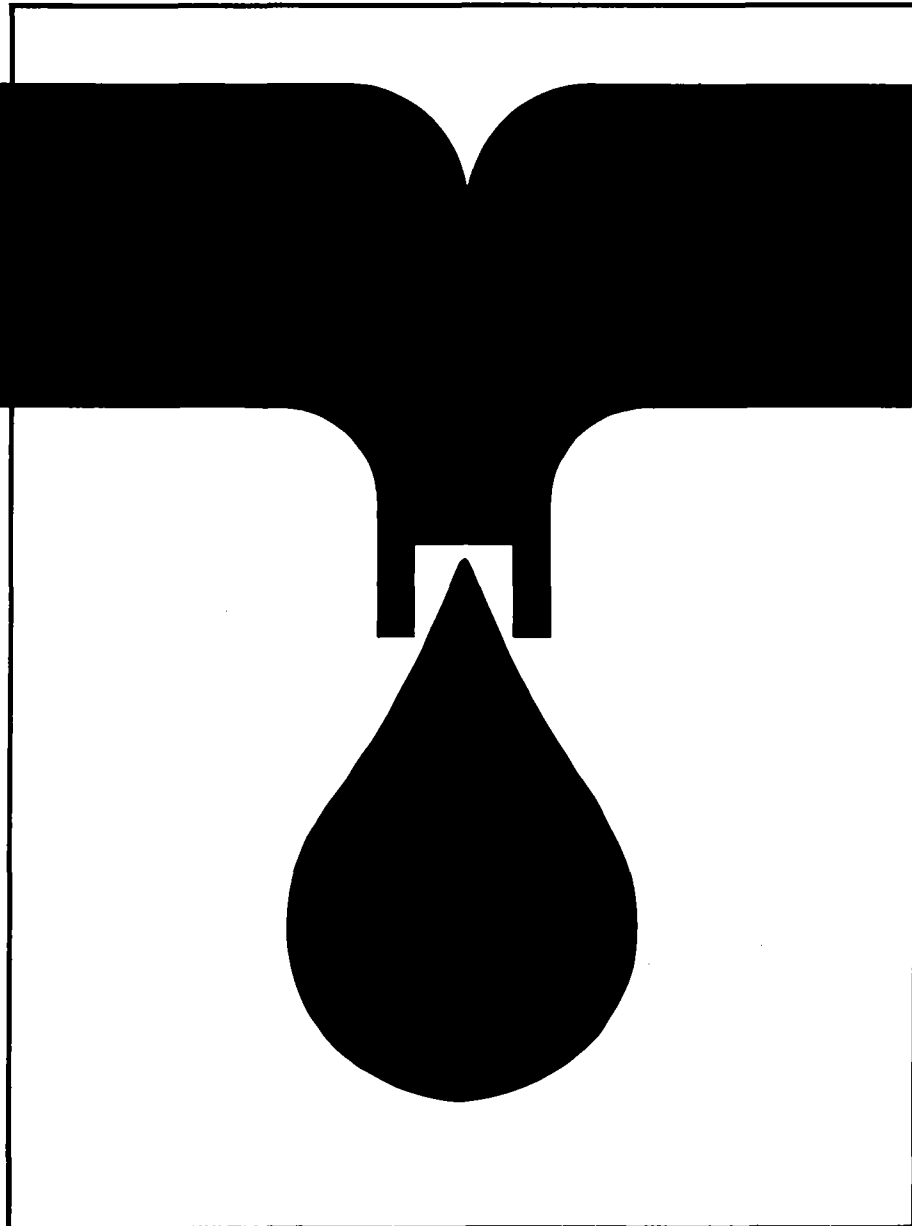




TRAINING MODULES FOR WATERWORKS PERSONNEL



Special Knowledge

2.1

Engineering, building and auxiliary materials

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Foreword

Even the greatest optimists are no longer sure that the goals of the UN "International Drinking Water Supply and Sanitation Decade", set in 1977 in Mar del Plata, can be achieved by 1990. High population growth in the Third World combined with stagnating financial and personnel resources have led to modifications to the strategies in cooperation with developing countries. A reorientation process has commenced which can be characterized by the following catchwords:

- use of appropriate, simple and - if possible - low-cost technologies,
- lowering of excessively high water-supply and disposal standards,
- priority to optimal operation and maintenance, rather than new investments,
- emphasis on institution-building and human resources development.

Our training modules are an effort to translate the last two strategies into practice. Experience has shown that a standardized training system for waterworks personnel in developing countries does not meet our partners' varying individual needs. But to prepare specific documents for each new project or compile them anew from existing materials on hand cannot be justified from the economic viewpoint. We have therefore opted for a flexible system of training modules which can be combined to suit the situation and needs of the target group in each case, and thus put existing personnel in a position to optimally maintain and operate the plant.

The modules will primarily be used as guidelines and basic training aids by GTZ staff and GTZ consultants in institution-building and operation and maintenance projects. In the medium term, however, they could be used by local instructors, trainers, plant managers and operating personnel in their daily work, as check lists and working instructions.

45 modules are presently available, each covering subject-specific knowledge and skills required in individual areas of waterworks operations, preventive maintenance and repair. Different combinations of modules will be required for classroom work, exercises, and practical application, to suit in each case the type of project, size of plant and the previous qualifications and practical experience of potential users.

Practical day-to-day use will of course generate hints on how to supplement or modify the texts. In other words: this edition is by no means a finalized version. We hope to receive your critical comments on the modules so that they can be optimized over the course of time.

Our grateful thanks are due to

Prof. Dr.-Ing. H.P. Haug
and
Ing.-Grad. H. Hack

for their committed coordination work and also to the following co-authors
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It is my sincere wish that these training modules will be put to successful use and will thus support world-wide efforts in improving water supply and raising living standards.

Dr. Ing. Klaus Erbel
Head of Division
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Eschborn, May 1987

Title: Engineering, building and auxiliary materials

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1 Pipe materials

Pipes of the following types are used in water-supply systems: cast-iron pressure pipes, steel pipes, reinforced concrete pressure pipes, plastics pipes and asbestos cement pressure pipes.

1.1 Cast iron

The high carbon content of this material gives it its most important properties: i.e. good fusibility and casting properties. Cast iron is especially suitable for the cheap production of parts with intricate shapes. A distinction is made in pipe manufacture between three types of cast iron: cast iron with lamellar graphite, cast iron with spherical graphite and malleable cast iron.

Cast iron with lamellar graphite

The surfaces of fracture of this material are grey, because the carbon separates chiefly as graphite. If its structure is examined under a microscope, the lamellar flakes or segments of graphite are visible as dark veins. The segments can be regarded as cavities, filled with a body of graphite, which sharply notch the casting, reducing its load-bearing surface and thus considerably detracting from its properties of strength. When the material is machined, the graphite acts as a dry lubricant and the cavities cause the shavings to break off short.

Advantages of cast iron with lamellar graphite:

Good casting properties, vibration absorption and resistance to corrosion.

Disadvantages:

Low strength, high brittleness, thus poor impact resistance, liable to fracture under tensile stress (i.e. not ductile), comparatively heavy.

Cast iron with spherical graphite (ductile cast iron)

In cast iron with lamellar graphite, the graphite segments interrupt cohesion of the steely matrix and notch it, thus reducing the cross-sectional area of the metal parts, which is decisive for their strength. The lowest reduction of cross-section is achieved when the graphite separates in spherical form, since of all bodies having the same volume the sphere has the smallest surface area. The spherical shape of the graphite also means that the cavities do not have small radii of curvature, thus diminishing the notch effect. Castings in which the separated carbon has this optimum shape can be obtained by treating the smelt with magnesium and cerium. This type of cast iron is as easy to pour in its molten state as grey iron; following heat-treatment of the matrix it has properties similar to those of steel. However, the heat-treatment processes may double or even treble the price of the material. Vibration absorption and thermal conductivity are lower than those of cast iron with lamellar graphite.

Pipes and fittings are cast in sand moulds or produced centrifugally. The structure of centrifugally cast pipes on solidification is generally ferritic, that of pipes and fittings cast in sand moulds ferritic/perlitic. Pipes are produced in lengths of 5 to 6 m; the most common diameters are between 80 and 800 mm.

Advantages of cast iron with spherical graphite:

Centrifugally cast pipes have a high bursting strength; the material has good mechanical and bending strength and is impact-resistant.

