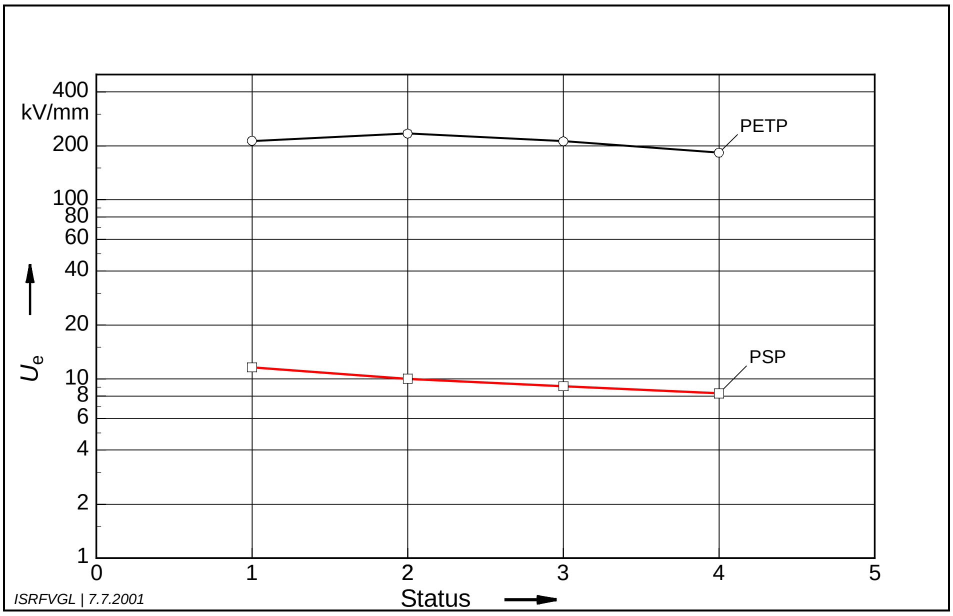


Fig. 14.1.2 Breakdown strength (U_e) of laminated fiberboard (PSP) and polyethylene teraphthalate (PETP) film as a function of relative humidity (RH)

Status :

1 - Drying 2 h at 105 °C
2 - Storage for 4 days at 50% RH
3 - Storage for 4 days at 65% RH
4 - Storage for 4 days at 85% RH
according to tests carried out by for this report by A. KREMPEL Soehne GmbH

The effect of humidity cannot be prevented by a high degree of IP protection because the moisture penetrates the enclosure together with the air and because even the highest IP Code does not guarantee air-tightness. The standard for the »Specification for degrees of protection provided by enclosures (IP Code)« EN 60529 is therefore determined expressly in Section 2 »Scope«:
"Measures to protect ... the apparatus ... against external influences such as moisture ... are matters for the relevant product standard."
In plain language:
Protection against moisture cannot be achieved by a high degree of IP protection.

Progress made in the insulation technology has either solved or alleviated the problem in a simple manner:
Modern insulating sheeting (such as polyester films, aromatic polyamides, polyamides) are practically ***non-hygroscopic*** and offer a very high degree of ***protection against high humidity levels*** when combined with other insulating systems.

14.2 Tropical conditions

The standards have neither a unified definition of the zone covered by the designation »tropics« nor a specification for requirements on »tropical safety«, »tropical protection« or »tropical insulation«.
The terms are used interchangeably by different manufacturers, but often indicate different special measures depending on the status of the basic model.
The following explanations have been provided to clarify the terms without claiming to be complete.

14.2.1 Geographical area

The section highlighted in the table can be added to the »tropics« classified as »open air climates« in accordance with DIN IEC 721-2-1:1992. The climatic map from this standard is shown on Pages 14/4+5 with permission from the DIN Deutsches Institut für Normung e.V. Users of this standard should refer to the edition with the newest date of release, which can be obtained from Beuth Verlag GmbH, Burggrafenstraße 6,10787 Berlin.

EC	C	CT	WT	WDr	MWDr	EWDr	WDa	WDaE
					TROPICS			
extremely cold	cold	cold temperate	warm temperate	warm dry	mild warm dry	extremely warm dry	warm damp	warm damp equable

The following extracts are taken from the excellent paper [13] by W. Rudolph (etz-b, 1/1976): The tropics are zones of the Earth in which constantly high temperatures prevail throughout the day, frequently combined with high levels of precipitation. These zones experience little or no seasonal variation. The tropics are generally understood to be mainly those zones with a tropical climate, though the definitions of a tropical climate vary greatly:

- ☐ 20 °C isotherm in the coldest month
- ☐ northern and southern limits of the trade winds or palm trees
- ☐ southern and northern limits of snow
- ☐ the lines of latitude at which the annual temperature fluctuations are greater than the daily temperature fluctuations.

The climate in the tropics stretches from the muggy tropical rain forests at the equator to the arid desert climates around the Tropics of Cancer and Capricorn. There are also areas with climates that differ markedly from the average conditions for these latitudes due to their high altitude, for example: the solar radiation and atmospheric pressure or ice and snow on mountain peaks. The ambient conditions in some regions of the tropics are characterized by uniform conditions, while other regions are subject to extreme influencing factors.

Equable conditions:

- ☐ ***Temperature fluctuations:*** minimal daily and seasonal temperature fluctuations, sometimes less than 1 °C or no more than 6 °C
- ☐ ***Day lengths***: average between 10.5 and 13.5 h
- ☐ ***Solar radiation:*** uniform.

Extreme conditions:

- ☐ ***Precipitation:*** showers throughout the year near the equator; showers during certain periods of the year near the Tropics of Cancer and Capricorn
- ☐ ***Tropical storms in maritime regions:*** wind speeds of 100 km/h (60 mph) gusting at over 200 km/h (120 mph), for example: the typhoons in the West Pacific and the hurricanes in the Caribbean.

14.2.2 Environmental influences

The most important environmental influences affecting electrical equipment in the tropics are:
temperature and humidity, storms and precipitation, condensation and radiation.
Additional climatic conditions should also be noted:
corrosive atmospheres near the sea due to the salt content of the air, atmospheric discharges (lightning) in tropical storms, sandstorms in deserts.

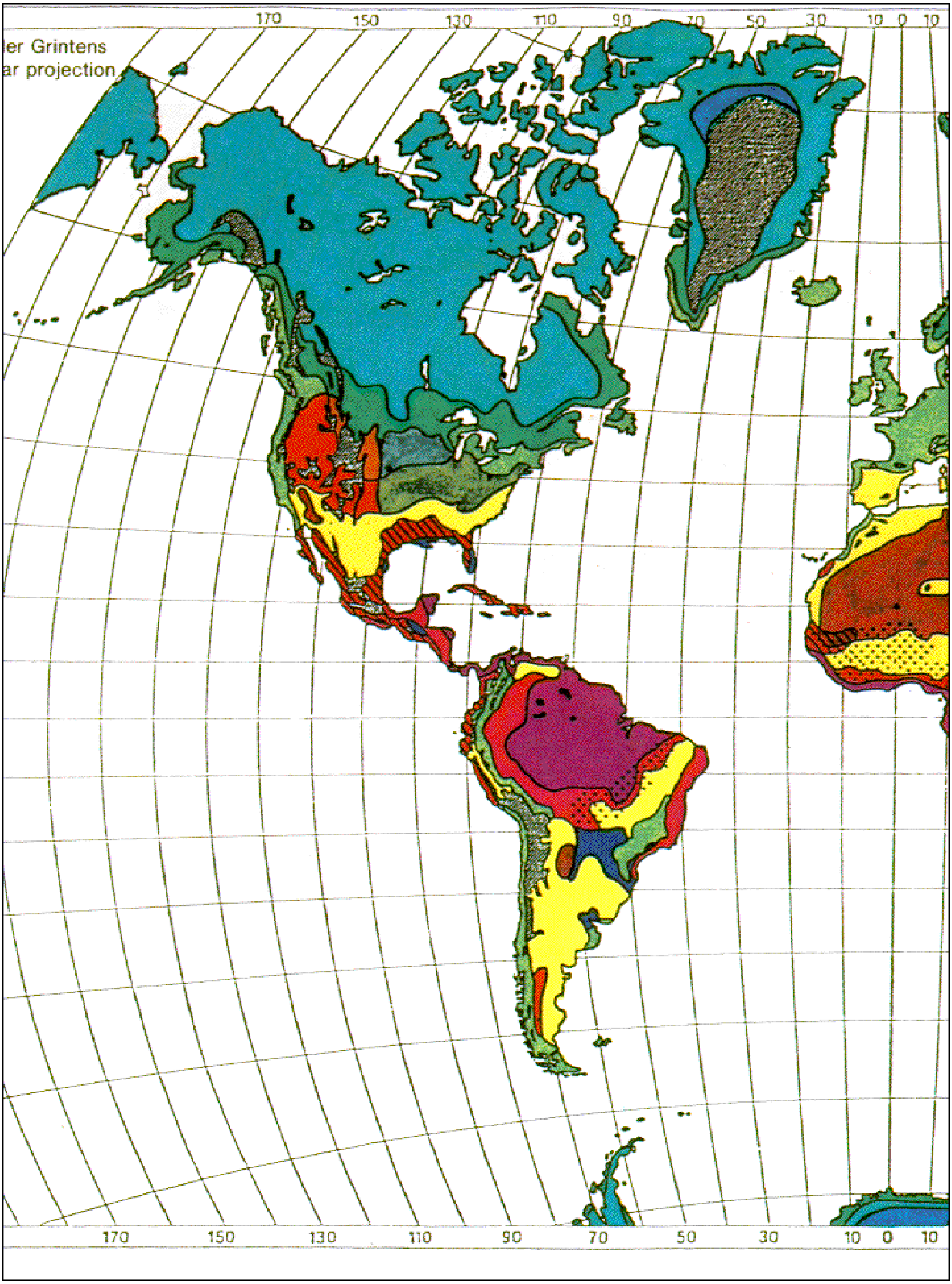


Fig. 14.2.1.1 Open air climates (west) according to DIN IEC 60721 Part 2-1 and L. Gittel (see Page 14-3)

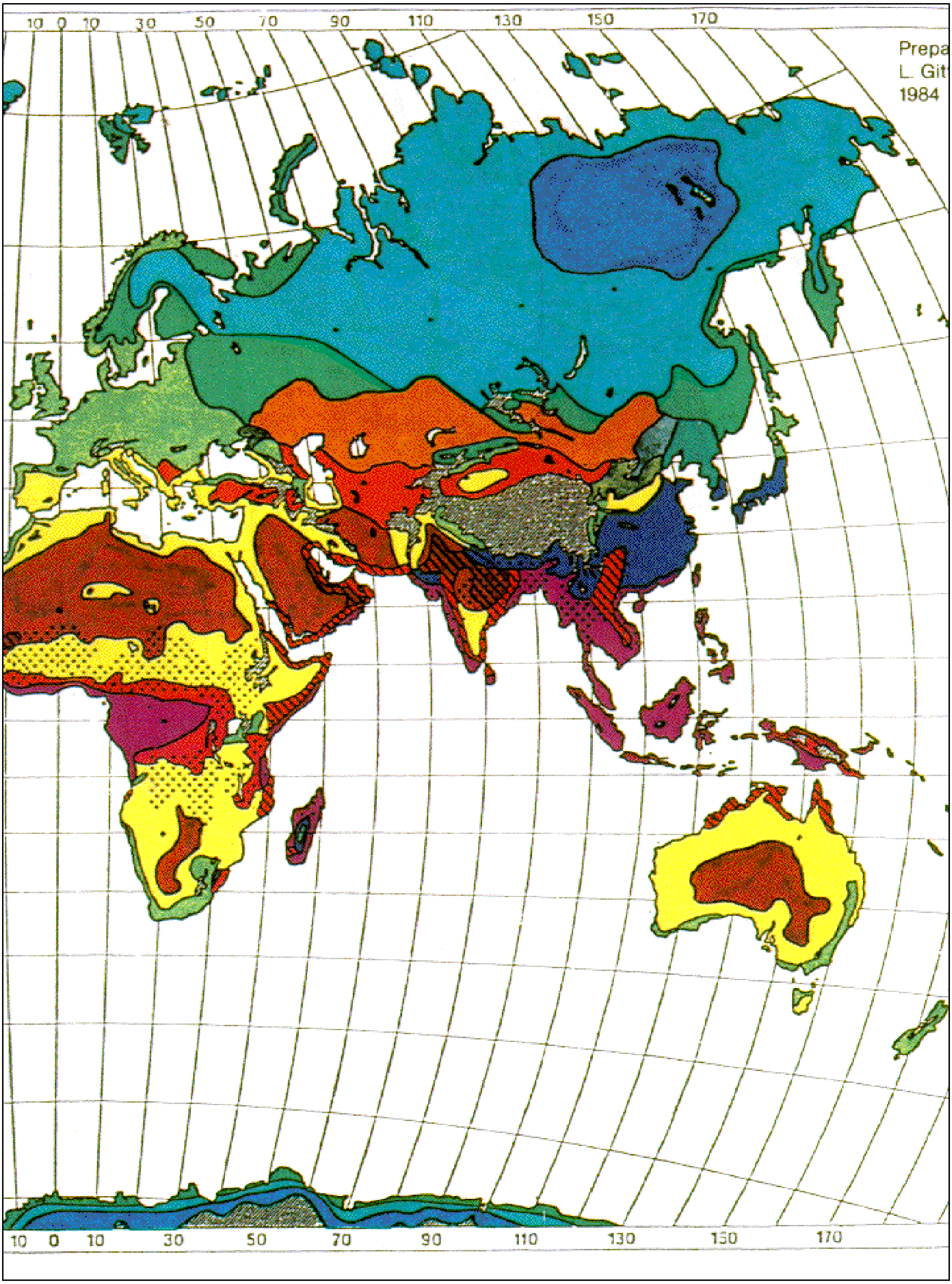


Fig. 14.2.1.2 Open air climates (east) according to DIN IEC 60721 Part 2-1 and L. Gittel (see Page 14-3)

Fig. 14.2.2 Conveyor line made up of mobile belt conveyors with drum motors for salt extraction in a tropical region

14.3 Mold

Mold grows in all humid climates in still air conditions if temperatures are suitable and the correct culture medium is present. Mold thrives in the 25 to 30 °C temperature range when combined with high relative humidity. Mold may cause the following problems:
Accumulation of moisture, discoloration of surfaces, corrosion, rotting and degradation of plastics, reduction in insulating properties and creepage paths. Materials favored by mold (such as leather, cardboard, animal and vegetable fats) should not be used in electrical apparatus. It is better to use materials which provide no nourishment for mold (such as silicone, plasticized PVC).

14.4 Termites

There are approximately 2000 known species of termite. About 500 of these should be regarded as harmful, and are mainly found in the tropics. Termites will gnaw through anything that stands between them and their food if the material is softer than their jaws and its shape allows it to be grasped by their jaws. Wood, plastics and metals or other materials that can be gouged with a fingernail are at risk.
Technical materials such as plastics or dry timber are only usually attacked by termites if their natural food runs out. The best living conditions for tropical termites are temperatures between 26 and 30 °C and a relative humidity of 90 to 97 %.

The best protection against termites is given by a metallic casing with a high degree of IP protection, i.e. at least IP5X, as is used today for nearly all three-phase standard motors. The closure must be metallic or, in the case of shaft seals, for example, it must have a gap width of approximately less than 1 mm. Plastic or rubber seals should not be accessible. This also applies to connecting leads and auxiliary leads. These should take the form of metal-armored cables or metallic conduit.

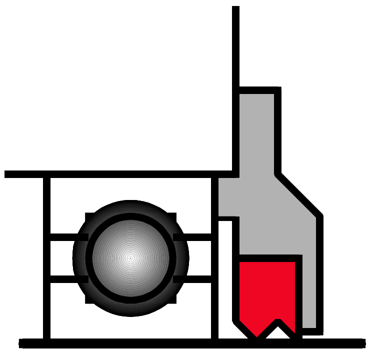
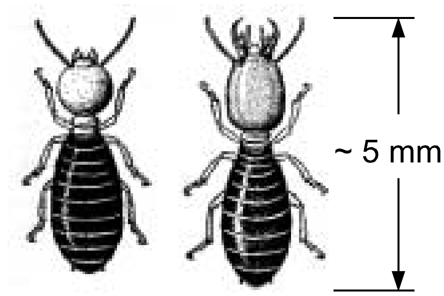
	

Fig. 14.3.1 Shaft seal with metallic guard on neoprene parts	Fig. 14.3.2 One of the many species of termite left: worker right: soldier

15 Dust explosion protection

Cumbustible materials (wood, coal, foodstuffs, plastics, aluminum) can form an explosive mixture with air when present in the form of dust (grain size < 0.4 mm). Fig. 15.0.1 shows the percentage of various types of dust in the dust explosions registered in Germany as documented by the BIA. The effects of a dust explosion can be seen in Fig. 15.0.2.

