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D03145

Distr.
LIMITED
ID/WG.105/26 Rev.1*
6 July 1972
ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Seminar on Furniture and Other
Secondary Wood Processing Industries
Finland, 16 August - 11 September 1971

GLUES[1/]

by

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* Revised for use at Seminar on Furniture and Joinery Industries, Lahti, Finland, 6 - 26 August 1972.

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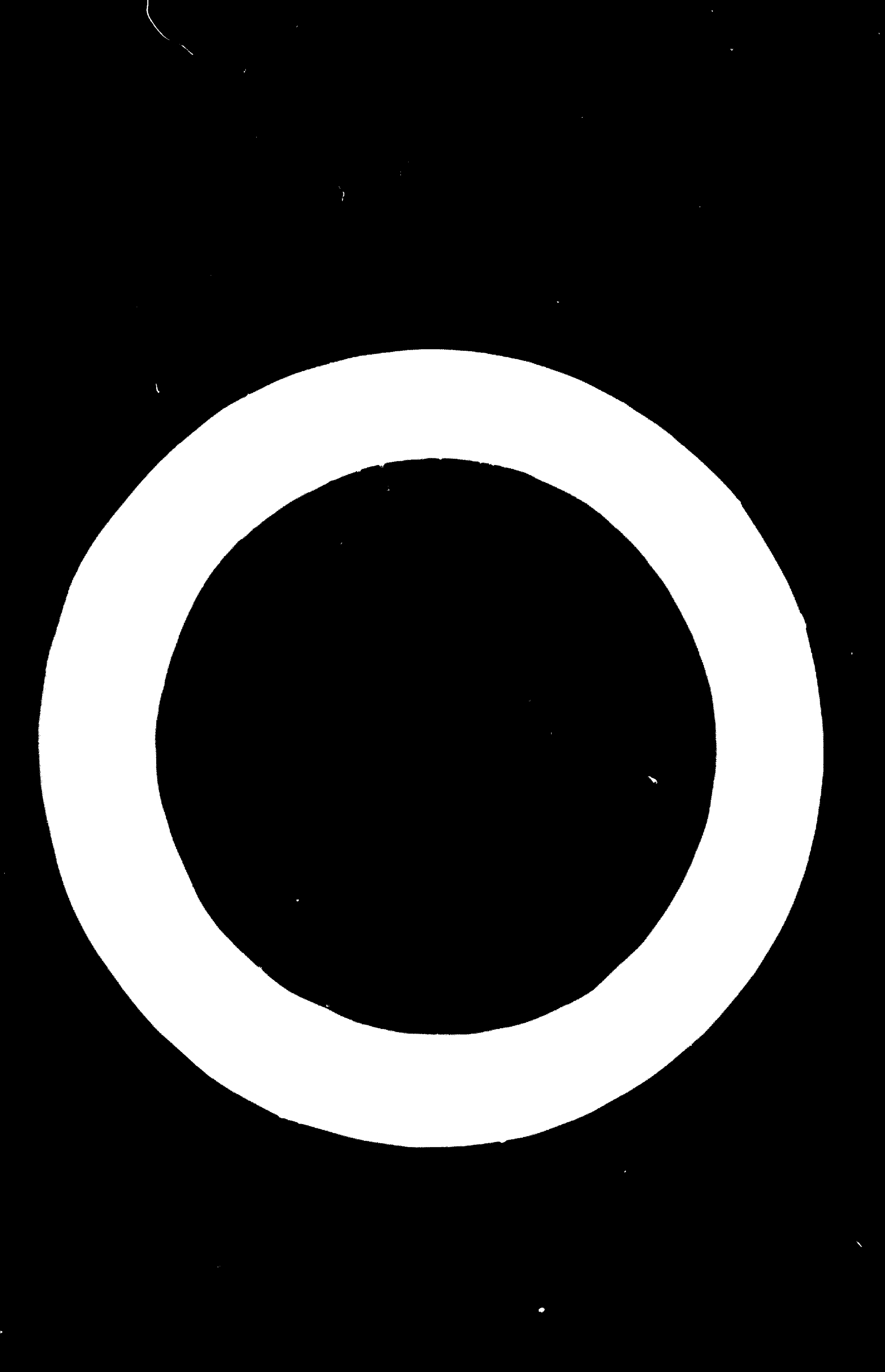
id.72-4247



PRINCIPLES OF GLUING

Jaako Meriluoto

1.1. History

Joining pieces together with glue is an ancient art. It dates back to the very limits of historic times.