Disadvantages:

Susceptibility to corrosion is greater than that of grey cast iron; pipes must be protected when bedded in aggressive soils or transporting aggressive water.

Malleable cast iron

Malleable cast iron is especially suitable for the production of thin-walled fittings, often of complicated shape. This is due both to the fact that white-solidifying cast iron flows well and is relatively easy to pour into intricate shapes, and also to the possibility of transforming the hard, brittle casting by subsequent heat-treatment into a material with steel-like properties.

Malleable cast iron is the term used for any alloy of iron and carbon, the carbon content generally being between 2.5 and 3.5%, which in its raw casting state is graphite-free, brittle and hard, and which through heat-treatment in a decarbonizing atmosphere becomes tough and malleable.

Malleable cast iron is used mainly in the production of parts having a relatively complicated shape and low wall thickness, for which grey cast iron is unsuitable because of its brittleness and cast steel because of difficulties in casting, and the production of which by forging or pressing steel is either technically impossible or prohibitively expensive.

The characteristic features of malleable cast iron, i.e.: good casting properties, high tensile strength, good toughness, optimum machinability, have made this material indispensable in the production of pipe fittings.

1.2 Steel

The many different varieties of steel can be grouped into two main categories, based on their use: constructional steels and tool steels. Steels in both groups may be unalloyed, low- or high-alloy.

Constructional steels are used to make machines and appliances, in structural steelwork, general building and pipe manufacture. General constructional steels are unalloyed steels classified according to their tensile strength. They can be easily moulded and welded. They are supplied as bar, structural and sectional steel and piping.

Welded pipes are generally made of steel types St 37-2 and St 52-3.

The abbreviations have the following meanings:

St 37-2: General constructional steel with a tensile strength between 360 N/mm^2 and 440 N/mm^2 , Grade 2.

St 52-3: General constructional steel with a tensile strength between 510 N/mm^2 and 610 N/mm^2 , Grade 3.

The special feature of St-52 is the fact that it has the strength of St-50 and the weldability of St-37. A normal St-50 steel is no longer weldable without special treatment, due to its carbon content.

Grading of general constructional steels:

Grade 1: Thomas steels for low requirements.

Grade 2: Siemens-Martin or oxygen steels for medium requirements; good resistance to brittle fracture, low phosphorus and nitrogen contents.

Grade 3: Siemens-Martin or oxygen steel for high requirements; low phosphorus and nitrogen contents.

Seamlessly extruded pipes are made from St-35. Steel pipes are supplied lined and with an exterior coating. Welded pipes are supplied in diameters from DN 80 to 2000 (DN diameters are given in mm), extruded pipes from DN 80 to 500.

Pipes are supplied in lengths between 8 and 18 m. The advantages of steel as pipe material are its high elasticity

and good weldability, plus both good mouldability and machinability with relatively low weight.

A disadvantage is its high susceptibility to corrosion, especially at joints.

1.3 Asbestos cement

Asbestos is a mineral silicate consisting of fibrous crystals. Properties: acid- and fire proof, poor conductor of heat and electricity, can be spun with cotton, flax or hemp into yarn and is easily combined with other materials.

Applications: fireproof clothing, boards and rope, clutch and brake linings; asbestos combined with rubber is used to make heat-resistant seals (Klingerit), and asbestos with cement (= asbestos cement) is highly resistant to weathering and is used for roofing and for pipes carrying raw, irrigation or drinking water under pressure or domestic and industrial sewage.

Asbestos cement pipes may be made only of asbestos fibres which do not contain other organic or inorganic fibres or contaminants of any kind. It must be possible to cut, saw and drill the finished pipes.

Asbestos cement pipes are produced in diameters from DN 65 to DN 400 and supplied in lengths of up to 4000 mm.

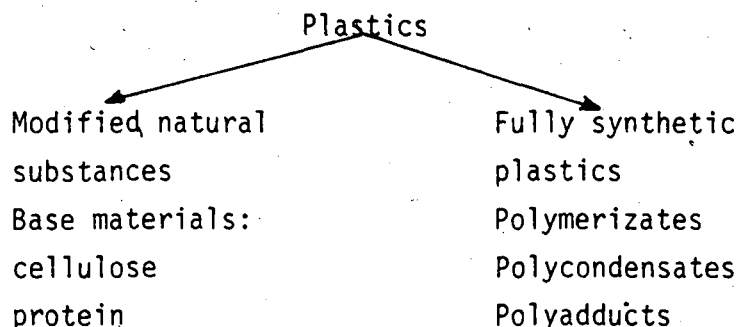
The outstanding advantage of asbestos cement pipes is their low weight. Care is necessary in cutting and drilling, however. These operations produce a fine dust which, if inhaled in, can cause silicosis and is also carcinogenic (cancer-producing). Asbestos cement pipes must therefore always be cut with special tools which do not produce the dangerous fine dust.

1.4 Plastics

Plastics are artificial materials consisting of organic macromolecules. These macromolecules either result from the

modification of natural materials which are already large-molecular (e.g. celluloid from cellulose), or else their production is fully synthetic. Coal, crude oil, natural gas, lime, water and air are the main raw materials used in the production of fully synthetic plastics.

Depending on the processes by which the material is formed from its structural units, a distinction is made between polymerizates, polyadducts and polycondensates.



The macromolecules of plastics are threadlike (linear) in shape and may or may not be cross-linked. Where the molecules are not cross-linked, they form no particular arrangement in relation to each other. Cross-linked molecules are joined together by valency bonds, forming a more or less dense, three-dimensional network.

Plastics in which the molecules are not cross-linked can be softened by heating and re-harden on cooling; these are known as thermoplastics (e.g. celluloid, PVC, PE).

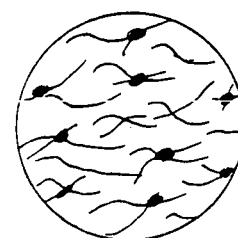
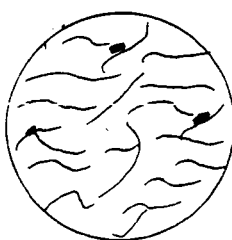
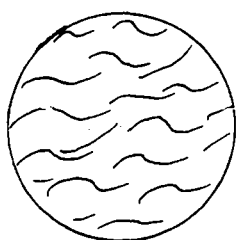
Plastics in which the molecules form a three-dimensional network - i.e. which are intensively cross-linked - lose their plasticity once they have been subjected to heat. They are infusible and insoluble in their final moulded shape, and decompose without softening if over-heated. These plastics are known as thermosetting (thermocuring) plastics (e.g. unsaturated polyesters, phenoplasts).

Elastic (rubberlike), only partially corss-linked plastics which, like thermocuring plastics, are also not made plastic by heating, are called elastomers, or vulcanized plastics (e.g. buna, silicone rubber).

Thermoplastics

Elastomers

Thermosetting



Threadlike (linear) molecules, not cross-linked

Large-meshed, three-dimensionally cross-linked network of macromolecules

Three-dimensional network of intensively cross-linked macromolecules

Becomes plastic on being heated

Do not become plastic on being heated; decompose at very high temperatures

Pressure pipes are produced from

Rigid PVC (polyvinyl chloride)

High-density PE (polyethylene/polyethene) and

Low-density PE

Polythene (PE) is a thermoplastic produced by polymerization of ethylene (ethene).

Polyvinyl chloride (PVC) is a thermoplastic produced by polymerization of vinyl chloride.

Rigid PVC, high-density PE and low-density PE are all used for buried pipes; the last two mainly for communication pipes and other small-diameter pipes and tubing.

Because of the permeability of PE pipes to certain volatile aromatic substances, these are not used where the soil can be expected to smell strongly (e.g. due to use of liquid manure etc.).

Plastics pipes are produced by extrusion, without seams. Rigid PVC and high-density PE pipes are supplied in lengths between 6 and 12 m; low-density PE pipes in coils of up to 200 m in length. Diameters are between 5 and 160 mm. Depending on wall thickness, the pipes are classified as follows: rigid PVC pipes as "light", "medium heavy" or "heavy"; low-density PE pipes as "light", "medium heavy" or "heavy"; high-density PE pipes as "medium heavy" or "heavy".

At temperatures above 40°C, the creep rupture strength of these materials drops sharply, so that their use at higher temperatures must be given careful consideration in each case.

Impact and shock resistance decrease as the temperature drops. This must be remembered when transporting or laying plastics pipes at sub-zero temperatures.