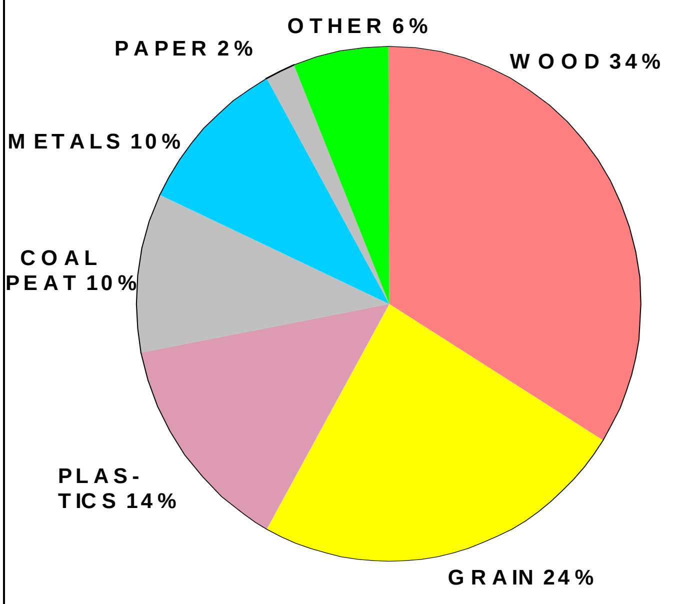


Fig. 15.0.1
Percentage of dust types involved in dust explosions

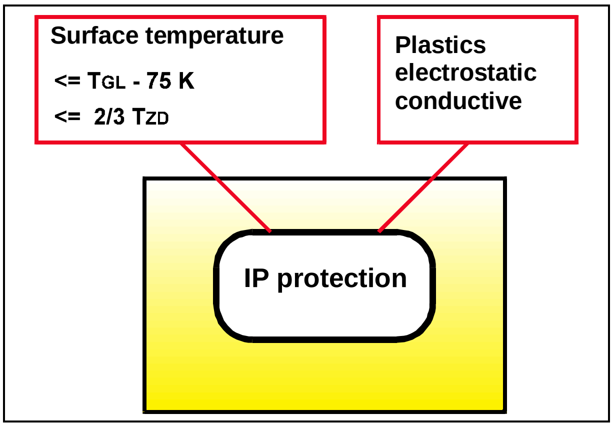
Fig. 15.0.2
Dust explosion in a feed stuff mill

15.1 Requirements

If it is possible to keep the inside of the motor housing free of dust this will be considered a zone free of the risk of explosion, even if the motor is installed in a dust-explosion endangered zone. The European standards EN 50281-1-1 and -2 are used on this principle in addition to the limitation and monitoring of the surface temperature under all operating conditions. Technical reasons justify the anticipation of the future standard IEC 61241-14 to determine the degree of protection for conductive dust in the following table.

Minimum IP degrees of protection		
Zone	conductive dust	non-conductive dust
20	IP6X	IP6X
21	IP6X	IP6X
22	active parts IP6X inactive parts IP5X	IP5X

Fig. 15.1
Basic requirements for dust explosion protection



15.2 IP degree of protection as part of dust-explosion protection

Thanks to the intensive and long-term efforts of German members of the relevant standards committees, the ***standard*** IP degrees of protection are being used both in the international standards (IEC 61241) and in the regional standards (EN 50281) that use it as a basis [10].
Special testing methods for tightness and temperature rise are specified only in the requirements designed for the ***North American market*** for »Practice B« of the IEC 61241 and the UL regulations (Underwriters' Laboratories). In a dust-tightness test using a grain dust mixture, a vacuum is generated by heating and cooling during six load cycles (6 x 6 hours of rated load/6 hours of standstill). The temperature rise due to the dust deposits is simulated in the »***closed test«*** or »***dust blanket test«***.
According to the European standards a standard test procedure can be used for the dust-tightness test as well as for the determination of temperature rise, as is common for use in non-explosion-hazard zones. The temperature rise for dust deposits of 5 ... 50 mm is taken into account using diagrams compiled with empirical data.

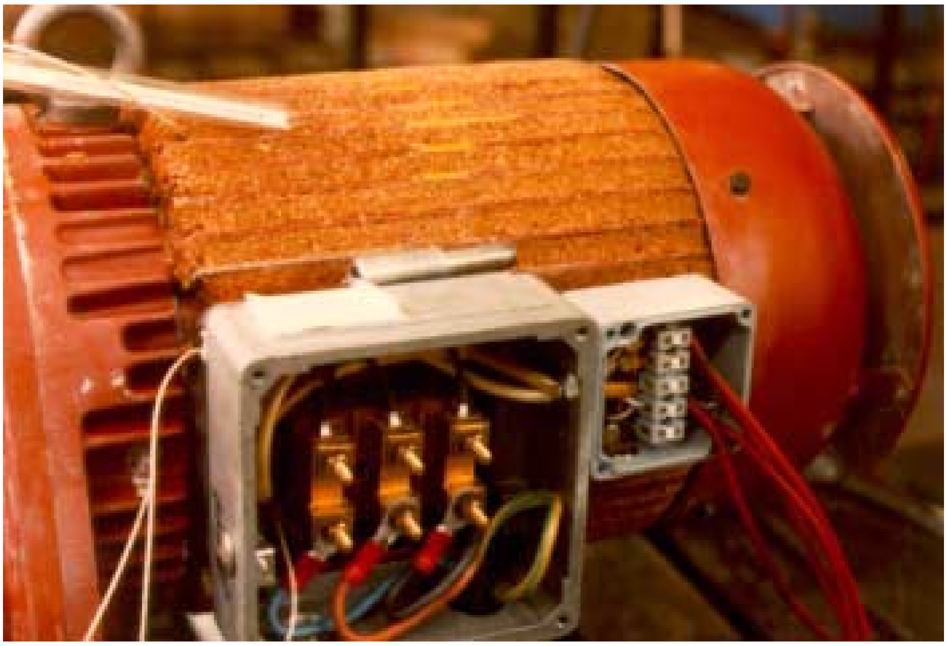


Fig. 15.2.1 Geared motor in a »closed test« with thick layer of dust according to »Practice B« in IEC 61241 and according to North American testing conditions specified by UL and CSA

If, however, ***»uncontrollable«*** dust deposits (thickness of over 50 mm) or ***dust blanket conditions*** are anticipated, the machine should be subjected to special acceptance testing in the laboratory of a test house (third party testing).

Fig. 15.2.2 Geared motor under “dust blanket conditions” in a malt factory

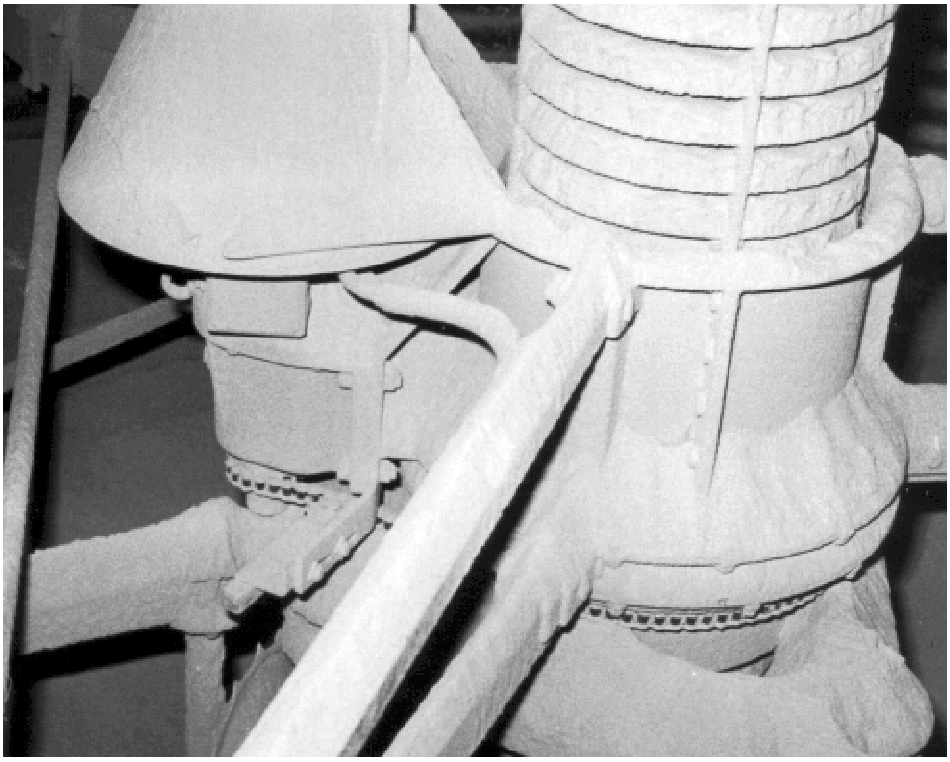


Fig. 15.2.3 Dust-explosion protected geared motor driving a scraper unit in Zone 10 of a silo. The dust hood minimizes »uncontrollable dust deposits«

16 IP degree of protection and types of protection

In the revised edition of the standards the term »degree of protection« has been chosen with reference to the IP code in order to distinguish clearly between protection against contact, foreign objects and water and the methods of ***protection against explosion***, the latter usually being termed »type of protection«.
IP degrees of protection and types of protection are technically related. For gas explosion protection, one method would be to seal the motor hermetically. However, such a construction for an electrical machine could be extremely expensive due to the necessary shaft sealing involved. Consequently, the types of protection »p« ("pressurization", previously »f« "external ventilation") is applied. The frequently used type of protection »e« ("increased safety") provides protection against explosion by a different method, so that according to DIN EN 50019 the degree of protection IP54 (and even IP20 is permissible) can be used for general purposes for installation in clean rooms.
For protection against dust explosions the dust-tight enclosure has an important function with regard to safety – in addition to the limitation of surface temperature.

When selecting electrical apparatus for potentially explosive atmospheres, an important factor is the probability of the occurrence of an explosive atmosphere at the same time as the occurrence of an incendive fault. For this reason areas are classified into zones according to the likelihood of a flammable gas mixture being present.
Zone 2 applies to areas where it can be assumed that dangerous ***explosive atmospheres are unlikely to occur and then only for short periods of time***.
A totally enclosed design will prevent rapid ingress of the explosive gas into the motor housing. By the time an explosive concentration of gas has accumulated within the enclosure the external gas concentration can be expected to have dispersed.
The already low probability of the simultaneous occurrence of an incendive fault within the motor and the presence of an explosive gas mixture becomes virtually zero in the case of a totally enclosed machine.
Reference has already been made to the use of the term "restricted breathing" with regard to the additional protection offered by a relatively gas-tight enclosure, reflecting a high degree of IP protection. Fig. 16.1 shows the basic idea: a cloud of gas passing by an enclosure penetrates the enclosure so slowly and incompletely that the concentration of gas remains below the lower explosive limit.

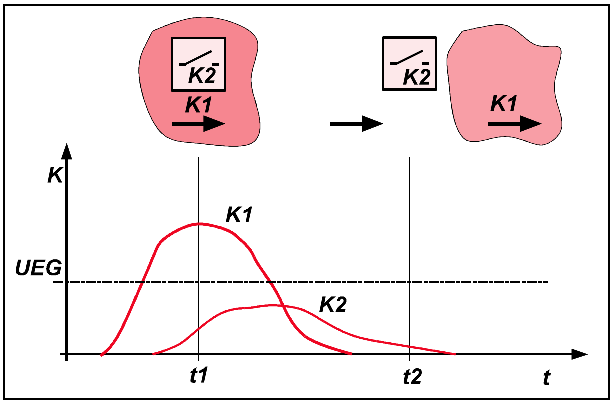


Fig. 16.1
Schematic diagram of the protection type "restricted breathing"

K1 Concentration within fumes
K2 Concentration within enclosure
t Time interval
UEG Lower explosive limit

In the revised national standard DIN VDE 0165, Section 6.3.1.4, restricted breathing enclosures were permissible for machines that had internal sparking, arcing or unacceptably high temperatures. The enclosure had to correspond to a degree of protection of no less than IP 54; a pressurization level of 4 mbar required a time period of at least 30 seconds to fall to 2 mbar.

Fig. 16.2 shows this type of test and demonstrates the enormous effect of the IP degree of protection.

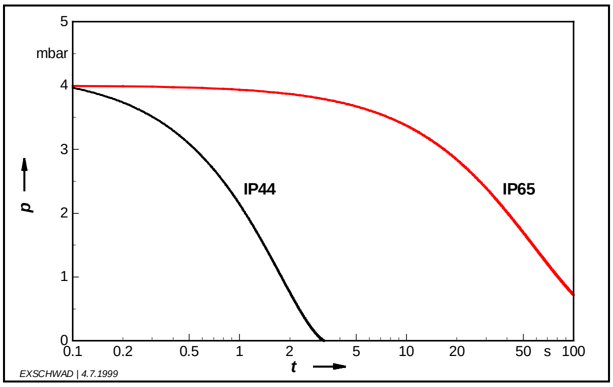


Fig. 16.2
Diagram showing the rate of pressure loss of motors with degree of protection IP44 and IP65 for testing “restricted breathing” according to the former
DIN VDE 0165: 1991

Typical applications for restricted-breathing designs included commutator motors (normal sparking) and mechanical brakes (unacceptable heat on the friction linings).
A test rig as shown in Fig. 16.3 was used to determine whether the standard IP 65 motors made by Danfoss Bauer met this criterion. Even with standard cable glands according to DIN 46320 the times determined for the pressure to fall from 4 to 2 mbar were between 30 and 60 seconds, depending on the frame size. With special attention given to the cable entry, about 3 minutes was achieved, whereas the times for normal IP 44 motors were less than one second.
Thus, with the high quality of design required for IP 65 motors, normal production of these ***standard*** three-phase cage motors provides the same enclosure safety level as is required when normally ***sparking*** motors are used in Zone 2.

Requirements for the degree of protection "nR" have been made stricter in the new standards IEC 60079-15 : 2001 and EN 50021.

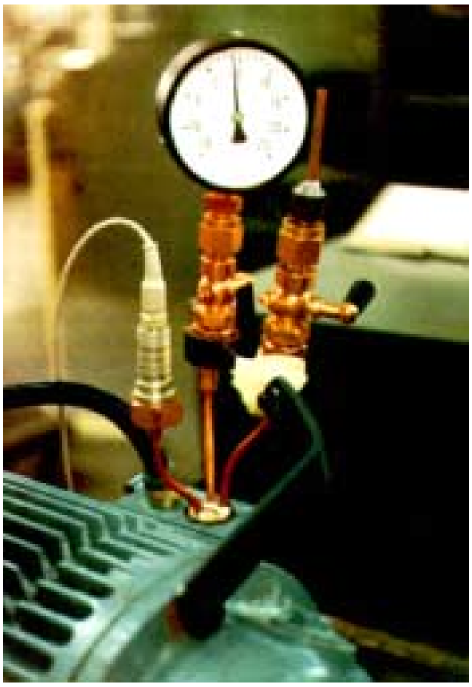


Fig. 16.3 Test arrangement to determine the time for the pressure within an IP65 motor to fall from 4 to 2 mbar

17 PTB report on testing the degree of protection

In earlier test certificates for explosion-proof motors the Federal German Laboratories (Physikalisch-Technische Bundesanstalt – PTB) indicated the degree of protection "increased safety" as the highest degree of protection IP44 (P33), even if the motor actually conformed to IP65 (P54). The statement by PTB must therefore be understood as meaning the minimum required degree of protection determined by their tests. The guarantee of a higher degree of protection is accordingly left to the manufacturer.
The complete range of the Danfoss-Bauer three-phase geared motors was then tested by the PTB in a separate test to verify conformity with IP65 protection. The test report is shown below. Though the test was based on the then-current edition of DIN 40050 and an earlier motor series, it technically remains fully applicable in this regard.

Physikalisch-Technische Bundesanstalt

Bericht

Gesch.-Nr. 2.42-7192/75

über die Prüfung von Drehstrom-Getriebemotoren

Typenreihe

		D 1A...		
	D 2A...	D 4A...	D 5A...	
D 6A...	D 7A...	D 8A...	D 9A...	D 10A...
DK 5...	DK 6...	DK 7...	DK 8...	DK 9...

der Firma

Eberhard B a u e r ,
Esslingen

auf Einhaltung
des Berührungs-, Fremdkörper- und Wasserschutzes
nach DIN 40 050, Blatt 2, Juni 1972,
Elektrische Maschinen
Schutzart IP 55

bzw. nach DIN 40 050, Blatt 1, August 1970,
für elektrische Betriebsmittel
Allgemeines
Schutzart IP 65

Anlagen: (vom Antragsteller zusätzlich zu den Prüfmustern eingereichte Prüfungsunterlagen)

Zeichnung:	250 000-A2	vom 22. 3.1967
	248 000-A2-6pol.	vom 6. 4.1967
	257 000-A2	vom 3. 4.1967
	255 000-A2-6pol.	vom 10. 4.1967
	240 000-A1	vom 9. 2.1967
	219 000-A1-6pol.	vom 11. 4.1967
	150 000-A1	vom 18.11.1965
	192 050-A2-1-6pol.	vom 15. 7.1964

Die Prüfungsunterlagen wurden zur Festlegung der Bauart mit dem Dienstsiegel der Physikalisch-Technischen Bundesanstalt versehen.

- 2 -

Prüfmuster: Drehstrom-Getriebemotoren

D 1A 83/253	Motornummer	1.448 837
D 2A 66 HZ/309	"	1.443 265
DNF 6A 20/499 R	"	1.267 509
DK 660 H/163 L	"	M 4.521 469

mit Klemmenkästen nach den beigefügten Unterlagen.

Die Zentrierränder an den Lagerschilden und die Paßfläche am Getriebeflansch werden bei allen Baugrößen vom Hersteller mit einer flüssigen Dichtungsmasse zusätzlich abgedichtet.

Die Einführungsöffnungen an den Klemmenkästen wurden zur Prüfung betriebsmäßig abgedichtet.

Für die Prüfung angewandte Richtlinien und Anweisungen:

DIN 40 050 Blatt 1, August 1970
DIN 40 050 Blatt 2, Juni 1972
DIN 40 052 Blatt 1, April 1972
DIN 40 053 Blatt 4, April 1972

Prüfungen:

1. Prüfung nach DIN 40 052, Blatt 1, in der Staubkammer 1 auf Einhaltung des Schutzgrades IP 5- bzw. IP 6-

   Ergebnis: In den Getriebegehäusen, Motorengehäusen und Klemmenkästen der obengen. Getriebemotoren waren nach Beendigung der Prüfung keine Staubablagerungen festzustellen.

2. Prüfung nach DIN 40 053, Blatt 4, mit dem Strahlrohr D1 auf Einhaltung des Schutzgrades IP -5

   Ergebnis: In die Getriebegehäuse, Motorengehäuse und Klemmenkästen der obengen. Getriebemotoren ist kein Wasser eingedrungen.