When plastics pipes are bedded, concentrated (point) loads, caused e.g. by stones in the soil, must be precluded. Extended exposure to sunlight (ultra-violet radiation) should also be avoided, since it may lead to embrittlement of the material.

1.5 Concrete

Concrete consists of an intimate mixture of water, sand, stone and a binder (e.g. cement) which hardens to a stone-like mass. Reinforced concrete is a composite material containing a reinforcement of steel. In water supply systems, pipes made of reinforced and of prestressed concrete are used.

Prestressed concrete pressure pipes and prestressed concrete pipes are usually produced in nominal diameters ranging from 500 to 2000 mm; the production of pipes with diameters greater than this depends on the manufacturing technique, and is currently possible up to 3500 mm. These pipes are generally supplied in lengths of 5 to 8 m. The main field of application of prestressed concrete pressure pipes covers nominal pressures up to ND (=German "Nenndruck") 16. Pipes for pressures higher than this can also be produced.

Reinforced concrete pressure pipes and reinforced concrete pipes are produced in nominal diameters from 250 mm up to, currently, 3500 mm; the usual lengths are between 2.50 and 5.00 m.

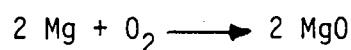
Reinforced concrete pressure pipes are generally used where pipes have to sustain a permissible operating pressure of up to approx. 4 atm. Occasionally it may be economical to produce pipes for higher pressure with small diameters; the same is true of reinforced concrete pressure pipes with sheet-metal sheaths, including, in this case, larger diameters.

Reinforced concrete pipes are subjected in operation to compressive, tensile and shear stresses. The compressive stresses are absorbed by the concrete, the tensile and shear stresses have to be withstood by the steel reinforcement. In the tensile stress zone, hair cracking may occur. Where pipes are exposed, the same effect may result from weathering. Premature destruction of the bond due to corrosion of the steel, especially in uncovered pipes, need not be feared if the width of the crack at the reinforcement is less than 0.4 mm. The steel rods or mesh embedded in the concrete are protected against rusting provided the concrete cover and cement content are adequate.

2 Corrosion

Corrosion is the chemical or electrochemical reaction of the surface of a metal with its environment. Corrosion has a detrimental effect on the properties of a material.

Chemical corrosion is the direct reaction of a metal with its environment, i.e. there is a direct exchange of electrons between the metal and its reactant, the metal giving up electrons. The reactant in chemical corrosion is usually oxygen; the metal oxidizes to metal oxide, e.g.



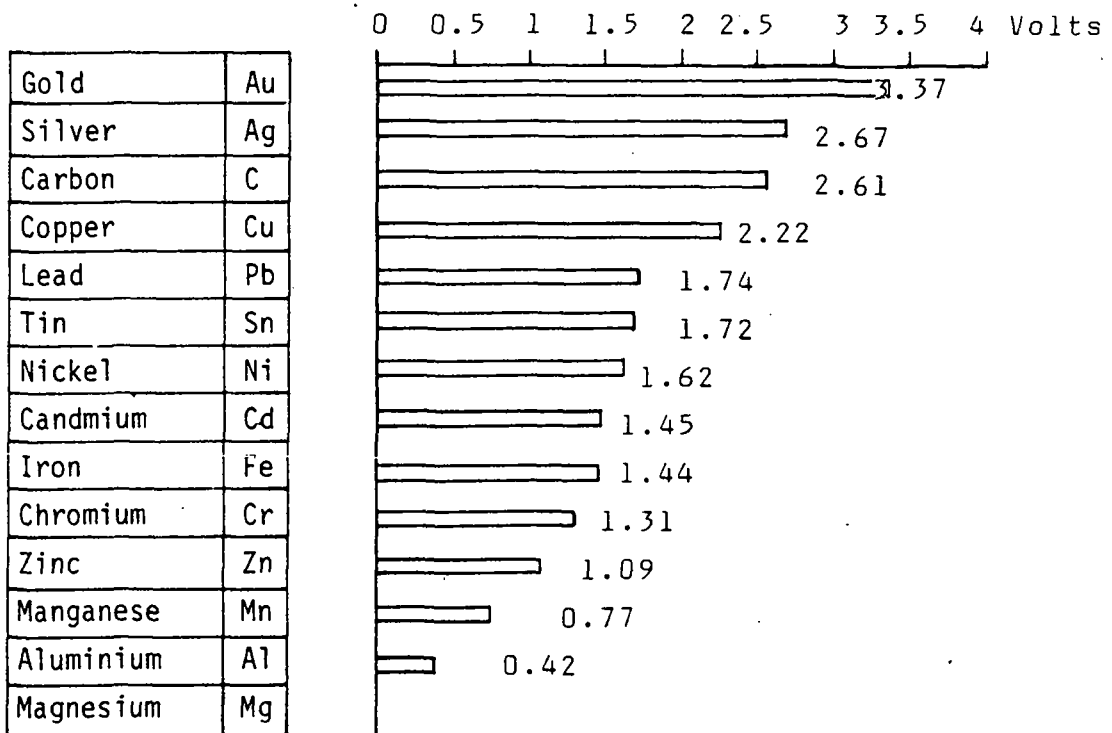
Oxidation is particularly marked at higher temperatures; the corrosion product is then called scale, the process referred to as scaling.

The term oxidation is used generally to cover all chemical reactions in which an atom gives up electrons, not necessarily to oxygen: for instance, the NaCl molecule is formed through oxidation of sodium.

Electrochemical corrosion

Electrochemical corrosion results from the processes that take place in an electrolytic cell. Such a cell consists of two electrodes made of different substances, e.g. copper and zinc, and a liquid which conducts electric current, the electrolyte. A potential difference exists between the two electrodes, its magnitude depending on the materials.

The cell consisting of copper and zinc, for instance, results in a voltage of 1.13 V. If the potential difference between different materials (metal, carbon) and a magnesium electrode is measured and the figures obtained arranged in order of decreasing magnitude, the result is the table known as the electrochemical series (see page 12).



Electrochemical series

For iron, this potential difference is 1.44 V, for zinc, 1.09 V. In the electrolytic cell Fe-Zn, there thus results a voltage of $1.44\text{ V} - 1.09\text{ V} = 0.35\text{ V}$. The baser metal, which is nearer to magnesium and acts as the cathode, is thereby dissolved. In the electrolytic cell under consideration, this is zinc.

An electrolytic cell is formed, leading to electrochemical corrosion, if, e.g. a drop of water at a damaged spot on a metal surface acts as electrolyte, connecting e.g. the zinc layer in galvanized steel with the parent material iron. The result is dissolution of the zinc layer.

The two partial reactions of electrochemical corrosion require an exchange of electric charges. Inside the metal this is quite possible due to the capacity to conduct electrons. Outside the metal, the circuit is closed by an electrolyte.

Electrolyte

An electrolyte is a medium in which ions can move (ionic conduction). Electrolytes are generally aqueous solutions, but ionic conduction is also possible in soils or in fusions of salts. In an electrolyte, some of the molecules are always split into ions; they are dissociated. In an aqueous solution of copper sulphate, for instance, there are CuSO_4 molecules split into copper ions Cu^{++} and sulphate ions SO_4^{--} , but also water molecules into H^+ and HO^- (hydroxyl group).

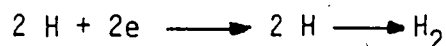
The aggressivity is greater the more the concentration of ions differs from the concentration in water. Since hydrogen ions are present in all electrolytes, their concentration is used to indicate the degree of dissociation. This is expressed as the pH. Water with a pH of 7 is in a state of neutrality.

If the two electrodes of a source of direct current are dipped into an electrolyte, the negatively charged ions are attracted to the positive electrode, the anode. The negative ions are thus called anions. The positively charged ions, called cations, move towards the negative electrode, the cathode. Electrochemical reactions take place at both electrodes.

The cathode reaction is a reduction. The cations are reduced through capture of electrons. They are metallic, thus there result metal atoms:



The reduced metal is deposited on the cathode; this is the principle of galvanic coating. In every case, however, hydrogen is reduced at the cathode:



The nascent hydrogen (composed of single atoms) can diffuse into the cathode, hydrogen molecules which form on the surface escape as gas (development of gas in starter battery when being charged).

The anode reaction involves loss of electrons, i.e. an oxidation. The partial reactions taking place at the anode depend in each case on the electrolyte and the electrode material.

Electrolytic solution pressure: both the anode and the cathode reaction require an anode or cathode flow of current, which is made possible by the supply of direct current. In corrosion processes, however, there is generally no exterior source of current; the flow of current must result directly from the electrode/electrolyte system. The cause of this is the unequal electrolytic solution pressure of the metals. The endeavour of the ions of a solution to deposit (separate out) is called osmotic pressure.

2.1 Types of corrosion

Uniform surface corrosion

In chemical corrosion, the surface is uniformly attacked by corrosive forces.

This attack and destruction take place at a constant speed, so that the effects of corrosion are largely calculable and can be countered e.g. by making the metal part thicker.

Uniform surface corrosion is not serious in economic terms; above all, however, it is not dangerous. At high temperatures, very rapid uniform surface corrosion occurs, known as high-temperature scaling.

Preferential or local corrosion

Much more dangerous is preferential or local corrosion, where, in addition to the uniform removal of metal from the surface, shallow depressions form on the outside of the material and eat their way inwards, becoming funnel-shaped

pits and possibly resulting in perforation.

Since this type of corrosion proceeds rapidly, the consequences can be very serious - e.g. perforation of oil tanks can result in leakage of oil into the soil, endangering drinking water supplies.

Contact corrosion

If different metals come into contact through an electrolyte, an electrolytic cell is formed (called in this case a corrosion cell). The baser metal in each instance, e.g. cast iron, acts as cathode, the more noble metal, e.g. cast iron alloyed with chromium, acts as anode. Due to the potential difference between cast iron and cast iron alloyed with chromium, a current flows and the baser cast iron is dissolved at the point of contact. This type of corrosion is called contact corrosion.

2.2 Corrosion in steel and cast-iron water mains

Every differential concentration of gas on two neighbouring areas of a metal surface favours local corrosion. Frequent causes of this type of corrosion are grit, mud and rust carried into the main by the water, also residues of fluxes, hemp or caulking materials remaining in the pipe. Such foreign substances are called aerating elements. They prevent oxygen from reaching the untreated metal surface, so that the untreated metal underneath the foreign element gradually dissolves. This type of corrosion occurs only in horizontal mains. The corroded areas are always on the floor of the pipe ("six o'clock" position).

Precautionary measure: installation of filters.

In contrast, locally higher concentrations of gas (oxygen, hydrogen, free carbonic acid) result in local corrosion on the roof of horizontal water mains ("twelve o'clock" position). The risk of corrosion through differential aeration is greater with standing than with flowing water.

Thus "dead" pipe runs and crevices produced by incorrect caulking of threaded pipe joints are particularly endangered. Precautionary measure: installation of air valves.

2.3 Corrosion on the outside of steel and cast-iron water mains

Where metal parts are comparatively small, with surface areas in the order of a few cm^2 , the soil surrounding them can be regarded as being homogeneous. However, this assumption is already questionable in the case of e.g. larger tanks, and where long pipe runs are concerned it quite definitely no longer applies. The different soils through which a pipe route passes have varying permeability to air and water at different volumes of voids, moisture contents and grading, resulting in an unequal diffusion velocity of the oxidation agent (atmospheric oxygen) to the surface of the metal. This causes separate areas of the metal to become cathodic or anodic, i.e. concentration cells are formed, resulting in local corrosion as long as the anodic areas are small compared with the cathodic areas. The rapidity of this local corrosion grows with increasing ratio of the cathodic to the anodic area and with diminishing soil resistance. The effects of the concentration elements depend on the size of the metal part, and must be given special attention where welded pipes are used.

The aggressivity of the soil along the complete length of a pipe route is much harder to evaluate than the aggressivity at any one point. This is because extreme aggressivity can result from the formation of macrocells at the anodic areas, which cannot be determined through an analysis of local soil aggressivity.

Reliable reference values for the formation of these macrocells or for a determination of the anodic areas at risk cannot yet be given. However, it is possible to identify

the conditions which favour or make probable the formation of macrocells. This is e.g. always the case if neighbouring soil areas have different resistivities. Low-resistance soils are generally less aerated and have a higher salt concentration than high-resistance soils. In this case, the formation of concentration cells is particularly favoured if a relatively high salt concentration activates the un-aerated anodes, whilst on the other hand a relatively low salt concentration does not hinder the passivation of the aerated cathodes. The corrosion flow which occurs depends not only on the extent of the differential aeration and the soil resistance, but also on the polarization resistance of the anodic and cathodic areas, the longitudinal resistance of the pipeline and the ratio of anode to cathode area. Very little is known, however, about the effects of soil composition on the polarizability of iron and steel.

An interplay between local soil aggressivity and macrocell formation must be given particular attention. In unaerated soils, for instance, corrosion can facilitate the formation of macrocells through depolarizing bacterial activity,; the corroded areas being simultaneously enlarged. Macrocells with low-polarizing, spatially defined anodic areas cause the most intensive attack.

2.4 Protection of cast-iron and steel pipes against corrosion

Cement mortar lining

The object of lining pipes with cement mortar is to prevent corrosion damage resulting from attack by drinking water or nearly neutral aqueous solutions.

The thickness of the lining depends on the diameter of the pipe, and is between 3 and 9 mm in cast-iron pipes and 4 and 14 mm in steel pipes. If damaged or faulty areas in the cement mortar lining have to be repaired, this can be

carried out by hand. The faulty section of the lining is removed and replaced with fresh mortar of the following composition:

1 part of cement to 2 parts of sand,
 plus water containing a plastics dispersion
 which has no harmful effects on drinking water.

Field of application (according to DVGW/W 342)

Pipes lined by the manufacturer with cement mortar can be used when analysis of the water gives the following results:

- a) The carbonic acid sum Q_C ($CO_2 + HCO_3^{--} + CO_3^{2-}$) must be greater than 0.25 mol/m^3 .
- b) The lime-dissolving carbonic acid concentration must be lower than $0.7 \text{ mol/m}^3 \approx \text{approx. } 30 \text{ mg } CO_2/l$.
- c) The calcium concentration $Q_C \times (Ca^{2+}) = L$ must be at least 0.02 mol/m^3 .
- d) When pipes carry aggressive water (pH 7.8, saturation index - 0.3) and repair work has to be carried out, suitable measures must be taken to ensure that the cement mortar lining does not dry out, even temporarily.
- e) If any of the limiting values are exceeded, or not attained, the use of cement mortar lined pipes must be discussed by pipe manufacturer and user with reference to the specific case. This also applies if pipes with cement mortar linings are to be used for the transport of non-potable water, e.g. sea water, brine, sewage, trench or pit water, etc.

Coatings and linings on a bituminous base for cast-iron and steel pipes.

The term "bituminous compound" is used both for compounds based on asphaltic bitumen obtained from crude oil and those based on coal tar pitch.

Cast-iron pipes are normally given only a thin coat, for which either dip-coating compounds on a tar basis or coating

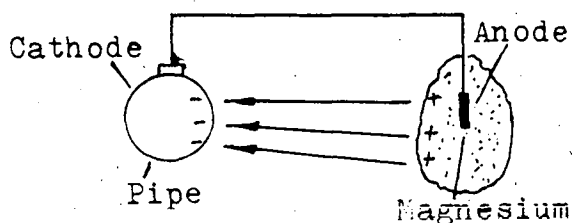
compounds on a tar or bitumen base may be used. Both materials can also serve as adhesive primer layers where pipes are to be given thicker coatings.

Steel pipes are usually given a 4 mm thick coat of filled bitumen with nonwoven glass fabric as carrier.

Other measures taken to protect steel pipes are exterior coating with polythene, replacement of the aggressive soil with sand or gravel, use of corrosion-resistant stainless steel screws for flange joints or wrapping of flange joints in insulating bandages.

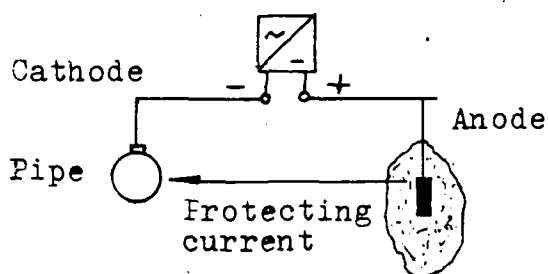
Cathodic protection

Metal parts which are underground and susceptible to corrosion (e.g. oil tanks, pipes, wires) are at high risk. The damp soil acts permanently as an electrolyte. Effective protection can be achieved through use of sacrificial anodes. The structure to be protected is made the cathode in a direct current circuit where the anode, of baser metal, is designed to be worn away. Corrosion is transferred from the structure to the anode, which is replaceable. This method is called sacrificial protection.