   Bei einer elektrischen Prüfung gem. Abs. 7.3 DIN 40 050, Blatt 2, im Anschluß an die Prüfung auf Wasserschutz an den Motoren D 1A..., D 2A... und DNF 6A... wurden keine Schäden an der Isolierung festgestellt.

Weitere Prüfungen wurden nicht durchgeführt.

Beurteilung:

Durch die Prüfungen wurde nachgewiesen, daß die Getriebegehäuse, Motorengehäuse und die angebauten Klemmenkästen für Getriebemotoren der Typen

D 1A 83/253
D 2A 66 HZ/309
DNF 6A 20/499 R
und DK 660 H/163 L

bei sachgemäßer Abdichtung des Gewindes für Einführungsteile - 3 -

und fachgerechter Einführung der Anschlußleitung ausreichend gegen Staubablagerungen im Inneren und Strahlwasser entsprechend IP 55 nach DIN 40 050, Blatt 2, Juni 1972 (Elektrische Maschinen) bzw. IP 65 nach DIN 40 050, Blatt 1, August 1970, für elektrische Betriebsmittel (Allgemeines) geschützt sind.

Unter der Voraussetzung, daß sich die Motoren und Klemmenkästen der vorgenannten Typenreihe D 1A... bis DK 9... aus der laufenden Fertigung von den geprüften Mustern in den für die Abdichtung der Gehäuse wesentlichen Teilen nicht unterscheiden, wird bescheinigt, daß diese Getriebemotoren die Schutzart IP 55 nach DIN 40 050, Blatt 2, darüberhinaus auch die Schutzart IP 65 nach DIN 40 050, Blatt 1, einhalten.

33 Braunschweig, den 3.6.1975
Bundesallee 100

Physikalisch-Technische Bundesanstalt
Abteilung 2
Im Auftrage

(Dipl.-Ing. H. Wickboldt)
Oberregierungsrat

18 Terminal box construction

The design and manufacture of terminal boxes merit particular attention. The supply cables should be brought into the motor from the most convenient direction. The center section of the terminal boxes on larger Danfoss-Bauer geared motors can therefore easily be turned when installed on site. Gaskets effectively seal the faces between the terminal box connection at the stator housing, and the adapter and cover are effectively sealed against dust and water. In some types of motor the effective sealing of the precision ground faces is further improved by a rubber-cork gasket.

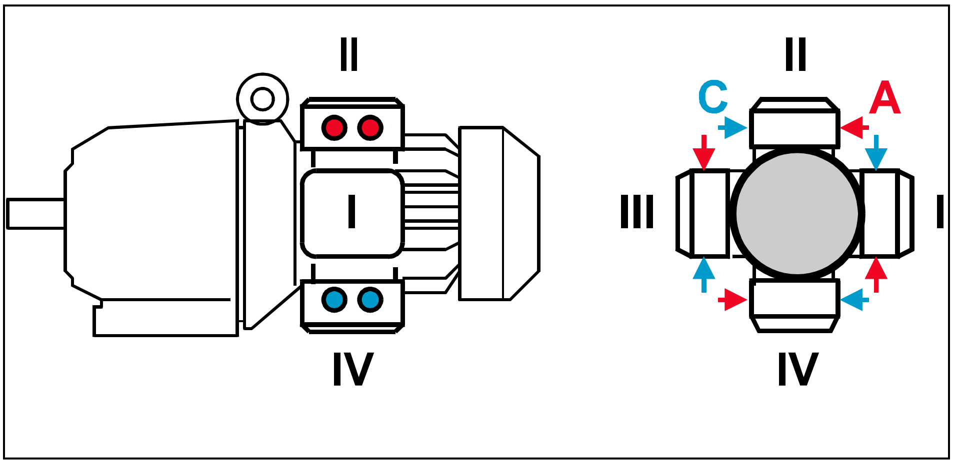


Fig. 18.1 Possible terminal box positions on geared motor units
Cable entry A (standard) or B (optional)

Fig. 18.2 Gasket between stator frame and terminal box with conducting contact points for bonding connection

The interior of the terminal box should be a spacious as possible and enable reliable connections while satisfying the relevant regulations. When a motor has to be connected under adverse conditions – such as in confined spaces in extreme cold (resulting in the fitter having stiff fingers) or when the terminal box is located on top of the motor – there is a risk of small parts such as nuts, washers or locking washers falling into the interior of the motor. This may cause immediate or subsequent damage to the winding after the motor is started. To prevent malfunctions of this type, a plastic filler is fitted in the opening of the frame between the interior of the stator and the terminal enclosure. The filler surrounds the winding ends and separates the two enclosures.

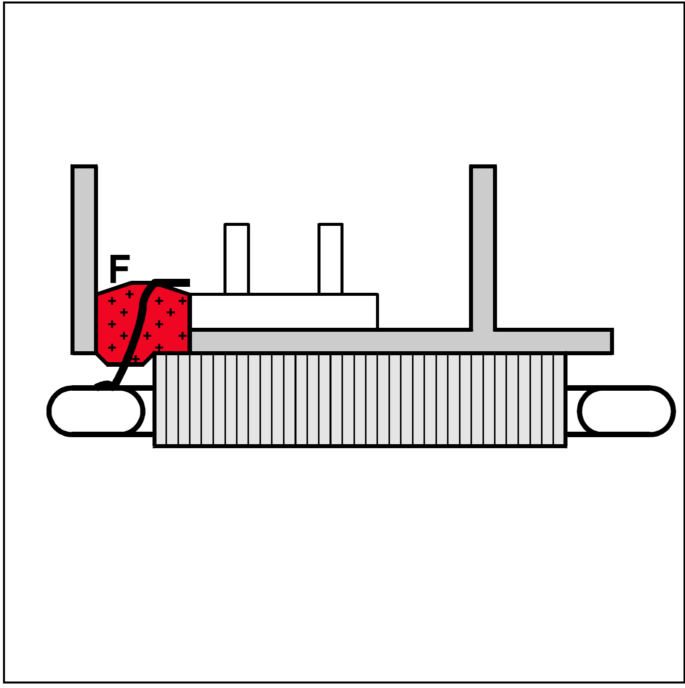


Fig. 18.3

Arrangement of rubber filler between the terminal enclosure and motor interior.

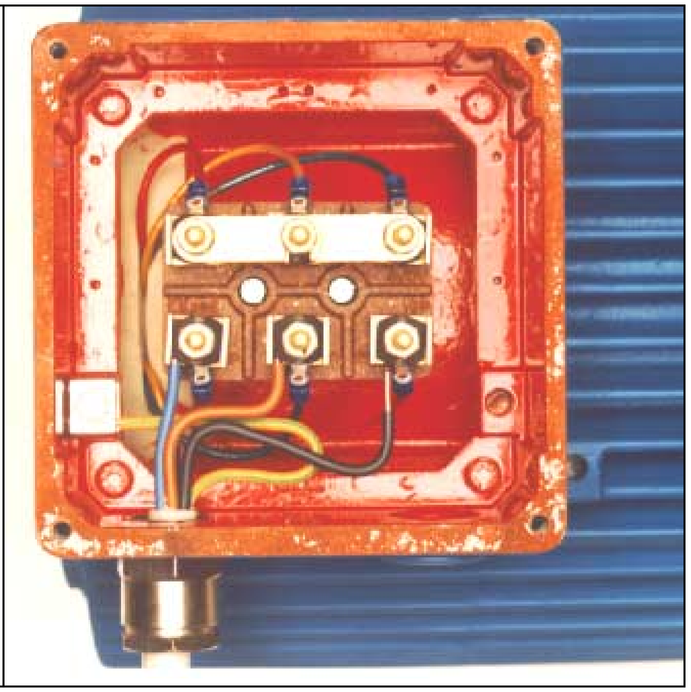


Fig. 18.4

Terminal box with 6-pin terminal plate

The cable inlet holes in the terminal box are sealed in the factory with a molded plug (metal plugs are used for explosion-protected motors). The contact area between the flange of the plug and the unmachined exterior face of the terminal box is additionally sealed with a special rubber ring (O ring). This prevents water or dust from penetrating into the interior of the terminal box of the motor during transport. It also ensures that unused cable entry holes are actually blanked off.

These additional provisions on Danfoss-Bauer terminal boxes are not a matter of course or general practice. The ends of the windings are sealed onto the terminal board studs with special compression-type cable shoes.

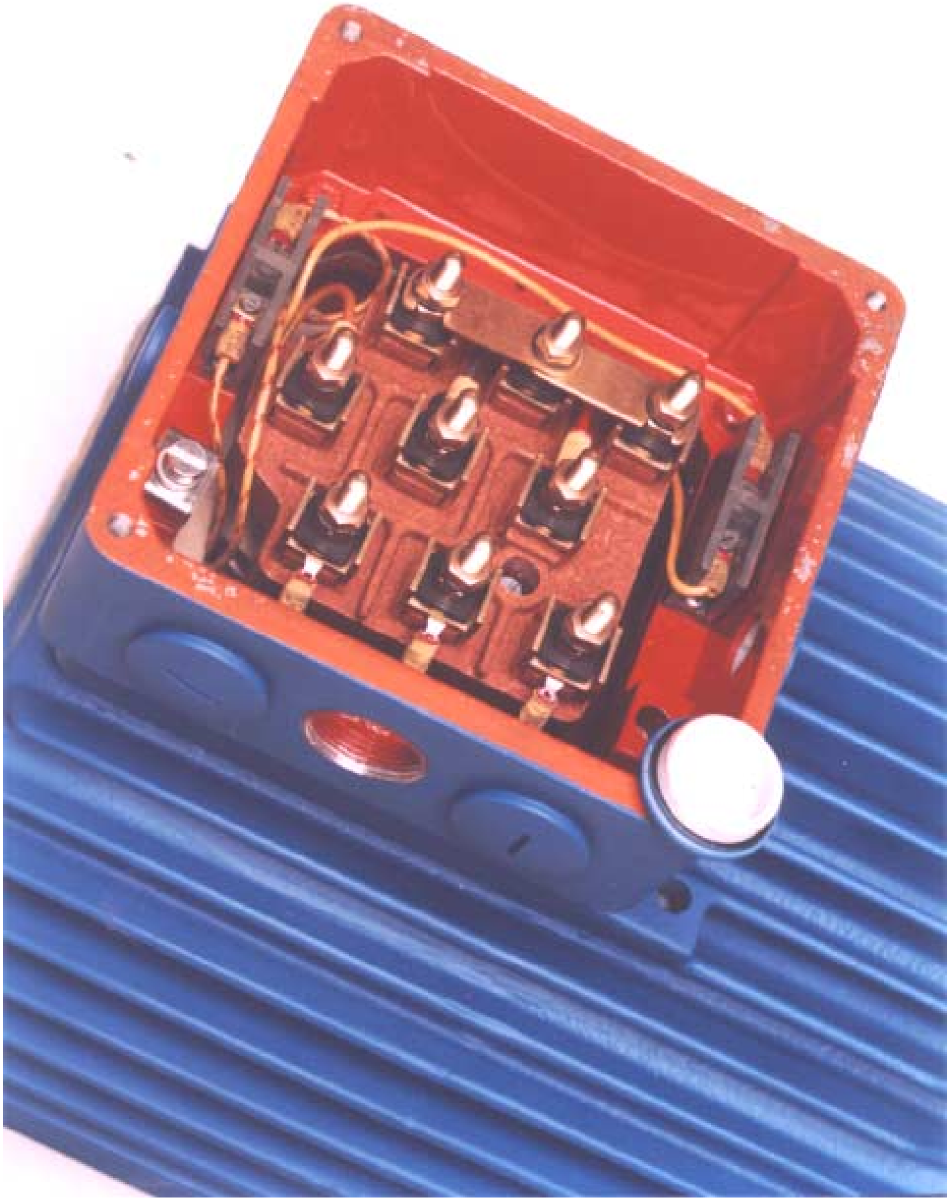


Fig. 18.5 Cable entries to terminal box with plugs

19 Corrosion protection

The standard for degrees of IP protection expressly excludes protection against corrosion from its scope of protection. Although it can be assumed that a high degree of mechanical protection for the terminals and the winding will also include a certain degree of protection against chemical assault, the materials used must also be resistant over an extended period of time. For this reason gray cast iron parts are available as an option for the housing of larger motors. The parts are sandblasted after casting and coated with a synthetic resin reaction primer. The terminal box consists of a corrosion-resistant aluminum die-casting alloy (Silumin = GD Al Si 12). The standard synthetic resin-base coating naturally offers only a limited degree of protection under aggressive atmospheres.

19.1 CORO 1

The factory designation »CORO 1« indicates an external coating with a two-component paint based on Desmodur-Desmophen for three-phase geared motors. The chemical formulation of this special coating, which is applied to a thickness of 0.065 mm, provides an increased measure of protection against aggressive gases and fumes.

19.2 CORO 2

The increased level of corrosion protection designated as »CORO 2« covers a series of measures in addition to the special coating described in the previous section. The fan hood is galvanized steel sheet. The bolts for the terminal box cover are rust-proofed to ensure easy access to the terminals even after extended operation. The gear enclosure is filled with lubricant in the factory to preserve it during the often extended storage period until it is put into operation. A gasket with two rubber lips provides effective protection for the external bearing at the end of the shaft.

19.3 CORO 3

IP 66 provides an unusual degree of IP protection for electrical machines. In conjunction with the increased level of corrosion-proofing »CORO 3« it offers a particularly high degree of protection against the effects of water and corrosion. The special measures described in Section 19.2 for increased corrosion protection are combined here with some additional features: the motor winding is insulated with thermally resistant, non-hygroscopic Class F insulating materials; casting resin separates the terminal enclosure from the motor interior and all bolts and facing surfaces are specially sealed.

19.4 Summary

Three corrosion protection packages for three-phase geared motors are offered which are classified under the factory designations »CORO 1« to »CORO 3« on the basis of specific requirements. These were developed using the direct exchange of information between users and manufacturers to ensure that the slow-running drives installed in endangered systems could be made even more reliable. We reserve the right to adapt these special measures to reflect the current state of the art and manufacturing methods.

Fig. 19.4.1
Three-phase geared motors with special degree of IP66 protection (with extra protection against corrosion / CORO 3), driving a group of cooling tower fans

Fig. 19.4.2
Externally affected but fully functioning drum motor on portable belt conveyor under hard construction site conditions

20 Impact resistance

Mechanical damage caused by external influences and not the electrical machine itself are relatively common. Certain fields of application – mining, woodworking, construction sites – place particularly high demands on motors. The conditions of operation are frequently described as »normal«, but the process hides the true nature of the situation: a machine tool does not in itself represent an arduous application but a motor installed in an exposed location can easily be crushed by a forklift truck.

20.1Common standards

There are no limit values set in standards for the demands of mechanical impacts encountered in standard industrial applications. Occasionally a correlation is drawn with the ***degrees of IP protection*** that are not entirely justified. The »Scope« clause in EN 60529 states:
“This standard deals only with enclosures which are in all other respects suitable for their intended use as specified in the relevant product standard and which from the point of view of the material and workmanship ensure that the claimed degrees of protection are maintained under the normal conditions of use.”
The minimum requirements on and tests for the impact resistance of enclosures are not a component of the IP Code. If a specification of this type is required to guarantee safety, the standards specific to the product must be supplemented and observed, as has been tried in EN 50014, 23.4.3.1, for example. Here the impact resistance requirements are specified as follows:

Group	**I**		**II**	
Zone	Firedamp atmosphere below ground		Potentially explosive atmosphere above ground	
Mechanical danger	high	low	high	low
Impact energy (in J)	20	7		4

Table 20.1 Impact test for explosion-proof electrical apparatus to EN 50014

Equipment with the type of protection »e« (“increased safety”) derived in part from the normal series must, as a consequence, be able to withstand an impact test of 7 J. The illustrations show designs for fan cowls before and after reinforcement at the time of introduction of this standard (1978).

Fig. 20.2
Unreinforced fan cowl (1.0 mm) after the impact test

Fig. 20.3
Reinforced fan cowl (15 mm) after the impact test

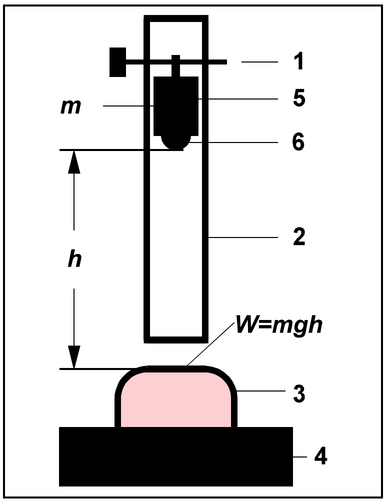


Fig. 20.1

Scheme of an impact test on the fan cowl of an electric motor using an impact energy of 7 J
Striker weighing 1 kg falls twice from a height of 0.7 m

1 - Height adjustment
2 - Guide tube
3 - Test specimen
4 - Steel base (m ≥ 20 kg)
5 - Mass (e.g. m = 1 kg) in steel
6 - Impact head of hardened steel diameter: 25 mm
h - Height of fall (e.g. 0.7 m)

Two further test devices have been standardized in addition to the impact test described in EN 50014. The instruments are manufactured by PTL, 95346 Stadtsteinach, Germany.

20.2 IK-Code

A new classification system, the »Protection provides by enclosures for electrical apparatus against external mechanical impacts (IK Code)«, was introduced in DIN EN 50102/VDE 0470 Part 100:1997 [7]. It is shown below to clarify the orders of magnitude. The classification system is based on the »third characteristic numeral« of the French standard NF C 20-010, which was not included in IEC 60529. It completes the series "IP, IM, IC". The code letter "K" is derived from its phonetic relationship with the French word "casser" (crush).