The figure shows the protection of a steel pipe using a block made of a magnesium alloy. Sacrificial anodes made of zinc alloys, which have a longer life, are also often used.

Good protection can also be achieved with the foreign current method (active corrosion protection). Here the protective current is fed via a power unit directly into the soil.



The anode does not have to consist of a baser metal than the structure, since it becomes the anode due to the polarity of the power source. Dissolution of ions can only take place from the anode. The parts which act as cathodes are protected.

In general, alloys of silicon and cast iron are used as anodes in soil, since these are worn away relatively slowly. They are embedded additionally in coke. This technique can also be used to protect the interiors of drinking-water storage tanks. Plated titanium is often used as anode.

The effectivity of a cathodic protection system must be constantly monitored through observation of the equipment and regular measurement of the protected pipelines. This applies equally to cathodic protection systems employing foreign power supply and to those using galvanic anodes. Faults may occur through a breakdown of the equipment, or be caused by external factors, e.g. foreign contact with the pipes when new electricity cables are being put down. A check can usually be kept on the cathodic protection system only on a sampling basis, at existing measuring points, an adequate number of which should be provided at suitable points along the length of the pipeline. The distance between measuring points should be less than 1 km in built-up areas, 1 to 2 km in open country. Measuring points should exist at insulators and pipe protection tubes. To facilitate the location of faults (e.g. due to foreign contact, bridging of insulators or interruptions of longitudinal conductivity), roughly every 4th measuring point should be used to measure pipe current.

Other, less frequently used methods of protecting pipes against corrosion are wrapping of the pipes in impregnated or PVC bandages, PE sheets or bituminized glass fibre cloth.

Galvanized steel pipes are used in domestic plumbing from the service main onwards.

If both copper and galvanized steel pipes are used, the copper pipes must be fitted in the direction of flow after the galvanized steel pipes, as a precaution against corrosion. The two materials must be separated by a street fitting made of brass.

The use of galvanized steel and copper tubing is discussed in detail in Module 3.1.

3 Building materials

3.1 Cement

Cement is a finely-ground hydraulic binder for mortar and concrete, consisting mainly of compounds of calcium oxide with silicon dioxide, aluminium oxide and iron oxide produced by sintering or smelting. When mixed with water, cement hardens both in air and under water (remaining hard under water). It must be sound and reach a compressive strength of at least 250 kp/cm^2 after 28 days.

Types of cement

Portland cement has a high heat of hydration (= heat produced during the reaction of the cement with water), hardens quickly and is therefore widely used because of the resulting short stripping times. On the other hand, ordinary Portland cement is not resistant to sulphate-bearing water. For this reason, it is preferred for use in building, and also in cold weather, but is less frequently used in civil engineering or for massive structures.

Iron Portland cement has a lower heat of hydration than ordinary Portland cement and is less easily attacked by sulphate. Its uses are similar.

Portland blast-furnace cement is highly sulphate-resisting and has a low heat evolution. It is thus widely used wherever water is likely to be aggressive and where high heat evolution is undesirable - e.g. in massive structures, such as dams.

Trass cement (Portland pozzolana cement) is used to produce a particularly workable and dense concrete. Its heat evolution and resistance to sulphate attack are similar to those of blast-furnace cement.

Strength classes and nomenclature

Normal-hardening cement must have reached a certain minimum compressive strength after 28 days. In the German classification system, they are grouped into strength classes 25, 35, 45 and 55 MN/m².

Cements in classes 35 and 45 with slow initial hardening are additionally identified by the letter L (=German "langsam" - slow). Cements with higher initial hardening are identified by F (= German "früh" - early, indicating high early strength).

To distinguish the cement classes, they are packed in sacks having a certain colour, or where bulk cement is kept in silos, the silo sheet has the appropriate colour. The silo sheet bears the delivery date and is fixed to the cement silo.

Strength class	Sack or silo sheet colour	Colour of print
25	purple	black
35 L	light brown	black
35 F		red
45 L	green	black
45 F		red
55	red	black

3.2 Concrete

Concrete is a mixture of cement, water and various kinds of aggregate. In unset concrete, the cement forms a plastic paste with the water. The mixture of cement, aggregate up to 1 mm and water is called fine-grained mortar. The cement paste hardens to cement stone, which binds the aggregate in the hardened concrete to a firm, stone-like mass.

Type of concrete	Volume weight (kg/dm ³)	Aggregate
Heavyweight concrete	More than 2.8	Heavy spar, granulated steel, scrap steel
Normal concrete	2.8 - 2.0	Sand, gravel, chippings, granulated slag, lump slag
Lightweight concrete	Up to 2.0	Expanded shale, expanded clay, foamed slag, natural pumice, brick chippings

Types of concrete with volume weights

As the table shows, the volume weight depends largely on the type of aggregate used. If there is no risk of confusing it with heavyweight or lightweight concrete, normal concrete is referred to as "concrete".

The concrete type can be more closely defined by the aggregate used - e.g. chippings concrete, graded sand concrete, foamed slag concrete, expanded clay concrete, etc.

The most important property of concrete is its compressive strength. Concretes with different strengths are produced to support the various loads (e.g. on foundations, columns, loadbearing prefabricated components) encountered in building.

In the German classification system, concretes are divided into strength classes B5 to B55. The strength is determined by examination of a test body (e.g. cube test). The letter

B stands for the German "Betonnenfestigkeit" (rated strength of the concrete); the figure after it gives the minimum 28-day crushing strength of each cube.

Concrete strength classes and their applications

Concrete type	Strength class	Crushing strength MN/m ²	Applications
B I	B 5	5	Only for non-reinforced concrete
	B 10	10	
B II	B 15	15	For non-reinforced and reinforced concrete
	B 25	25	
	B 35	35	
	B 45	45	
	B 55	55	

Properties of hardened concrete

- Hardened concrete has high compressive strength, but only low resistance to bending tension.
- The water-absorbing capacity of hardened concrete increases with the number of capillary pores in the concrete structure.
- Impermeability to water, resistance to sub-zero temperatures and to chemical attack require a concrete of low capillarity, carefully considered composition and good compaction. Concrete with highly porous cement stone is less corrosion-preventive, more affected by low temperatures, more permeable and less resistant to aggressive water.

3.3 Masonry

Masonry, i.e. solid walling, is a general term covering the use of both natural stones and artificially produced bricks or blocks.

Masonry from bricks or other artificially produced units

Types of bricks and units:

Burnt

Unburnt

Wall bricks

Lightweight bricks

High-strength and
clinker bricks

Ceramic clinker bricks

Sand-lime bricks

Slag bricks

Concrete blocks

Lightweight concrete blocks

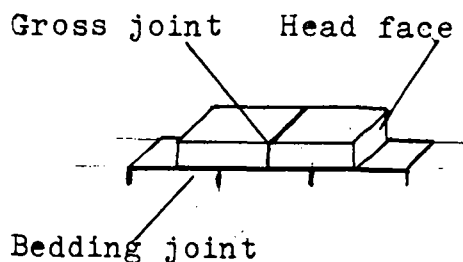
Lightweight concrete wall units

Gas concrete blocks and wall
units

Asbestos cement (panels and
slabs)

Mortar joints in brickwork

Since the joints are the weakest points in a brick wall, they must be given special attention.



The mortar joint has the task of bonding the bricks firmly together. The joints between the separate layers or courses are generally horizontal, and bond these courses into a unified body of brickwork. Because each layer of bricks is bedded in the mortar, the horizontal joints are called bed joints. They are normally 1.2 cm thick. The mortar

Names of joints

in the bed joint must be distributed evenly over the complete surface of the brick.

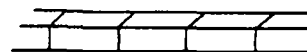
The vertical cross joints bond the ends, or head faces, of the bricks together. They are 1.0 cm thick.

Courses of bricks

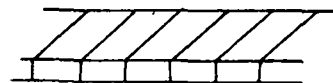
A "course" of bricks is a horizontal layer laid in a certain order to make an overall pattern, or "bond".

Three possibilities are:

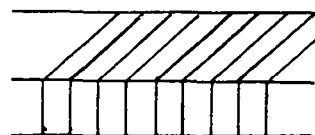
Stretching courses, where each brick is laid with its length parallel to the length of the wall.



Heading courses, where the bricks are laid across, instead of parallel to the length of the wall.



Upright courses, where the bricks are stood on their long sides. This results in high cross joints and relatively short bed joints.



To build a wall out of bricks or blocks, the following basic rules must be observed:

- The cross joints of succeeding courses must never be directly above each other, but at least one-quarter of the length of a brick or block from the nearest cross joint above or below.
- In walls which are 1, $1\frac{1}{2}$ and 2 bricks thick, stretching and heading courses alternate.
- At internal corners, there must be only one cross joint in each course.
- The courses must be horizontal, because loads exerted on walls are nearly always vertical.
- Wall bricks should be kept moist, especially in hot weather, so that the water is not extracted from the mortar during building.

Walls made from natural stone

Natural stone must be carefully selected and tested for its strength, resistance to weathering (erosion) and ease of dressing.

Metamorphic and igneous rocks are usually impervious, resistant to weathering and to compression, but difficult to work.

Sedimentary rocks include the widely-used sandstones and limestones. These are often readily available and are easy to work.

The following basic rules must be observed when building walls from natural stone:

- No more than 3 joints should ever coincide on front and back faces.
- Cross joints must not be more than 2 courses high.
- Heading and stretching courses should alternate, or there should be 1 heading course to at most 2 stretching courses.

- Each header must extend at least half a block-height deeper into the wall than the neighbouring stretchers.
- The depth of the stretcher should be at least equal to the height of the course.

Dry-stone walls are built according to the following principle:

Roughly dressed stones are placed on top of each other without mortar in such a way that the joints between stones are as narrow as possible and no cavities are left. Even small cavities must be filled in with smaller stones, which are used to produce tension in the wall.

3.4 Mortar

Mortar is a mixture of aggregate, binder and water which forms a stone-like mass.

Aggregate: The aggregate used is generally natural or crushed-stone sand, or more seldom slag sand or pumice sand. The sand gives the mortar its solid framework. In all mortars containing lime and/or cement, the sand also makes the mixture lean, since these binders alone are liable to shrink considerably. If the binder paste coats the aggregate grains with only a thin layer, the mortars do not shrink more than is admissible. In ordinary lime mortars, the sand provides the porosity which allows the necessary infiltration of air.

Binders: The chief binders used for mortar are lime and/or cement, for plastering mortars also gypsum and anhydrite. The binder must bond the aggregate together firmly and lastingly. Too much binder leads, in the case of lime or cement, to contraction cracking; not enough binder to dusting. Mixtures containing large amounts of binder are called "fat", those with a low binder content "lean".

Mixing water: The mixing water makes the mortar plastic and workable. The water must not contain substances which hinder the hardening process or cause efflorescence. If not enough water is used, the aggregate grains are not completely covered with binder paste; if too much is used, binder is washed out. In both cases the result is poorer strength and resistance to sub-zero temperatures.

Classification

Mortars are classified according to their use: as masonry mortars, plastering mortars (stuff) and screed mortars.

Masonry mortars: Masonry mortars must equalize unevenness in the surfaces of bricks or stones and join these units firmly together to ensure uniform transmission of forces. They should also be elastic, however, so that the bond is not destroyed by subsidence or shocks. Binders for masonry mortars are lime and/or cement.

Plastering mortars (stuff): Plastering mortars are used on the inside and outside of buildings. They must be workable and adhere well to the plaster base. They should harden to the point where they are able to withstand all foreseeable stresses, but at the same time remain elastic enough to sustain subsidence of the wall and extreme fluctuations of temperature without cracking or peeling. In addition, these mortars should also be permeable to water vapour, since the water vapour in inhabited rooms - from respiration, cooking etc. - must be able to pass through the walls. At the same time, outdoor plaster must be rainproof. Binders for plastering mortar are, as above, lime and cement, and in addition, for indoor plasters, gypsum and anhydrite.

Screed mortars: In screed mortars, strength and resistance to wear are decisive. Screed mortars are therefore usually cement mortars with a relatively high binder concentration.

3.5 Loam

Loams are soils which are a mixture of clay and coarser materials ranging from fine sand to stone: the granular framework. When dry, loams are strong enough to be used in building.

Nomenclature:

Loams with a high clay content are called fat, those with a lower clay content lean. Depending on the prevailing grain sizes of the granular framework, a distinction is made between stony, coarse-sand, fine-sand and silty loams. The reduction of volume when the loam dries out is known as dry shrinkage. The disintegration of dry loam in water is called suspendibility.

Loam as a building material:

Because of their high dry shrinkage, most loams have to be mixed with aggregates before they can be used as a building material. Clay can also be made into a building material if it is suspendible without an excessive amount of work.

Loam with a dry shrinkage below 4 mm does not normally require any further aggregate.

Properties as a building material:

Building loam is characterized above all by the fact that it hardens on drying out and becomes soft again whenever it absorbs water. The strength of the dry material results from the cohesive forces holding the platy-shaped clay crystals together. The effectivity of these forces lessens if the spaces between the plates are enlarged by infiltrated water. The strength of the material is thus in correlation with the water content. Building components which contain loam must therefore be permanently protected against the infiltration of water.

Dry building loam is proof against sub-zero temperatures. Use of the moist material in building should be concluded in time for it to dry out completely before the cold weather begins.

Compacted, dry building loam with a volume weight = $16 \frac{\text{N}}{\text{dm}^3}$ and in a thickness of at least 24 cm is fireproof. Walls made of loam with a volume weight between 9 and $18 \frac{\text{N}}{\text{dm}^3}$ are available.

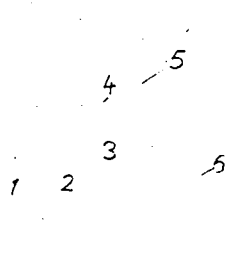
Building loam has a preserving effect. Enclosed wood or straw can remain unaltered for centuries.

3.6 Timber

Composition of wood (parts by weight)

Completely dry wood contains about 50 parts of carbon, 6 parts of hydrogen, 43 parts of oxygen, 0.7 parts of nitrogen, 0.3 parts of minerals (ash) and some protein (nutritive medium of destructive fungi).

The cross or bole section shows:

- 
1. Pith
 2. Heartwood (darker colour)
 3. Sapwood (paler colour)
 4. Cambium
 5. Inner fibrous bark
 6. Bark

Sometimes pith rays can be seen (oak).

The wood mass consists of micro-cells; the cell walls are made of cellulose.

The sap content in spring and summer is approx. 50%, in autumn and winter approx. 40% of the total weight of the wood. Seasoned wood should not have a moisture content higher than 20%.

Determination of the moisture content of timber, "u", in %:

$$u = \frac{(G_u - G_d) \times 100}{G_d} \%$$

where

G_u = weight of the unseasoned wood

G_d = oven-dry weight

Size of wood sample: 30 cm³

Electrical moisture meters show the moisture content on a scale as a percentage.

Growth of wood:

The period of growth is from the end of January to the end of November.

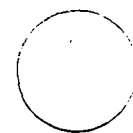
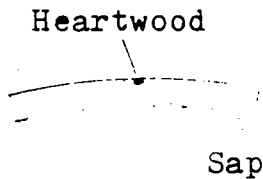
Cell formation:

This is rapid in spring, when cells are thin-walled and full of sap; in autumn cell formation is slow and cells contain much less sap. This is the reason for the formation of annular rings (which indicate the age of tree).

"Working" of timber:

Seasoned timber absorbs water from humid air and swells; in dry air it loses the moisture again and shrinks. This alternate swelling and shrinkage is called "working".

Since sapwood shrinks more than heartwood, boards, etc. which in cross-section have sapwood on one side and heartwood on the other warp on drying out. It is therefore expedient to have the heartwood side-upper or outermost when using timber in building - e.g. for stairs, skirting boards, door panels etc.



Faults in timber

Faults and diseases in timber:

- a) Seasoning checks, running across the rings from the outside to the heart centre, caused by uneven, over-rapid seasoning.
- b) Heartshakes, widest towards the heart centre and caused by unprotected storage, have a considerable effect on the bearing capacity of the wood.
- c) Twisted (spiral) growth: timber unusable.
- d) Fungal disease on standing timber; causes rotting of bole, heartwood, sapwood, or ring rot.
- e) Decay of felled, sawn and processed timber due to fungal attack: e.g. dry, pocket and wet rot. Blue stain is especially common on felled, unprotected pine logs.
- f) Attack by insects: larvae ("woodworms") of the wood wasp; bark, longhorn and death-watch beetles destroy wood with their tunnels (longhorn beetle 6mm, death-watch beetle 2 mm in diameter).