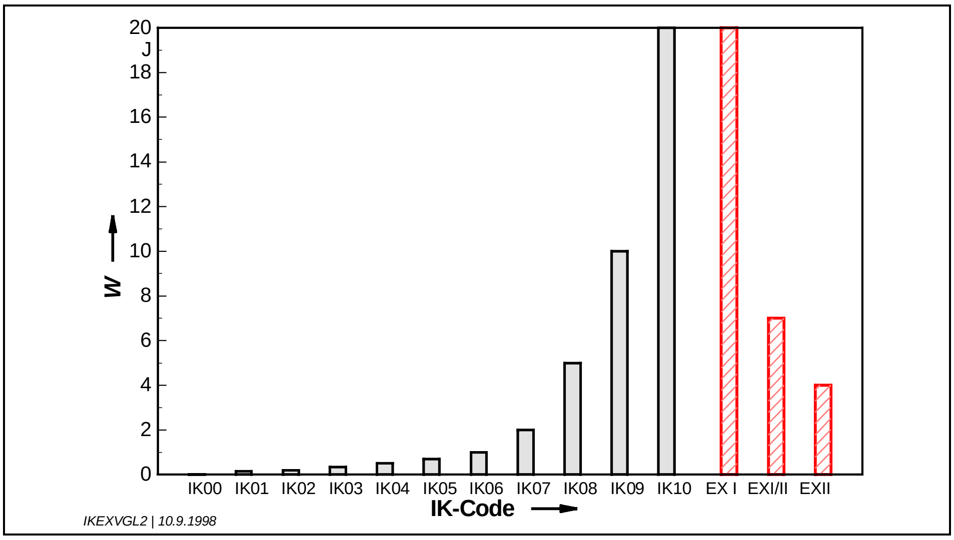


Fig. 20.2.1 Classification of the mechanical impact resistance of electrical apparatus in an »IK Code« according to EN 50102 in comparison to the specifications for explosion-proof apparatus »EX«

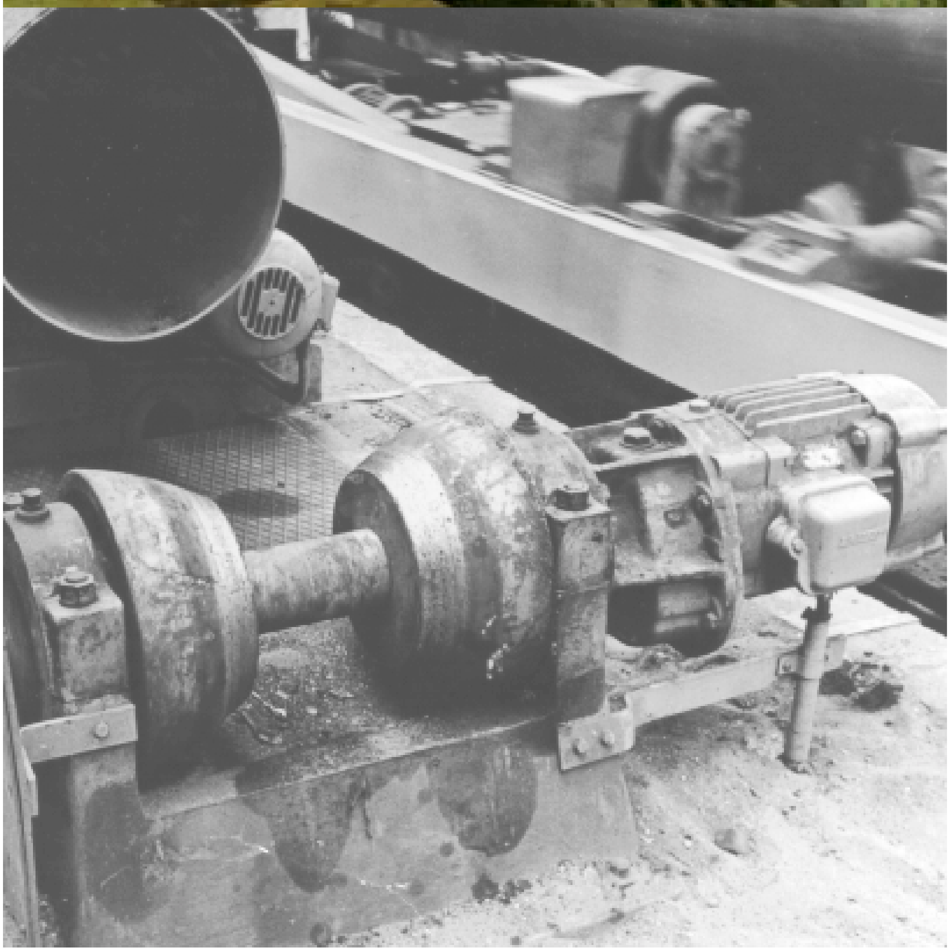
Consequences for the user:
Electrical apparatus (motors, switchgear and control units) should be arranged as far as possible such that they are protected against the mechanical influences to be expected from use in accordance with the intended purpose. An additional cover can sometimes be more effective and cost-efficient than creating a special design for the apparatus.

Fig. 20.2.2

Roller table drives on a cooling bank protected by a cover against mechanical damage caused by the red-hot material being conveyed

Fig. 20.2.3.

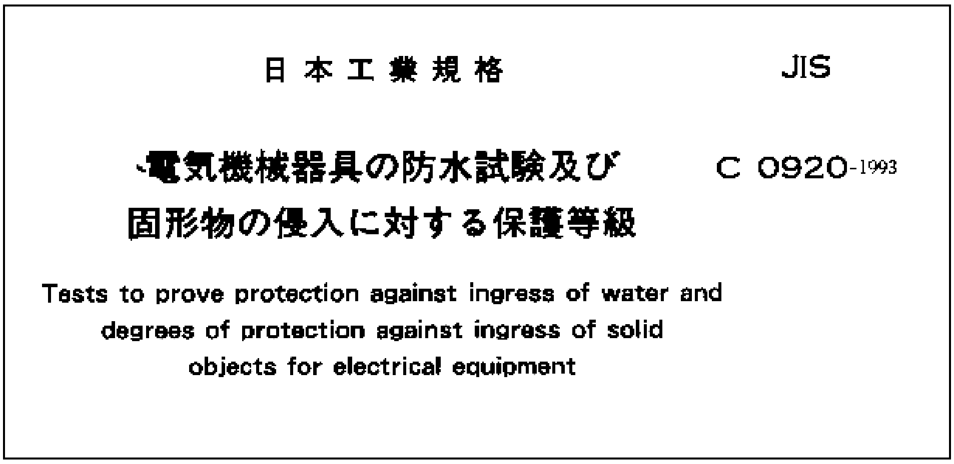
Roller table geared motors driving taper rollers for conveying pipe under heavy mechanical stress



21 International application of the IP Code

The IP system of indicating the degree of protection has been incorporated in the following national standards. Those shown in brackets are not yet in conformity with the latest edition of the IEC 60529:

Country	National standard
Australia	AS 1939
Austria	ÖVE-A50/2
Belgium	NBN C 20-001
Bulgaria	CT 778-77
Czech Republic	CSN 33 0330
Denmark	(DS/IEC 34-5)
Finland	SFS 2972
France	NF C 20-010
	NF EN 60034-5
	(NF C 51-115)
Germany	DIN 40050 to DIN 40053
	VDE 0470 Part 1
Great Britain	BS 5490
Hungary	MSZ 592
India	(IS: 4691)
Italy	(CEI 05515 u. 09414)
Japan	JIS C 0920-1993
Kenya	KS 04
Netherlands	NEN 2438
	NEN 10 034-5
Poland	PN-79/E-08 106
Portugal	NP 999
Romania	STAS 5325-79
Sweden	SS IEC 529
Switzerland	EN 60529
	(SEV 3428)
Spain	UNE 20-324


日 本 工 業 規 格　JIS

電気機械器具の防水試験及び　C 0920-1993
固形物の侵入に対する保護等級

Tests to prove protection against ingress of water and degrees of protection against ingress of solid objects for electrical equipment

Fig. 21 Title of Japanese standard for IP degrees of protection based on IEC 60529

22 Degrees of protection in North America

In North America and other countries following technical practice in the USA, a series of abbreviations for the enclosure requirements can be found in standards, lists and common usage. These are shown in the list below, which has no claim to being complete. It is hardly possible to translate these into the equivalent IP degrees of protection since the requirements and test methods are different or even undefined in some cases. The abbreviations denote a mixture of criteria involving degrees of protection and methods of cooling. Although NEMA (National Electrical Manufacturers Association) presented the IP Code as early as 1980 in its »Guide for the development of metric standards for motors and generators« and as »Classification of degrees of protection provided by enclosures for electrical machines« in Part 5 in MG1 in 1998 [5], the ***IP Code*** generally remains rather ***unknown*** in North America.
Abbreviations according to the following table are used for electrical machines. The examples for the corresponding IP and IC Codes are nonbinding since the definition and testing conditions deviate greatly in some cases:

Common abbreviation	Definition in NEMA MG1-1.25/26	German translation	Code acc. to IEC	
			IP	**IC**
GP	General purpose	Offene Maschine für allgemeine Verwendung	-	-
DP	Drip-proof	Tropfwassergeschützt	IP12	IC01
ODP	Open drip-proof	Offen, tropfwassergeschützt	IP12	IC01
ODDP	Outdoor drip-proof	Offen, tropfwassergeschützt, für Aufstellung im Freien	IP12	IC01
SP	Splash-proof	Spritzwassergeschützt	IP23	IC01
PV	Open pipe-ventilated	Offen, mit Rohranschluss am Lufteintritt, eigenbelüftet	IP23 IP44	IC11
FV	Open externally-ventilated	Offen, mit Rohranschluss am Lufteintritt, fremdbelüftet	IP23 IP44	IC16
WP	Weather-protected	Offene, durchzugbelüftete Maschine mit Wetterschutz durch besondere Konstruktion der Luftführung	IPW23 IPW24	IC01
TE	Totally-enclosed	Völlig geschlossen	IP44	-
TENV	Totally-enclosed nonventilated	Völlig geschlossen, unbelüftet	IP44	IC410
TEFC	Totally-enclosed fan-cooled	Völlig geschlossen, oberflächenbelüftet	IP44	IC411
TEFV	Totally-enclosed forced-ventilated	Völlig geschlossen, fremdbelüftet	IP44	IC416
TEPV	Totally-enclosed pipe-ventilated	Völlig geschlossen, mit Rohranschluss für Durchzugbelüftung	IP44	IC31
WPRF	Water-proof	Völlig geschlossen, strahlwassergeschützt	IP56	IC411
TEWA	Totally-enclosed water-air-cooled	Völlig geschlossen, Luft/Wasser-Wärmetauscher	IP54	IC51W
TEWC	Totally-enclosed water-cooled	Völlig geschlossen, Leiter direkt wassergekühlt	IP54	IC(W5)W7
XP	Explosion-proof	Explosionsgeschützt	Eex d II	-
TEFP	Totally-enclosed flameproof	Völlig geschlossen, druckfest gekapselt	Eex d II	-
DIP	Dust-ignition-proof	Staubexplosionsgeschützt	ST.EX.	-

Table 22.1 Designation of degrees of protection / cooling methods according to NEMA MG1-1.25 and 1.26, and common abbreviations (not standardized). Corresponding IC Codes are non-binding

In addition – and especially in the case of switchgears – the »NEMA Types of enclosures« are also specified in NEMA Pub. No. 250. These cannot be directly compared with the IP degrees of protection, as additional environmental conditions such as coolants, oil, corrosion, icing, hail, etc. are also specified. The following table should be taken as a nonbinding guideline. Additional determinations and the national rules for certification of explosion-protected motors must be observed.

NEMA Enclosure type	IP Code Degree of protection	Type of explosion protection	Additional requirements
1	IP20	-	-
2	IP21	-	-
3	IP54	-	icing
3R	IP24	-	icing
3S	IP54	-	icing
4	IP55	-	-
4X	IP55	-	corrosion
5	IP50	-	-
6	IP67	-	-
6P	IP68	-	-
7	-	EEx ll d	indoor
8	-	EEx ll d	outdoor
9	IP65	DIP (St Ex)	-
10	-	EEx I d	-
11	-	-	oil immersion
12	IP52	-	-
12K	IP52	-	-
13	IP54	-	coolant

Table 22.2 Guidelines indicating the relations between »NEMA Enclosure types« and the lP Code (see notes in text!).

IP	**X0**	**X1**	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**
0X	-	-	-	-	-	-	-	-	-
1X	-	-	-	-	-	-	-	-	-
2X	1	1+2	1+2	1+2	1+2+3R	1+2+3R	1+2+3R	1+2+3R	1+2+3R
3X	1	1+2	1+2	1+2	1+2+3R	1+2+3R	1+2+3R	1+2+3R	1+2+3R
4X	1	1+2	1+2	1+2	1+2+3R	1+2+3R	1+2+3R	1+2+3R	1+2+3R
5X	5	1+2	12+12K	1+2	3+3S+13	4+4X	1+2+3R	1+2+3R	1+2+3R
6X	5	1+2	12+12K	1+2	3+3S+13	4+4X	1+2+3R	6	6P

Table 22.3 Guidelines indicating the relations between »lP degrees of protection« and »NEMA Enclosure types«

Additional requirements for NEMA
Type 3/3R/3S : Protection against icing
Type 4X : Protection against corrosion
Type 13 : Protection against coolants (oils)

The complete IP Code comprises the abbreviation for particle protection (lines) and the abbreviation for water protection (columns). The degree of protection shown in the intersecting cell includes:
- the NEMA enclosure protection at the intersection
- in the line above
- to the left of the column.

Example:
IP 54 covers approximately: NEMA 1, 2, 3, 3R, 3S, 5, 12, 12K, 13

23 Outdoor installation

This term does not appear in the standards for the IP Code. No assignment of degree of IP protections or ambient conditions is specified.
The reasons, which had been discussed in detail in the standards committees, are summarized below.

23.1 References in protection standards

In the comparison of typical rainfalls with the »severities« indicated in the IP tests, the normal stresses from the natural occurrence of rain in our latitudes appear to be covered with the relatively low IP degrees of protection.

Typical rainfalls according to IEC 721-2-2:	
Drizzle	< 1 mm/h
Light rain	1 mm/h
Moderate rain	4 mm/h
Intensive rain	15 mm/h
Heavy rain	40 mm/h
Cloudburst	> 100 mm/h
Degrees of IP protection:	
IP X1 test	1 mm/min = 60 mm/h
IP X2 test	3 mm/min = 180 mm/h
Duration of each test: 10 minutes	

One should bear in mind that the standardized IP test lasts for 10 minutes, though there are 8760 hours in a year! The IP test cannot simulate long-term outdoor installation, even if the volume of water is increased. This requires special long-term testing or the particular experiences of the manufacturer. Explicit catalog data are rare.

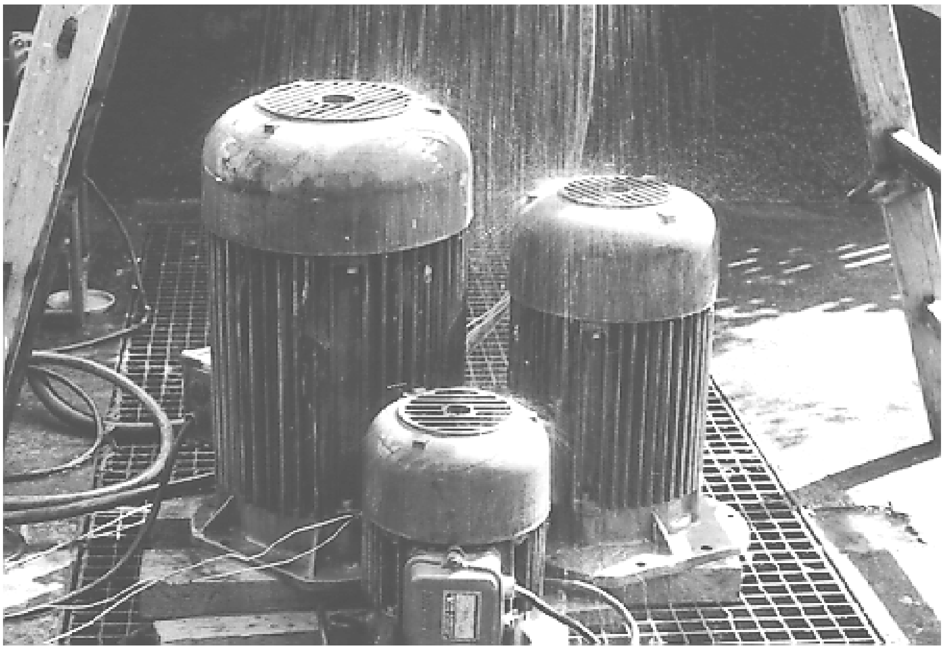


Fig. 23.1 Long-term exposure of geared motors to rain to test fitness for outdoor installation

The sole reference to outdoor installation is made in the concept »weather-protected machines« in IEC 60034-5.
Clause 10 of this standard makes it clear that the degree of protection »W« is intended for a specific design of open-circuit air-cooled machines and as such is not applicable to totally enclosed, surface-cooled (TEFC) machines.
There are other good reasons for the standard's reticence:
When viewed globally, »outdoor installation« can entail extreme cold, extreme air temperatures, heating by solar radiation, high humidity, mold, corrosion and much more. Even in our moderate climate, additional demands can be placed on machinery operating in a sewage works or in an outdoor facility of a chemical plant, for example. These demands are not covered by the sweeping term »outdoor installation«.
The "Scope" clause of the applicable standards on degrees of protection EN 60529 exclude the following influences ***from their field of application*** with good reason, even though they are relevant in this context:

- Corrosion
- Mold
- Vermin
- Solar radiation
- Icing
- Moisture (e.g. produced by condensation).

This clarification, however, is not included in IEC 60034-5 (see Section 4).

The standards cannot, therefore, be used to determine the measures to be taken to equip an electrical machine for outdoor installation. The manufacturer must be consulted if information on this is not provided in the catalog or operating instructions (as is the case with Danfoss Bauer).

23.2 References in the installation codes of practice

The situation described by the installation codes specified in DIN VDE 0100 is somewhat different:
Part 737 »Humid and wet areas and rooms; outdoor installations« clause 5.2, state:
"Apparatus in unprotected outdoor installation must be protected against spray water as a minimum (IP X3 according to DIN 40050)."
One should note the following about this statement:

- This is a ***minimum requirement.***
- The installation codes are directed primarily at the ***safety*** of persons and property. The maintenance of the ***function*** of a machine ***used under special conditions*** is still governed by an agreement reached between the manufacturer and the customer.

The ***new standard DIN VDE 0100 - 510*** has the following field of application:
"510.1 This section is concerned with the selection of apparatus and its installation. The effectiveness of the protective measures and the observance of the requirements in respect of the satisfactory operation of the machine when used as designated and in respect of the external influences to be expected shall be ensured."

The standard lists in an eight-page annex the »external influences« to be taken into account in the selection of the apparatus. This provides a list of environmental influences rather than the sweeping term »outdoor installation«. Only the »occurrence of water« or the »occurrence of foreign objects or dust in significant quantities« is referred to in a degree of IP protection as a »typical property« in terms of the selection of machinery. All other influences must be accounted for by »appropriate design or execution«.

Code	**Air temperature (°C)**		**Relative humidity (%)**		**Selection**
	low	high	low	high	
AB1	-60	+5	3	100	Special
AB2	-40	+5	10	100	Special
AB3	-25	+5	10	100	Special
AB4	-5	+40	5	95	Normal
AB5	+5	+40	5	85	Special
AB6	+5	+60	10	100	Special
AB7	-25	+55	10	100	Special
AB8	-50	+40	15	100	Special

Table 23.2.1 Assignment of climatic ambient conditions and the selection of electrical apparatus in accordance with DIN VDE 0100-510 : 1997; Table 51 A

Code	**External influences**	**Selection of apparatus**
	Water	
AD1	negligible	IPX0
AD2	Dripping water	IPX1
AD3	Spraying water	IPX3
AD4	Splashing water	IPX4
AD5	Water jets	IPX5
AD6	Powerful water jets	IPX6
AD7	Immersion	IPX7
AD8	Submersion	IPX8
	Solid foreign objects (dust)	
AE1	negligible	IP0X
AE2	Small (< 2.5 mm)	IP3X
AE3	Very small (< 1 mm)	IP4X
AE4	Lightweight dust, low quantity	IP5X, if it does not endanger the function of the machine
AE5	Moderate quantity of dust	IP6X, if no dust should penetrate the machine
AE6	Significant quantity of dust	IP6X

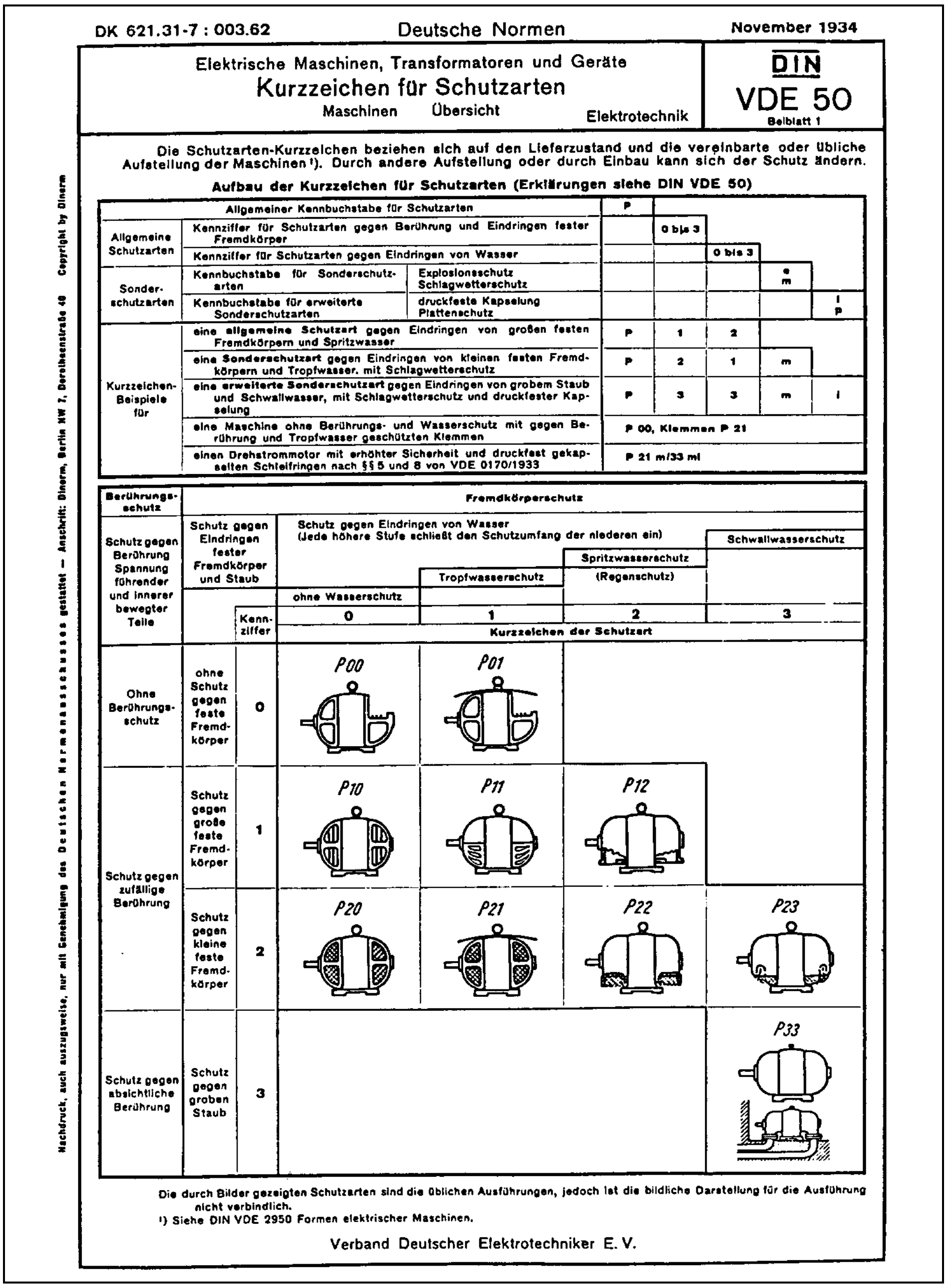
Table 23.2.2 Assignment of the occurrence of water and foreign objects on the selection of apparatus according to DIN VDE 0100-510 : 1997; Table 51 A

Following from the work of TC 75 of the IEC, all the standards in the DIN IEC 60721 series »Classification of environmental conditions« have been under revision. The aim is to classify both the requirements on electrical apparatus and the suitability for all types of environmental conditions by means of abbreviations. The system is just as complex and complicated as the natural conditions being standardized.

Fig. 23.2.3 »Outdoor installation« cannot be avoided for a skilift drive. The long idle periods are as critical as the effects of snow, ice and rain

24 Origin of the IP Code

The IP Code is the evolution of a designation system which was initially introduced in November 1934 by the German Standard DIN VDE 50 »Electrical machines, transformers and apparatus; Codes for the degrees of protection; Definitions« [11]. The system was taken over in various national standards and in the international recommendations IEC 144 (1963) »Degrees of protection of enclosures for low-voltage switchgear and controlgear« [1] and IEC 60034-5 (1968) »Rotating electrical machines; Part 5: Degrees of protection by enclosures for rotating machinery« [2].



DK 621.31-7 : 003.62 Deutsche Normen November 1934

Elektrische Maschinen, Transformatoren und Geräte
Kurzzeichen für Schutzarten
Maschinen Übersicht Elektrotechnik

DIN VDE 50 Beiblatt 1

Die Schutzarten-Kurzzeichen beziehen sich auf den Lieferzustand und die vereinbarte oder übliche Aufstellung der Maschinen[1]). Durch andere Aufstellung oder durch Einbau kann sich der Schutz ändern.

Aufbau der Kurzzeichen für Schutzarten (Erklärungen siehe DIN VDE 50)

Allgemeiner Kennbuchstabe für Schutzarten			P				
Allgemeine Schutzarten	Kennziffer für Schutzarten gegen Berührung und Eindringen fester Fremdkörper			0 bis 3			
	Kennziffer für Schutzarten gegen Eindringen von Wasser				0 bis 3		
Sonderschutzarten	Kennbuchstabe für Sonderschutzarten	Explosionsschutz Schlagwetterschutz				e m	
	Kennbuchstabe für erweiterte Sonderschutzarten	druckfeste Kapselung Plattenschutz					l p
Kurzzeichen-Beispiele für	eine allgemeine Schutzart gegen Eindringen von großen festen Fremdkörpern und Spritzwasser		P	1	2		
	eine Sonderschutzart gegen Eindringen von kleinen festen Fremdkörpern und Tropfwasser. mit Schlagwetterschutz		P	2	1	m	
	eine erweiterte Sonderschutzart gegen Eindringen von grobem Staub und Schwallwasser, mit Schlagwetterschutz und druckfester Kapselung		P	3	3	m	l
	eine Maschine ohne Berührungs- und Wasserschutz mit gegen Berührung und Tropfwasser geschützten Klemmen		P 00, Klemmen P 21				
	einen Drehstrommotor mit erhöhter Sicherheit und druckfest gekapselten Schleifringen nach §§ 5 und 8 von VDE 0170/1933		P 21 m/33 ml				

Berührungsschutz	Fremdkörperschutz		Schutz gegen Eindringen von Wasser (Jede höhere Stufe schließt den Schutzumfang der niederen ein)			
Schutz gegen Berührung Spannung führender und innerer bewegter Teile	Schutz gegen Eindringen fester Fremdkörper und Staub	Kennziffer	ohne Wasserschutz 0	Tropfwasserschutz 1	Spritzwasserschutz (Regenschutz) 2	Schwallwasserschutz 3
			Kurzzeichen der Schutzart			
Ohne Berührungsschutz	ohne Schutz gegen feste Fremdkörper	0	P00	P01		
Schutz gegen zufällige Berührung	Schutz gegen große feste Fremdkörper	1	P10	P11	P12	
	Schutz gegen kleine feste Fremdkörper	2	P20	P21	P22	P23
Schutz gegen absichtliche Berührung	Schutz gegen groben Staub	3				P33

Die durch Bilder gezeigten Schutzarten sind die üblichen Ausführungen, jedoch ist die bildliche Darstellung für die Ausführung nicht verbindlich.

[1]) Siehe DIN VDE 2950 Formen elektrischer Maschinen.

Verband Deutscher Elektrotechniker E. V.

Fig. 24
DIN VDE 50 – origin of the coding system for degrees of protection in 1934 (no longer in use)

The IEC Technical Committee No. 70 (IEC/TC70) was set up in 1970 to process a proposal by a working group of the Committee of Action for bringing together, in a single document, the requirements of IEC publications IEC 144 and 34-5. This was accomplished in 1974 at the meeting in Paris, which led to the creation of IEC 529 (1976) »Classification of degrees of protection provided by enclosures«. In the course of its transfer from a national to an international standard the code letter has been changed from »P« to »IP« (= International Protection).

25 Symbols

The household appliances and installations sector in particular have used so-called »droplet symbols« to designate the degree of protection. This type of classification found occasional acceptance with the IEC (International Electrotechnical Commission) via the previously quite significant specifications of the CEE (international commission for rules for the evaluation of electrical products). It also continues to be found in VDE regulations, though its use is decreasing.

For water protection – and this is traditionally the aim of the droplet code – the classification of the degrees of protection corresponds almost exactly with the groupings in the IP Code. Only two symbols are indicated for protection against the ingress of foreign objects, as shown in Fig. 25.

The most important areas of application and the reduced range of symbols for selection have forced the common use of a single symbol on the machine, usually a »droplet symbol«.

This was the case, for example, according to the most recent »Specifications for plugs, sockets and couplings for industrial applications« DIN EN 60309, Part 1 / Classification VDE 0623, Part 1 in a transition phase extended to 1998.

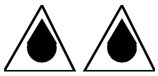
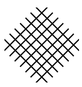
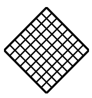
Symbol	Definition
	Protected against dripping water
	Protected against spraying water and rain
	Protected against splashing water
	Protected against water jets
	Protected against immersion and flooding, water-tight
 . . . **bar** . . . **m**	Protected against submersion, pressurized-water-tight
	Dust-protected
	Dust-tight

Fig. 25 Symbols identifying degrees of water protection and dust protection for electrical apparatus in household appliances and installations

25.1 ACOS commissioning of the replacement of the graphic symbol

In the early 1980s, ACOS (Advisory Committee on Safety) commissioned the TC 70, which was responsible for degrees of protection within the IEC, with the establishment of prerequisites to replace the symbol classification in the revision of the IEC 60529 as the fundamental safety standard. In the long, still ongoing transition phase, often both types of symbol indicating degree of protection can be found on appartus and in catalogs.

The minor discrepancies found in some cases in the testing and acceptance conditions for the two classification systems have been compared in lengthy consultations in order to make a transition from the symbol code to the IP Code possible.
At the request of technical committees for household appliances (IEC/TC61) a divergence from the previously valid regulation in the designation for water protection was agreed to, in which the indication of a certain degree of protection always implies that all the lower degrees of protection are met as well. The exception applies to the transition from protection against water jets (IPX5 and IPX6) to immersion protection (IPX7 and IPX8).
In accordance with another request from the household appliances sector, oscillating pipes up to a radius of 1600 mm are now permissible for the spraying and splashing water tests IP3X and IP4X. The water throughput rate was determined to produce an approximately equally high degree of stress for each unit area.

The aim is to create a unified and international code for degrees of protection for all types of electrical apparatus.

25.2 Comparison of the IP Code and symbols

There is no standardized »conversion table« for the two classification systems, since the conditions for testing and acceptance deviate slightly.
If one assumes that the conditions of the standard will be met in practice with a sufficient degree of reliability, the comparisons shown in the following table may be used:

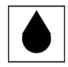
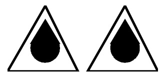
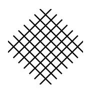
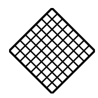
Degree of IP protection	Graphic symbol
IPX1	
IPX2	
IPX3	
IPX4	
IPX5	
IPX6	
IPX7	
IPX8	 **. . . bar . . . m**
IP5X	
IP6X	

Fig. 25.2 Approximate comparison of IP Code and graphic symbols

25.3 No correlation between the first and second code number in the IP Code

Whenever machines are installed for use in dust-laden areas that are marked only with a droplet symbol, the attempt is made to create an interrelation between the first code number (protection against foreign objects) and the second code number (water protection). Depending on the design of the machine this relationship may exist, though this may not necessarily be the case.

Two examples:

- ☐ When a high degree of dust protection (IP6X) is attained through the use of filters (e.g., several layers of fine wire mesh), ***this will not provide water protection*** (IPX0).

- ☐ A high degree of water protection (IPX5) can be obtained by casting the winding. The enclosure itself has relatively large openings that do not prevent the entry of dust. The specifications in the acceptance conditions of EN 60529 were used with regard to protection against the ingress of water, where winding parts – in compliance with the test – may become wetted with water so long as they are properly designed (with insulation). The requirements of the ***protection against dust explosion*** are not observed in this instance since the dust deposits could possibly begin to smolder on the hot winding parts.

Deriving the ***protection against ingress of foreign objects*** *from the* ***degree of protection for water protection*** strictly on the basis of the "hard copy" – i.e. using only the code – is therefore ***not possible***.
This does not exclude the establishment of a corresponding relationship in individual cases on the basis of experience or detailed knowledge of the design (see 23.4.1).

25.4 Machines with droplet symbols installed in dust-laden operating zones

The previous sections have indicated the problem for designers, erectors and operators when selecting machines marked with droplet symbols (i.e., without information on dust protection) for use in dust-laden zones.

The simplest and safest practice is to select a machine that uses the IP Code in its documentation (catalog, operating manual, etc.) and for its identification (rating plate, labels).
If this is not possible, a distinction must be made between the following types.

25.4.1 Zones with non-flammable dust

These zones (such as cement factories, lime works) "only" require the reliable function of the machinery; it is therefore permissible for a ***personally accountable electrician*** to select the appropriate type of machine.
It should be possible to install the proper machine in conjunction with an appropriate level of experience and knowledge of the design of the machine, and in consideration of the limitations in accordance with Section 5.

25.4.2 Zones with flammable dust

Since serious risks are associated with »operating areas at risk of fire or dust explosion« they are subject to ***official regulation.***
The requirements in these standards must also be ***formally*** observed for both safety-related and liability-related reasons. This means that dust protection must be guaranteed and evident in the form of an IP Code.

It is recommended to request a »***manufacturer's declaration«*** for machines marked with droplet symbols that confirms the complete IP Code for the given machine type.
A literal definition of dust protection is not sufficient.

26 Proof of effectiveness of IP65

The effectiveness of the IP65 enclosure has been verified by many typical applications. Operation under adverse ambient conditions over a period of many years has shown that there will be natural wear but no deterioration of the winding and its insulation resistance or other internal parts. Figures 26.1 to 26.7 show practical examples from the field: in all cases the windings still exhibited full insulation.

The fully enclosed design in accordance with IP65 is more and more the preferred design in various industrial sectors, and especially where faultless and maintenance-free operation is required of the drive motors in spite of adverse ambient conditions.
Figures 26.1 to 26.39 show a selection of the many different possible applications.

Fig. 26.1
Stator of geared motor with IP65 enclosure after many years in chemical-laden atmosphere. Although exterior of housing shows considerable signs of chemical attack the winding still has full insulation capabilities.