Measures to combat attack by insects are: preparations of chloronaphthalene, e.g. Xylamon, Witoxyl, Longhorn Beetle Basilium, or salts, such as Wolmanit, Osmol WB etc.

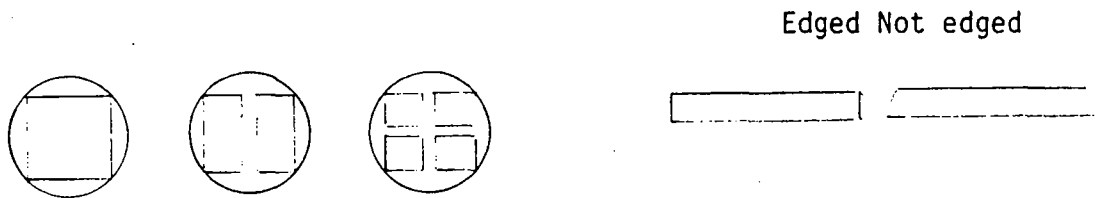
Fungicidal timber preservatives are, for instance: carbolineum, creosote, water-soluble salts.

Processing of timber:

First the tree is felled with an axe or saw and disbranched. The thick end is called the butt or root end, the thin end is the top end. Through hewing or sawing, squared timbers are produced from the logs.

Nomenclature of cutting methods:

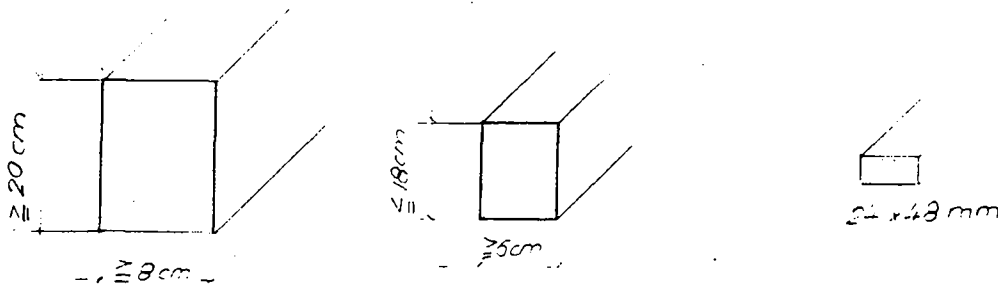
Boles which are not used in building directly as round logs are cut up in various ways. Depending on the diameter of the bole and on the intended use, the logs can be cut into whole timbers, half timbers, quarters, deals (planks) or boards. All are known collectively as sawn timber.



Baulks and square-sawn timbers

Boards and planks

The cross-sections of sawn timbers to be used in building must be dimensioned according to their load-bearing capacity. Timbers used in building are: baulks (whole and half timbers), square-sawn timbers (quarters) and battens.



4 Paints, protective finishes and insulating materials

Painting of metals

Painting is the even application of a coat of liquid (usually pigmented and decorative) to the surface of a building material. On metals, the most widely used paints are oil paints, tar paints and synthetic resin varnishes.

The paint system can consist, depending on the application and required quality of the finish, of one or more coats. A distinction is made between the undercoat and the top or finishing coat; both of which may also consist of several layers. The task of the undercoat is to bond the ground to the following coats. This undercoat must not react chemically with the building material, must adhere well and itself

act as a good adhesive ground for the succeeding coats. The finishing coat protects the layers of paint underneath it. It should be waterproof, light-fast, hard, but at the same time elastic, possibly heat-resistant, and finally decorative. The quality of the paint finish depends largely on the care taken in preparing the ground. All surfaces must be carefully cleaned before application of the paint, ensuring that rust, other corrosion products, dust etc. are completely removed.

When oil paints are used, effective protection against corrosion is provided by applying a priming coat with red lead (minium), Pb_3O_4 , mixed into linseed oil. Linseed oil paint is then used for the finishing coat.

In varnishing, the process begins with application of an undervarnish. If a particularly smooth finish is required, small indentations can then be filled in with a levelling compound and smoothed over, using abrasive paper and water. Finally the finishing coat of varnish is applied.

Varnishes consist of a volatile solvent (the vehicle) which evaporates, leaving the body of the varnish behind as a thin protective film on the building material.

Nitrocellulose lacquers and, above all, synthetic resin varnishes are very widely used. These are highly elastic and resilient and dry to give a glossy, decorative finish. The easiest resins to work with are those that dry at room temperature. More resistant to corrosion are the stoving enamels, which are dried at temperatures above $100^{\circ}C$. These have a more uniform structure, are scratch-proof and resistant to weathering.

Each separate coat of paint or varnish must dry well after each application, to ensure good adhesion.

Protective finishes

Because of their moisture-excluding effect, bitumen and tar are also often used as a base for protective finishes

on buildings and other structures. Such preservative materials can be divided into three main groups:

Hot-processed preservatives must be liquefied by heating before use. Pure bitumen or pure tar are used as finishing coats after preparation of the surface with a primer. Fillers are frequently added, however, such as e.g. stone dust or fibrous material (asbestos, glass wool, rock wool, etc.).

Cold-processed preservatives are produced by diluting the bitumen or tar with a solvent. Depending on the solvent concentration, they are used as priming or as a finishing coat. Stone dust and fibrous substances may be added here too, if thicker protective coats are needed. Tar coats are applied mainly where protection is required against decay, insects and fungi in addition to moisture.

Protective finishes on an emulsion base have the advantage that they can be applied to a damp ground.

Insulating materials

Felts treated with bitumen or tar play an important part in the damp-proofing of buildings.

Uncoated bituminous or tar felt is produced by impregnating felt with bitumen or tar. This material is then known as uncoated bituminous/tar felt "500" or "333", depending on the weight per square metre of the felt used. They find application in damp-proofing systems, and are stuck in position with bitumen or tar, the uncoated felt serving only as a carrier for the actual damp-proofing layer of bitumen or tar.

Bituminous or tar roofing felts are impregnated sheets of fibres matted into a felt, coated on both sides with a waterproofing compound and sanded. These felts do not need to be coated over their full surface, but are just bonded together.

Waterproofing sheets differ from roofing felt by having thicker coating layers. The carrier can be felt, jute, metal foil or plastics foil. Bitumen and tar are used as impregnating and coating materials.

5 Auxiliary materials

5.1 Lubricants

The task of a lubricant is to reduce friction between metal surfaces by forming a thin, adherent and pressure-resistant lubricating film, to ensure good heat elimination and to absorb machine-part vibration. Their viscosity should change as little as possible with temperature, so as to provide uniformly good lubrication under varying operating conditions. Lubricants should also be chemically resilient, i.e. they should not decompose or resinify.

One characteristic of a fluid lubricant is its flash point. This is the temperature at which the lubricant vapours ignite. Cylinder oils and oils in internal combustion engines, for example, must have a flash point higher than 200°C.

The temperature at which the oil just stops flowing on cooling is called the cold setting point. A gear oil, for instance, has a cold setting point of -15°C. Below this point, the oil can no longer lubricate.

Fluid lubricants:

Fluid lubricants are divided into mineral oils and synthetic oils. Mineral oils are produced from crude oil by distillation followed by cleaning. The permissible working load is increased by the introduction of additives into the oil. These additives are chosen according to the specific application. They may be required e.g. to retard the decomposition and resinification of an oil, prevent corrosion and excessive wear, keep contaminants in suspension, reduce the dependence

of an oil's viscosity on temperature (multi-grade oil), prevent foaming or increase the permissible contact pressure.

The choice of the most suitable oil depends on the viscosity at operating temperature and on the type of additives.

Synthetic lubricating oils:

These are artificially produced liquid lubricants, such as silicone oils or diester oils. Their viscosity is less affected by changes of temperature than that of mineral oils; they are less inclined to resinify and therefore need to be changed less frequently. Less advantageous are their tendency to creep and their low shear strength. They are also comparatively expensive, so that they are generally used only in special cases. Silicone oil, for instance, is also used as base oil for synthetic greases.

Lubricating greases:

These consist of mineral or synthetic oils mixed usually with sodium, lithium or calcium soaps, which cause them to thicken. The base oil and the thickening agent determine the properties of the lubricating grease, in which the soap acts as a kind of sponge holding the base oil. This is then fed to the bearing points as required.