Fig. 26.2
Drum motor. Severe chemical attack has destroyed the casing.

Fig. 26.3
Slip rings and brush holder of the motor shown in Fig. 26.2. The supply leads are protected according to IP65 and are still in working order.

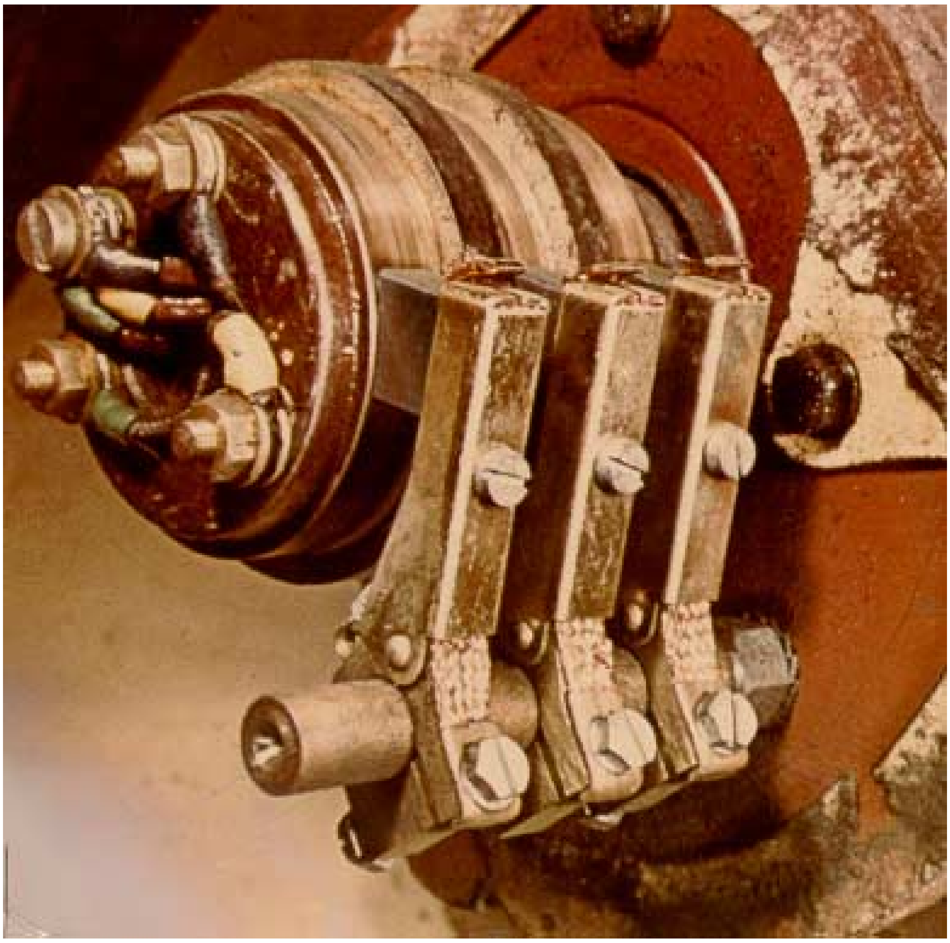


Fig. 26.4
Geared motor after humidity test. The motor was installed outdoors for one year and wetted by spray or natural rain.

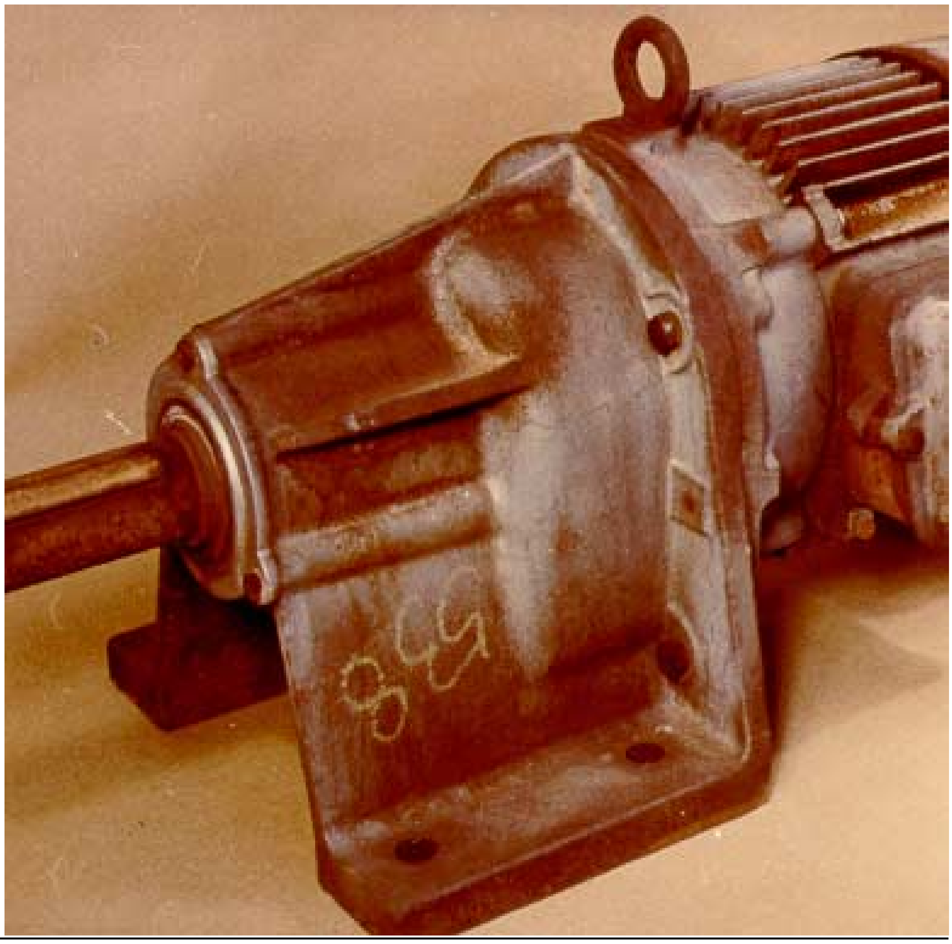


Fig. 26.5
Terminal box of the geared motor shown in Fig. 26.4 clearly shows no detectable ingress of moisture.

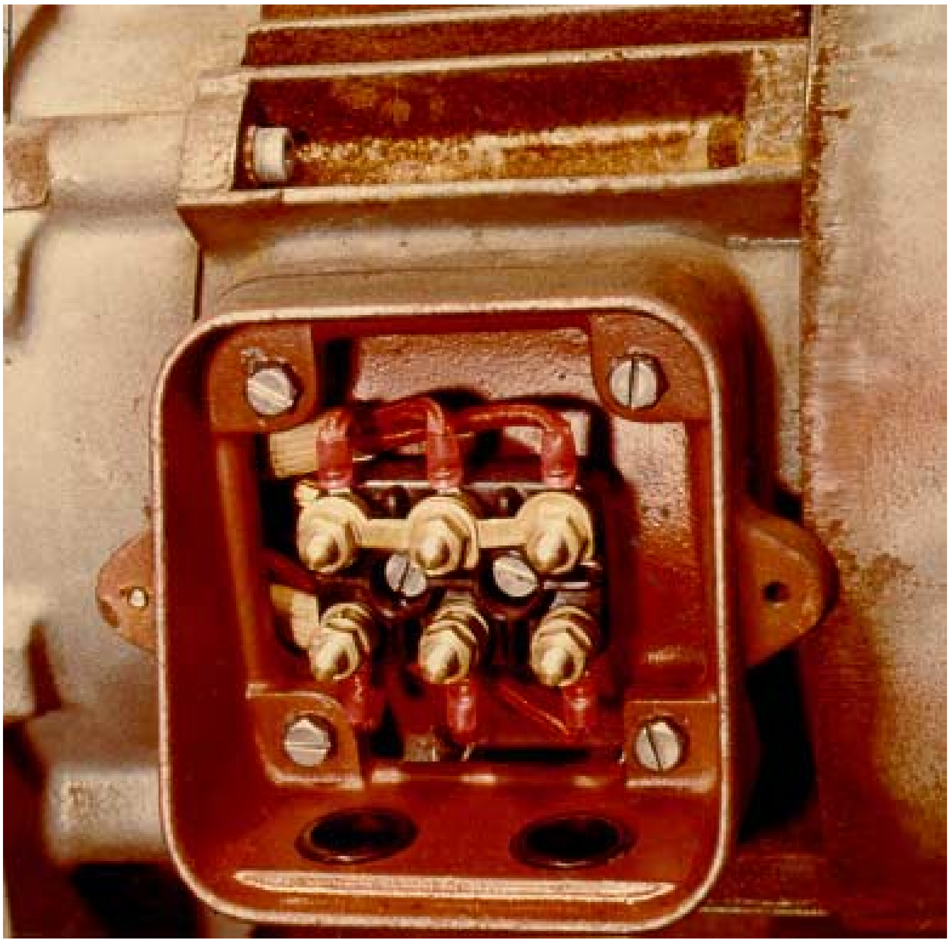


Fig. 26.6
Output shaft of the geared motor in Fig. 26.4. Considerable rusting is visible on the parts exposed to continuous rain for one year, but the perfect condition of the bearing (bearing flange and shaft seal have been removed).

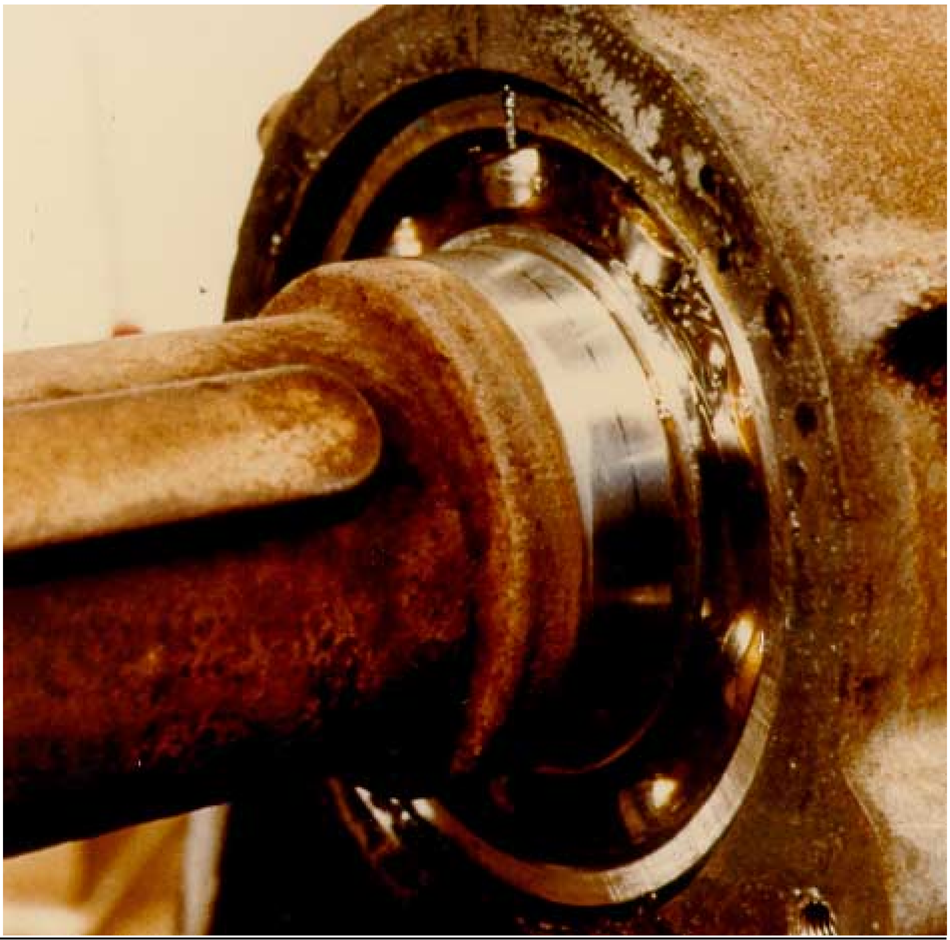


Fig. 26.7
Geared motor after one year's operation in adverse conditions.

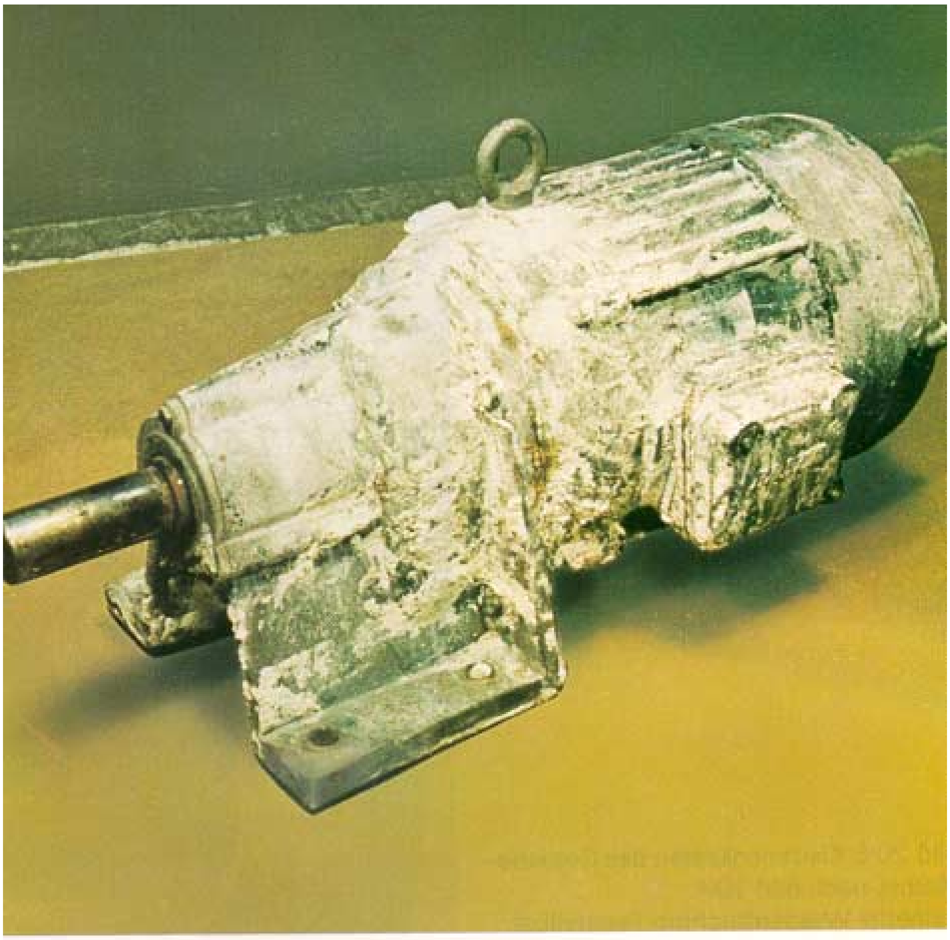


Fig. 26.8
Three-phase geared motors of various types in a sewage tank scraper.

Fig. 26.9
Three-phase geared motors of various types in a sewage treatment plant.

Fig. 26.10
Three-phase geared motor of vertical mounting on an agitator in a harbor filtration plant.

Fig. 26.11
Three-phase geared motor of various mounting on a scraper in a concrete mixing plant.

Fig. 26.12
Three-phase motors in a tar-macadam mixing plant.

Fig. 26.13
Three-phase of geared motors various mounting on an acid mixing plant.

Fig. 26.14
Three-phase drum motor driving the conveyor belt of a river bed excavator.

Fig. 26.15
Three-phase geared motor driving a screw conveyor for coarse solids.

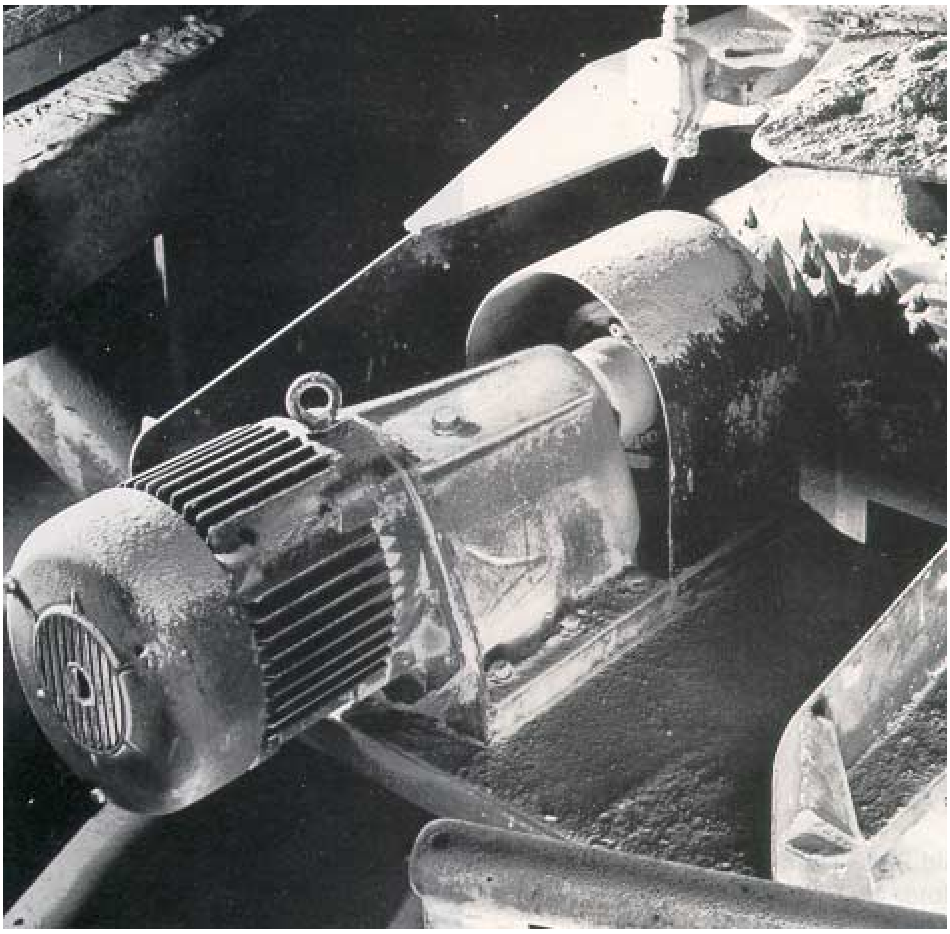


Fig. 26.16
Three-phase geared motor for driving a conveyor in a copper refining plant in a strongly corrosive atmosphere.