The advantages of grease lubrication result from the low flow tendency of the greases. Thus it is possible e.g. to lubricate roller bearings installed in any position. Lubricating greases keep dirt away from the bearings, prevent corrosion due to their water-repellant properties, provide a long-lasting supply of lubricant and thus permit the design of maintenance-free bearings.

Solid lubricants:

Where operating temperatures are very high or very low, solid lubricants are used. These are also used, however,

in machines which are exposed to radioactive radiation, in vacuum processing and in very small machine parts. In addition, they serve as emergency lubricants if ever the lubricating film of oil or grease fails. This can happen at low speeds or very high stresses.

The main solid lubricants in general use are graphite, molybdenite (MoS_2) and polytetrafluoro ethylene (PTFE).

5.2 Solders and fluxes

Solders have a range of fusion with an upper and a lower fusion temperature.

A distinction is made between soft solders and hard (brazing) solders.

Soft solders are alloys of tin (Sn), lead (Pb), silver (Ag), copper (Cu) and antimony (Sb) with working temperatures below 450°C . The abbreviations used for solders indicate their composition, e.g.

L-Sn Ag 5 = solder with 95% tin and 5% silver
(L = German "Lot" - solder).

The designation always begins with the main component of the solder.

Some soft solders are:

Abbreviation	Range of fusion $^\circ\text{C}$		Applications
	Solid	Liquid	
L-PbSn30sb	186	250	Lead smelting
L-PbSn40Sb	186	225	Coarse plumbing
L-Sn50PbSb	186	205	Fine plumbing
L-PbSn40(Sb)	183	235	Soldering of zinc sheets
L-Sn50Pb	183	215	Fitting of copper
L-SnAg5	220	235	pipes
L-SnSb5	230	240	Electrical industry

Soft solders are usually supplied in cast blocks weighing 10 to 12 kg, as cast rods with a length of 250 to 400 mm and weighing between 80 and 300 g, or soldering wire, diameter 1 to 5 mm, with and without a fluxing agent core.

Hard solders for heavy metals

These are classified by their composition, application and working temperature (see table on page 41).

Copper solders consist of copper or a copper alloy and are used for brazing parts made of iron, copper or nickel materials. The amounts of zinc and tin added largely determine the working temperatures of these solders, which are between 825 and 1100°C.

Hard solders with a silver component contain between 5 and 83% of silver, plus copper, zinc and cadmium. Their working temperatures are between 610 and 860°C, depending on composition. The low working temperatures mean lower wage costs, less energy consumption, easier soldering, and no scaling.

Hard solders containing phosphorus are copper or silver solders with the addition of 5 to 8% of phosphorus. Their working temperature is 710°C and is thus lower than that of comparable solders without phosphorus. Without a flux they are suitable for soldering copper, with the addition of a flux for the soldering of copper alloys. They must not be used to solder iron- or nickel-containing alloys (steel, CuNi, CuNiZn), since the strength of the resulting joint is not adequate.

Type	Abbreviation	Working temp.	Use
Copper solders	L-SCu	1100°C	Hard-metal cutting plates on tool shanks
	L-CuZn40	900°C	Steel, copper and nickel alloys
Silver-containing hard solders	L-Ag12	830°C	Steel, copper, nickel and their alloys
	L-Ag40Cd	610°C	Steel, copper, nickel and their alloys
	L-Ag45Sn	640°C	Copper tubing
Hard solders containing phosphorus	L-Ag2P	710°C Cu-alloys	Copper, nickel-free

Fluxes

Heated metals combine more rapidly with oxygen than cold metals. The resulting oxide layer hinders thorough wetting with the solder. To remove the oxide layer and prevent further oxidation, fluxes, protective gases or vacuum are used in soldering.

The task of a flux is to remove oxides and prevent further oxidation.

The choice of flux depends on the base material to be soldered and the soldering technique; above all, however, on the working temperature of the solder used. The activity of the flux must begin below the working temperature and continue beyond the maximum soldering temperature. Fluxes are therefore categorized by their active temperature range.

To ensure that the flux achieves its full effect, the liquid or pasty flux is usually not applied to the area which is to be soldered until just before the parts are joined. After soldering, any residues of most fluxes must be removed, otherwise they may cause corrosion.

In the German system of nomenclature, fluxes are identified by a system of letters and numbers, whereby F = flux (German "Flußmittel"), S = heavy metal (German "Schwermetall"), L = light metal ("Leichtmetall"), W = soft soldering ("weichlöten") and H = hard soldering ("Hartlöten"). The numbers after the letters then indicate, in fluxes for soft soldering, the corrosive action of the flux residues, or, in fluxes for hard soldering, the active temperature range.

Examples:

F-SW 11 (zinc chloride, $ZnCl_2$), an acidic solution of zinc chloride and ammonium chloride, used in soft soldering of strongly oxidizing metals; residues cause corrosion and must therefore be removed with warm water.

F-SW 21, pasty or liquid mixture of zinc chloride and ammonium chloride with organic fats. Its residues are slightly corrosive and must usually be removed with solvents.

F-SW 31 (rosin), an organic resin, used as a powder or the core of soldering wires, mainly in soft soldering in electrical engineering. Its residues are non-corrosive and need not be removed.

F-SH 1, fluorine- and boron-containing flux for hard soldering at working temperatures above 600°C, active temperature range 550 to 800°C.

F-SH 2 (borax), boron-containing flux for hard soldering at working temperatures above 800°C, active temperature range 750 to 1100°C.

5.3 Cleaning agents

Surfaces must be cleaned to remove oxides and layers of grease. Steel wire brushes are used for mechanical cleaning; or a particularly effective method is sand or shot blasting. In this technique, a surface is cleaned by projecting dry sand or steel shot onto it with a compressed-air blast.

For chemical cleaning, degreasing agents such as petrol, benzene (inflammable!), trichlorethylene, P3, Siliron (non-inflammable) are used, or a pickling process.

In pickling, surface layers are removed and the ground roughened. The pickling agent for steel, cast steel, cast iron and malleable cast iron, copper and copper alloys is diluted sulphuric acid 1 : 10. For zinc, a 40% caustic soda solution is used in a first stage, followed by a 5% sulphuric acid solution. Aluminium and aluminium alloys are pickled in a hot caustic soda solution saturated with common salt.

Whichever medium is used, pickling must always be followed by thorough rinsing with water.

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Some passages of text were taken unaltered from the above
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- 0.4 Basic principles of water transport
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- 1.2 Organisation and administration of waterworks

Special Knowledge

- 2.1 Engineering, building and auxiliary materials
- 2.2 Hygienic standards of drinking water
- 2.3a Maintenance and repair of diesel engines and petrol engines
- 2.3b Maintenance and repair of electric motors
- 2.3c Maintenance and repair of simple driven systems
- 2.3d Design, functioning, operation, maintenance and repair of power transmission mechanisms
- 2.3e Maintenance and repair of pumps
- 2.3f Maintenance and repair of blowers and compressors
- 2.3g Design, functioning, operation, maintenance and repair of pipe fittings
- 2.3h Design, functioning, operation, maintenance and repair of hoisting gear
- 2.3i Maintenance and repair of electrical motor controls and protective equipment
- 2.4 Process control and instrumentation
- 2.5 Principal components of water-treatment systems (definition and description)
- 2.6 Pipe laying procedures and testing of water mains
- 2.7 General operation of water main systems
- 2.8 Construction of water supply units
- 2.9 Maintenance of water supply units
Principles and general procedures
- 2.10 Industrial safety and accident prevention
- 2.11 Simple surveying and technical drawing

Special Skills

- 3.1 Basic skills in workshop technology
- 3.2 Performance of simple water analysis
- 3.3a Design and working principles of diesel engines and petrol engines
- 3.3b Design and working principles of electric motors
- 3.3c —
- 3.3d Design and working principle of power transmission mechanisms
- 3.3e Installation, operation, maintenance and repair of pumps
- 3.3f Handling, maintenance and repair of blowers and compressors
- 3.3g Handling, maintenance and repair of pipe fittings
- 3.3h Handling, maintenance and repair of hoisting gear
- 3.3i Servicing and maintaining electrical equipment
- 3.4 Servicing and maintaining process controls and instrumentation
- 3.5 Water-treatment systems: construction and operation of principal components: Part I - Part II
- 3.6 Pipe-laying procedures and testing of water mains
- 3.7 Inspection, maintenance and repair of water mains
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