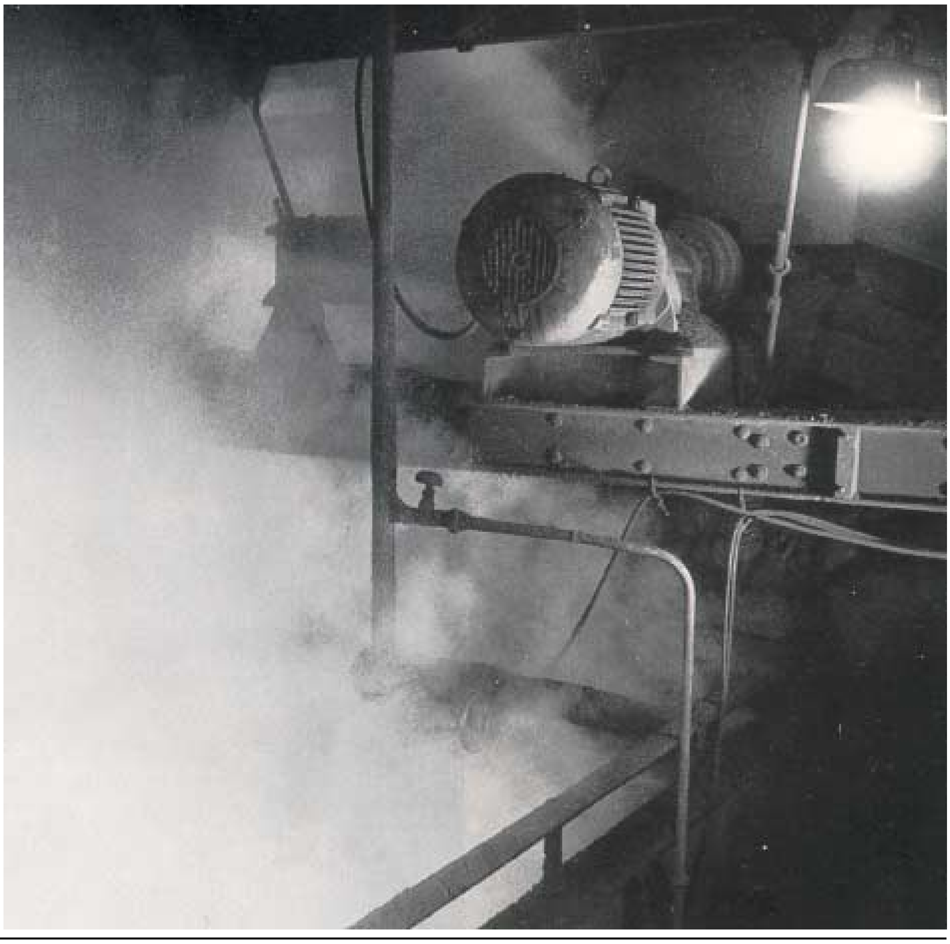


Fig. 26.17
Three-phase geared motors in a flanged housing, mounted vertically, in an animal feed plant producing a very dusty environment.

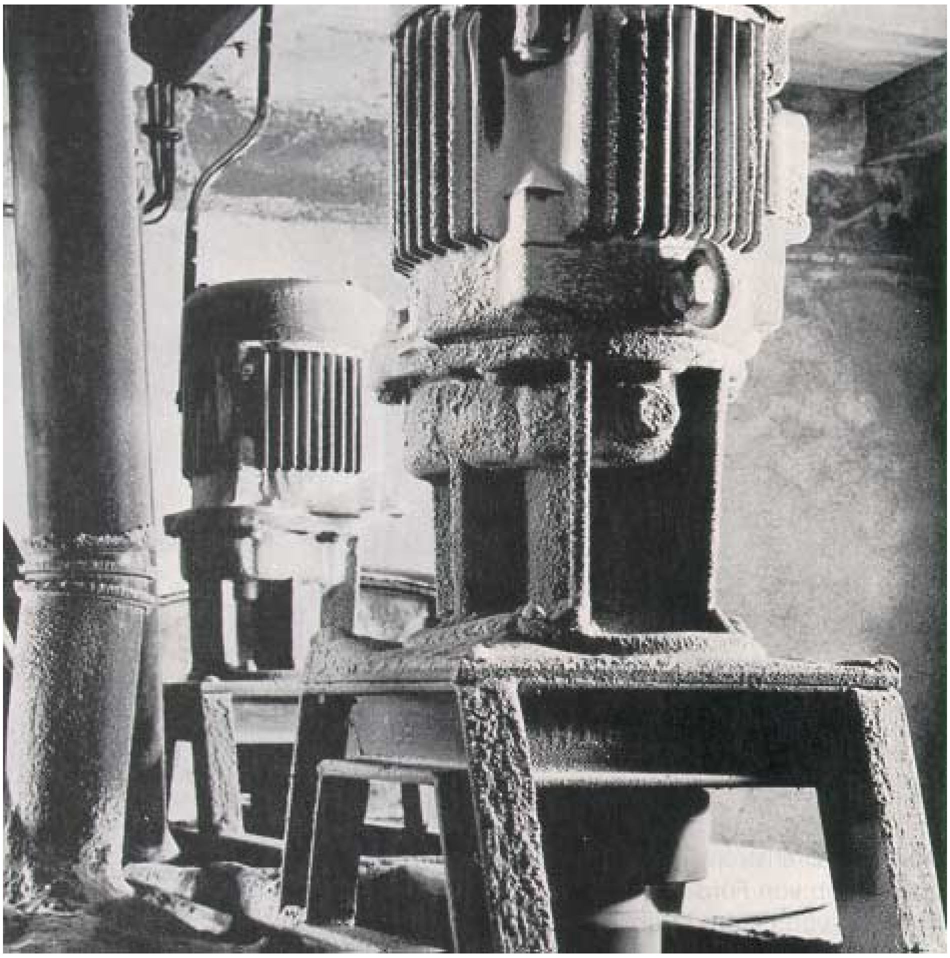


Fig. 26.18
Three-phase geared motor driving a fermentation drum in a damp and very aggressive atmosphere.

Fig. 26.19
Three-phase geared motor driving a stable mucking-out plant. Outdoor installation.

Fig. 26.20
Three-phase drum motors driving conveyors for the mixing of ores and salt in a copper plant.

Fig. 26.21
Fishing vessel after several months at sea, showing considerable rust formation.

Fig. 26.22
Adjustable speed geared motors with totally enclosed wide V-belt drive in a bottle cleaning and filling plant.

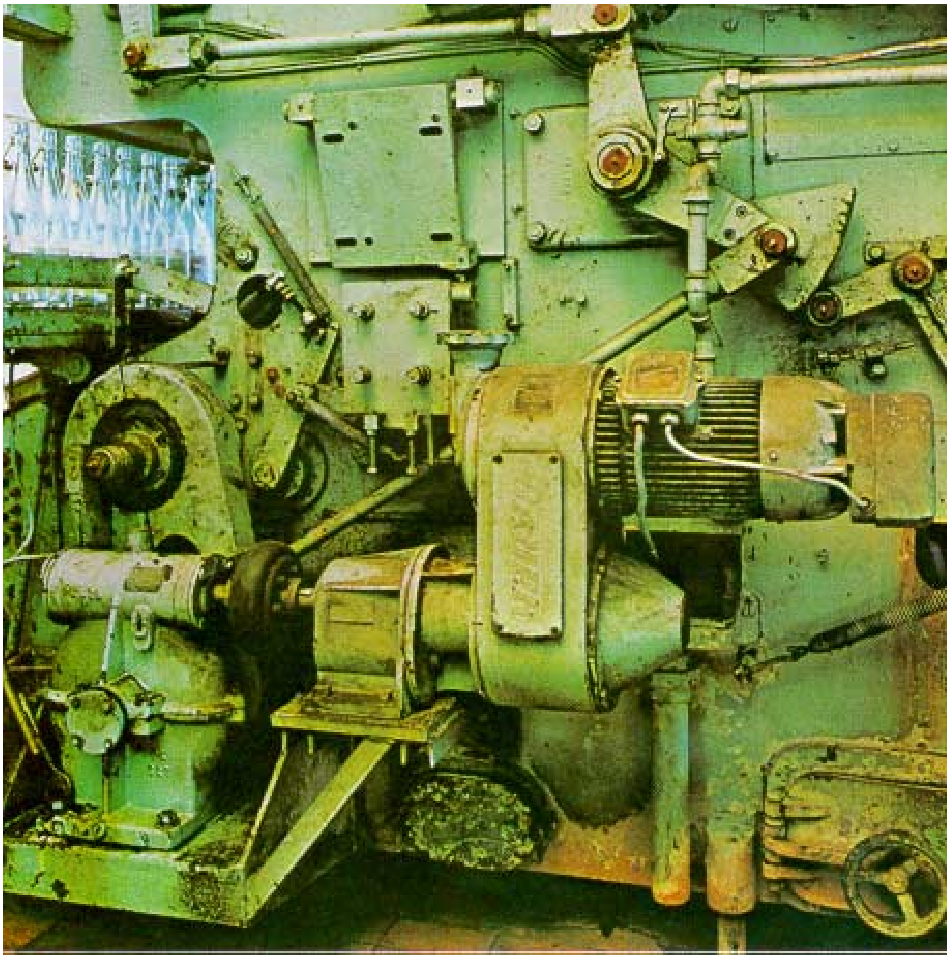


Fig. 26.23
Motor drive for a swing door in a fish auction hall with salty atmosphere.

Fig. 26.24
D.C. geared motor driving a variable-speed swimming pool training gantry.

Fig. 26.25
Beaters for dust filters in a cement factory. Motors installed in open air.

Fig. 26.26
Drives for conveying plant in a cement factory.

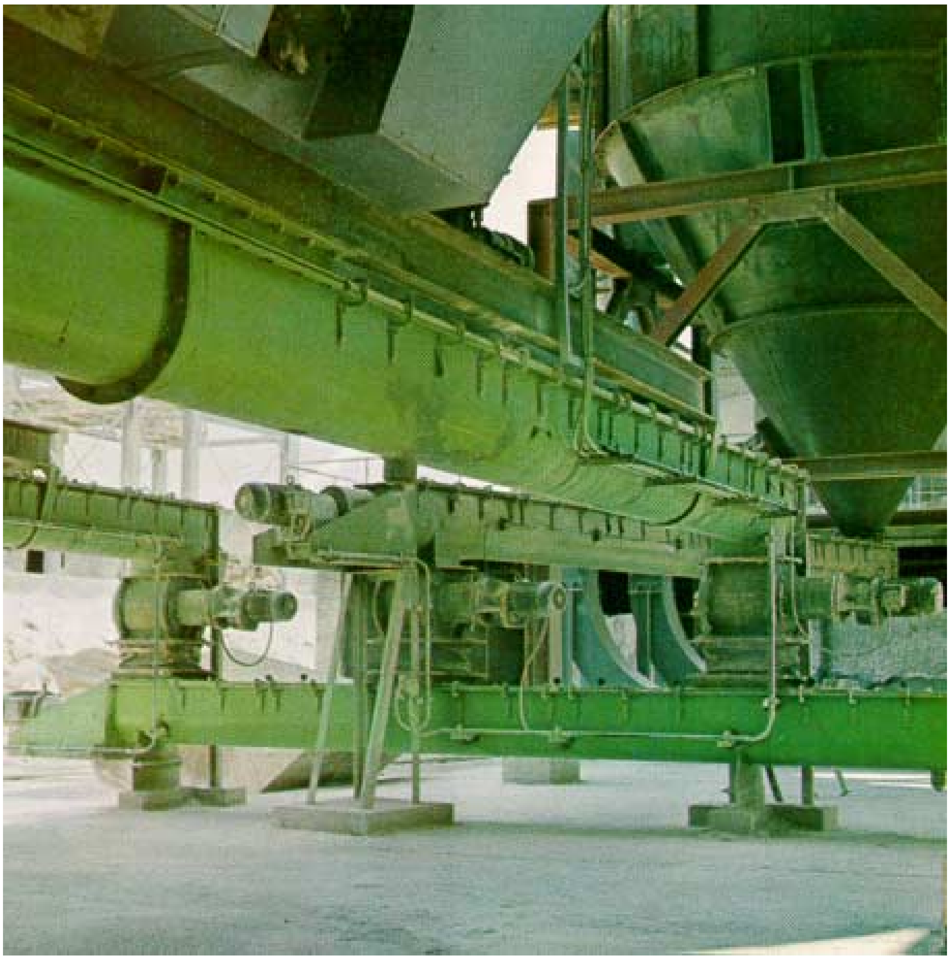


Fig. 26.27
Adjustable-speed geared motors driving a mixing arrangement in an animal feed blending plant.

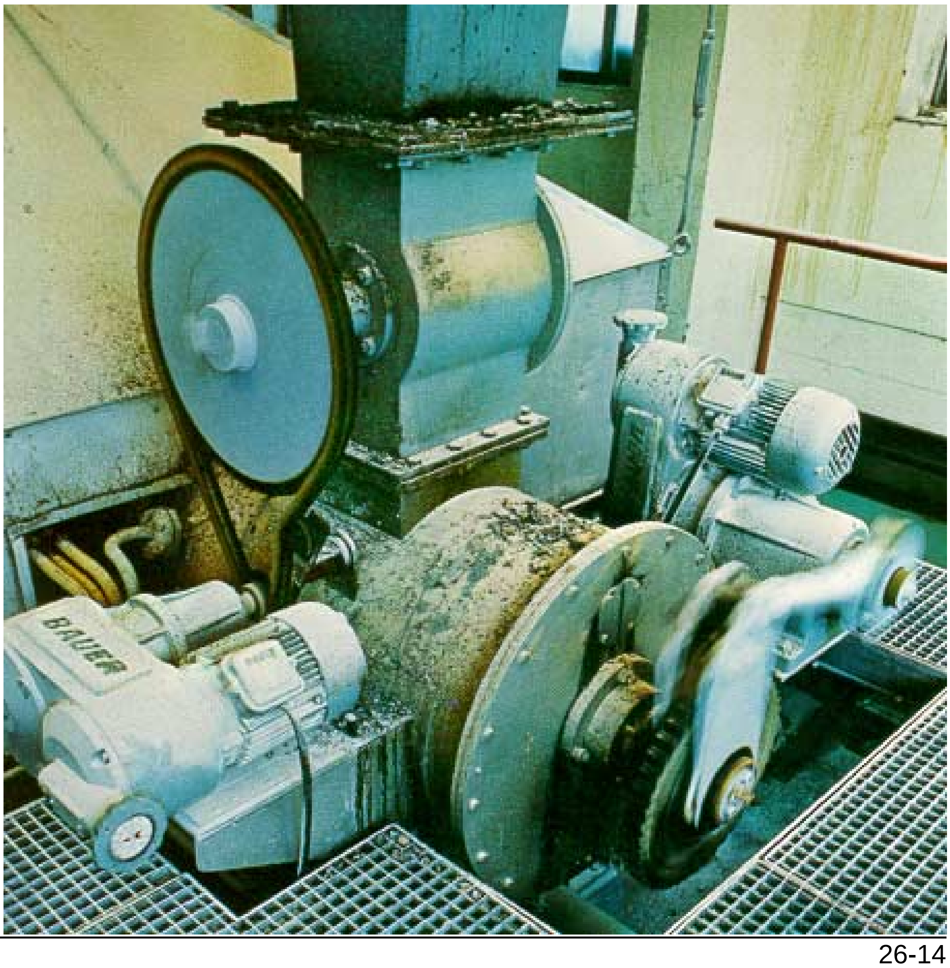


Fig. 26.28
V 1 arrangement of geared motors, driving aerators in a sewage treatment plant.

Fig. 26.29
Adjustable-speed geared motors driving aeration equipment at a settling tank.

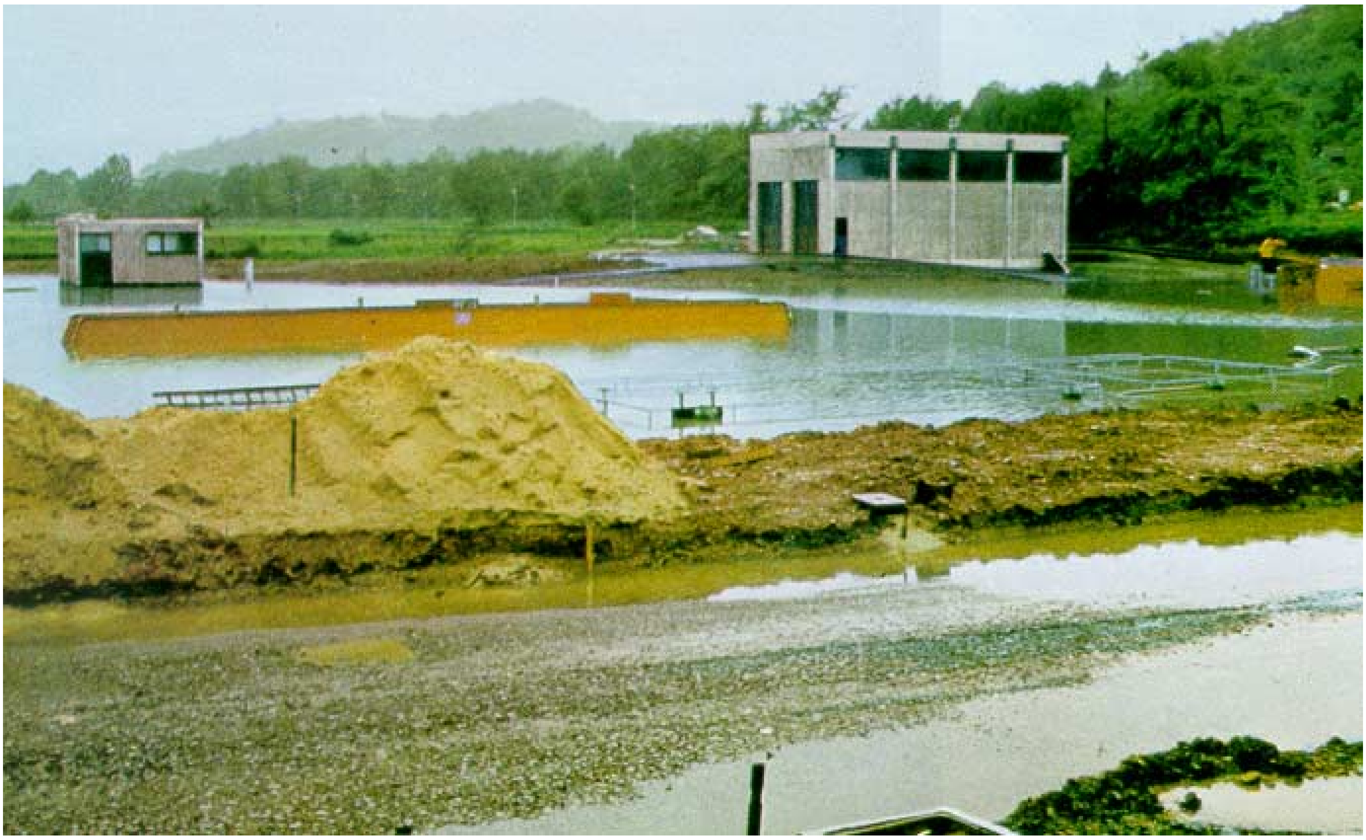


Fig. 26.30 Flooding of an aeration pond. The geared motors in the IP65 range, installed at the interceptor bridges have withstood this “test” extraordinarily well. Here the special degree of protection IP66 offer a real »chance of survival«.

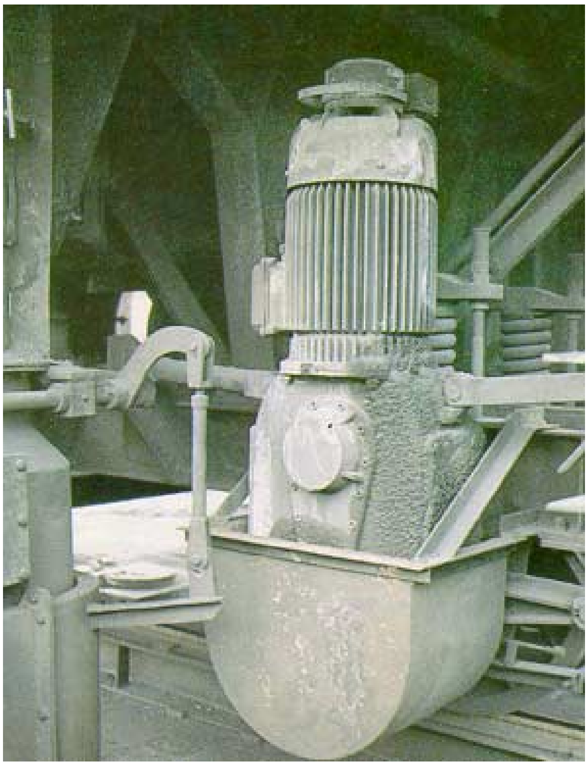


Fig. 26.31 Transport drive for a 60 ton coking oven loading wagon in a Swedish steelworks.

Fig. 26.32 Conveyor drive for saltwater fish.

Fig. 26.33
Open-air installation in South America.

Fig. 26.34
Drives for rising conveyor belts in a dry, dusty atmosphere.

Fig. 26.35
Screw conveyor for lime.

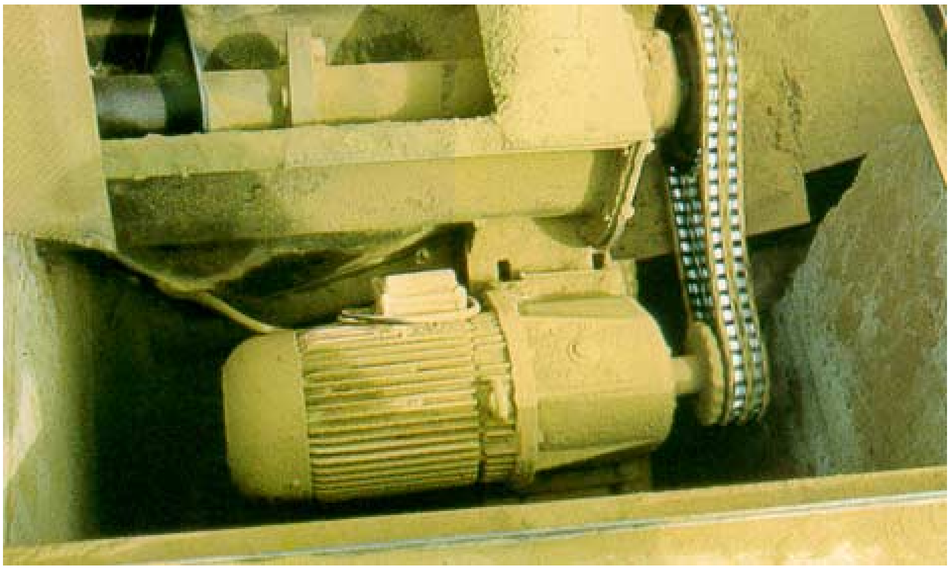


Fig. 26.36
Drive in a foundry.

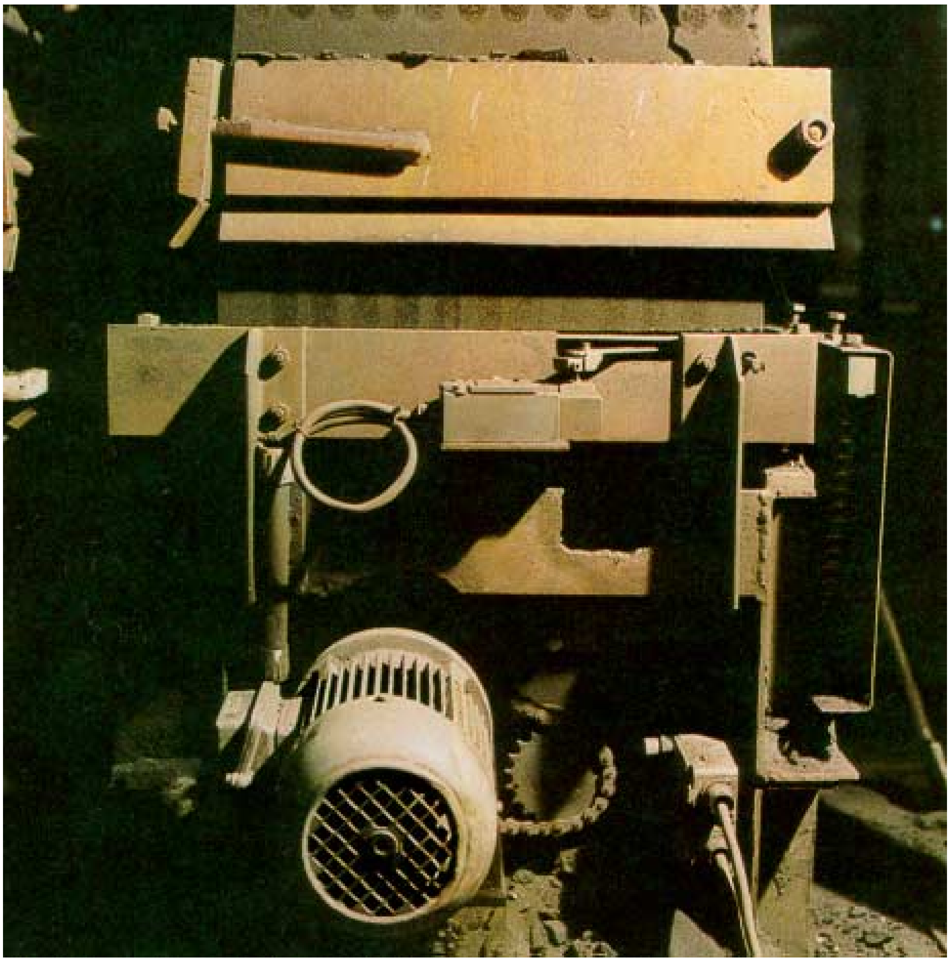


Fig. 26.37
Drive for a screw conveyor in adverse ambient conditions.

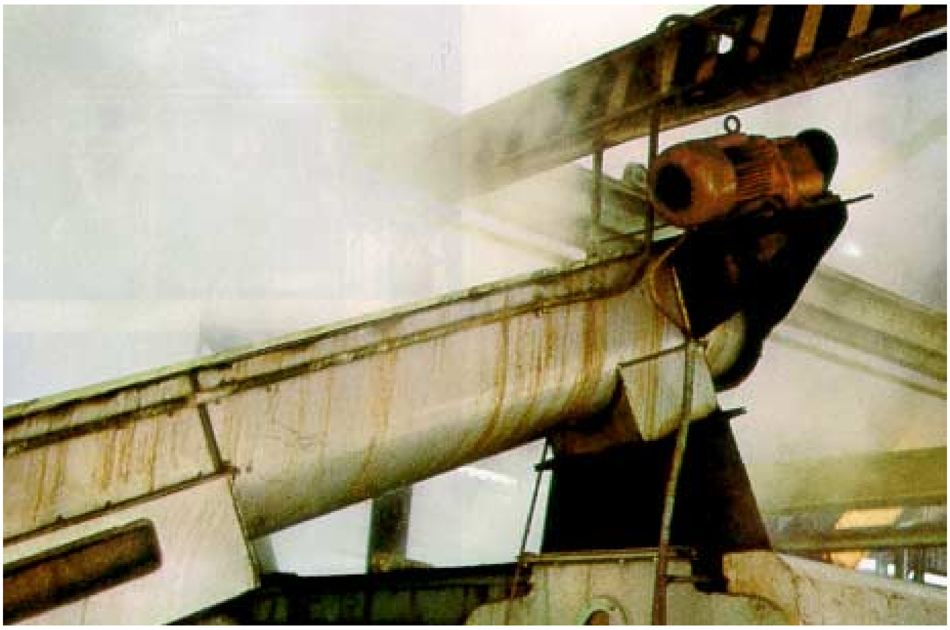
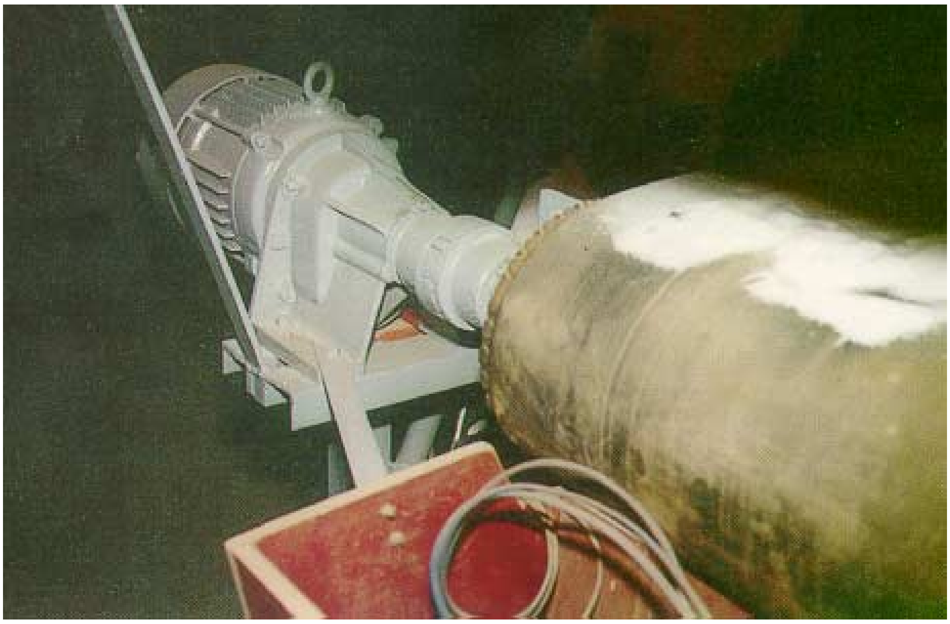


Fig. 26.38
Collector belt for salt downstream of an evaporator boiler.

Fig. 26.39
Conveyor belt drive in the Lüneburg salt museum. Built approx. 1950.



Bibliography

1 IEC 144 (First edition 1963)
Degrees of protection of enclosures for low-voltage switchgear and controlgear

2 IEC 34-5 (First edition 1968)
Degrees of protection by enclosures for rotating machinery

3 IEC 60529 (Second edition 1989)
Degrees of protection provided by enclosures (IP Code)

4 IEC 60034-5 (Fourth edition 2000) = EN 60034-5 = VDE 0530 Teil 5
Degrees of protection provided by the integral design of rotating electrical machines (IP code) – Classification

5 NEMA MG1 (1998)
Part 5: Rotating electrical machines – Classification of degrees of protection provided by enclosures for rotating machines

6 EN 60529 (1991 + A1:2000) = VDE 0470 Teil 1
Degrees of protection provided by enclosures (IP Code)

7 IEC 61032 = EN 61032 = VDE 0470 Teil 2
Test probes to verify protection by enclosures

8 IEC 62262 = EN 50102 = VDE 0470 Teil 100
Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)

9 EN 294
Safety of machinery – Safety distances to prevent danger zones being reached by the upper limbs

10 IEC 61241-1
Electrical apparatus for use in the presence of combustible dust
Part 1: Protection by enclosures "tD"

11 *Greiner, H.:*
Entwicklung der Schutzartbezeichnung von der nationalen zur internationalen Norm
Bd. 14 "Geschichte der Elektrotechnik"; VDE-Verlag GmbH; Berlin, Offenbach (1994)

12 *Nowak, K.:*
Normen und Schutzarten für die Elektro-Installation
Pflaum Verlag München (1985)

13 *Rudolph, W.:*
Safety of electrical installations up to 1000 V
VDE-Verlag GmbH; Berlin, Offenbach (1990)

14 *Vogl, G.:*
Umweltsimulation für Produkte
Vogel Buchverlag, Würzburg (1999)

15 *Greiner, H.:*
Protection measures for three-phase geared motors
published by Danfoss Bauer GmbH, D-73726 Esslingen (2000)

Index of keyword

Keyword	Section
A	
Access probe	12.1.4
ACOS	25.1
Additional letter for protection against access	3.3
Air-conditioning connection	13.4.2
B	
Back of the hand	3.3.1
C	
Child’s finger	12.3
Cleaning solvents	9.4.5
Clearance, protection against access	12.1.3
Code number	3.2
Condensation	13
Cooling tower fans	9.4.1
CORO	19
Corrosion protection	19
D	
Degrees of protection	1
Degrees of protection in North America	22
Degrees of protection IP65 (proof of effectiveness)	26
Degrees of protection, frequently used	4.1
Delivery rate	8.1
Dripping water	6
Drives	1
Droplet symbols	25
Dust chamber	10.1
Dust-explosion protection	15
Dust-proofing test	10
Dust-proofing test (variation)	11
E	
Effectiveness of degrees of protection IP65	26
Electrical accidents, statistics	12.2
Electrical machines (degrees of IP protection)	4
European standard for IP degrees of protection	2
External fan, access protection	4.2
F	
Finger safety	12.3
Fingers	3.3.1
G	
Gap width for dust-proofing test	11.1
Grain size for dust test	11.2
Grain size for dust test	11.2
Graphic symbols	25
H	
Hazardous part, protection against access	12.1.1
High-pressure cleaning	9.4.5
Humidity	14
I	
IK Code	20.2
Immersion, continuous	6
Immersion, temporary	6
Impact resistance	20
Impact test	20
Information on N. A. degrees of protection	22
Installation specifications, IP degrees of protection	9.1
International use of the IP Code	21
IP Code	3
IP Code – international	21
IP degree of protection	1
IP degree of protection for electrical machines	4

IP degrees of protection and types of protection	16
IP system (origin)	24
IP65 (proof)	26
IP66	9
L	
Long-term spraying	9.3
M	
Mold	14.3
N	
North America, degrees of protection	22
O	
Optional additional letter in IP Code	3.3
Origin of the IP Code	24
Oscillating pipe	8.1
Oscillating tube	8.1
Outdoor installation	23
Outdoor installation	23
P	
Penetration depth, test finger	12.3
Protection against access	5
Protection against access	12
Protection against dust	10
Protection against ingress of foreign objects	5
PTB report on degrees of protection test	17
R	
Rain	23.1
S	
Sewage treatment plants	9.4.2
Special degrees of protection IP66	9
Splashing water	6
Spraying water	6
Supplementary letters	7
T	
Terminal box	18
Termites	14
Test examples (water protection)	8
Test for degrees of protection (PTB report)	17
Test for dust protection	10
Test for protection against access	5
Test for protection against ingress of foreign objects	5
Test for water protection	6
Test probes	3.3.1
Tool	3.3.1
Tropical conditions	14
Types of protection	16
V	
Variation of the dust-proofing test	11
W	
Water jets	8.2
Water jets	6
Water protection	6
Water protection (test examples)	8
Wire	3.3.1