Precise information has been recorded in Egypt around 2000 B.C. There is also recorded information from around 1500 B.C. from Thebe, Greece. The time interval from these first indications to present times is, accordingly, 3500...4000 years. The well-known Roman historian Plinius the edler (23...74 A.D.) has in his book "Historia naturalis" given clear working instructions on gluing.

During the 17th and 18th centuries gluing was a fairly common working method in various parts of the world.

During the 19th century systematic research on gluing began to appear. All glues up to the end of 19th century were materials taken from the nature as such. Among these were various animal residues, milk cassein, gummy secretions of certain trees and other vegetable-based materials.

In the beginning of 20th century, synthetic materials made their appearance. Between 1902 and 1909 the Belgian BAEKELAND presented his phenol-based bakelite. This was the beginning of the tremendous rise of plastics and plastic-based glues that still goes on.

The nineteen-thirties brought several glues on the market, among them carbamide (urea). After that, particularly during World War 2 gluing techniques were intensively developed in the warfaring countries. As already was mentioned, we are still living in times of rapid progress in gluing particularly in the use of plastic-based glues.

1. 2. Gluing and other methods of joining

Gluing does not substitute other joining methods, but complements them in an excellent way. Its advantages (below, points A...H) and disadvantages (J...O) can be examined on the basis of following points of view:

A. An essential advantage of glued joints is the comparatively even distribution of stress. This, however, depends to a certain extent on the construction. Fig. 1 illustrates this advantage as compared with a riveted joint where the stress distribution is very uneven.

B. Glue can be used to join together very different types of materials which cannot be welded or which are difficult to work by mechanical means. Typical examples are hard metals, ceramic materials, cement-based and certain other inorganic materials. If the materials to be joined are very different with respect to temperature expansion, a glued joint might be the only alternative, provided the right glue is chosen.

C. Even distribution of stress makes possible the use of thin pieces, so that weight and costs can be saved. Gluing is, therefore, very advantageous in the case of dynamic loads (vibration, shaking etc.).

D. Glues can be used in sandwich structures and in connection with light insulating materials (e.g. hardened foams) where other joining methods are hardly possible.

E. Suitable types of glues show a smoothing action on pores and other surface irregularities. The glue layer is, moreover, resistant to pressure variations.

F. The glue layer can act as a vibration damper.

G. The surface of glued parts is smooth (cf. screw and rivet joints welded joints).

H. The glue seam prevents galvanic corrosion between metal parts due to its insulating qualities.

This list could be continued, but the pointe mentioned above show the main advantages of glued joints.
The list of disadvantages reads as follows:

J. All glue seams have a relatively narrow temperature zone of resistance to heat. If the temperature goes under or, especially, over its limits, the strength values and also the ability to withstand varying loads are impaired. The temperature value of 250°C (480°F) is to be regarded as the absolute top limit in this respect.

K. A static load of a very long duration can cause fatigue (strain) in the glue seam. In some cases the seam gradually begins to crack, which in turn especially increases sensitivity to impact. The continuous presence of water, solvents and other chemicals makes aging more severe.

L. Many glues need a certain time to harden. During this interval, very expensive equipment is often tied to the process.

M. The surface to be glued must be carefully prepared. In metal gluing this is a particularly laborious task.

N. Gluing requires great care during the process and continous control (suitable proportion of components of the glue, viscosity and acidity of the component parts and of the mixture, amount of dry substance in the mixture, amount of glue spread and the smoothness of the layer, the time interval during which the glue layer is open, pressure and pressing time, temperature, after-hardening time).

O. Inspection of glued joints is difficult to do in undisturbed conditions.

The rapid progress of gluing techniques and glue chemistry are continuously shortening this list of disadvantages. By means of careful workmanship and meticulous control these disadvantages can be avoided. In no case do the points J...U detract appreciably from the advantages of gluing as a joining method in furniture and joinery.

1.3 The factors affecting gluing

Some of the concepts connected with gluing have been mentioned above. The factors of gluing have been listed under point N. The gluing phenomenon itself is connected with molecular forces of attraction. The radius of the sphere of influence of a single molecule is very small ($3 \cdot 10^{-8}$ cm). Solid bodies cannot be brought together within this distance. Therefore, a liquid layer (glue) is put between the bodies, and this layer fulfills on both sides the distance condition. Thus, adhesion binds the pieces together by means of the glue. (fig. 6.2) Succesful gluing is greatly dependent on the spreading of glue liquid on the surface to be glued. Fig.6.3 presents some concepts connected with gluing factors.

1.4. Gluing of wood

Gluing in general has been treated above. Every material to be glued brings, of course, its own special features to the process - such is the case so does wood, which is the main topic of this seminar.

The special factors of wood gluing can be grouped as due to:

a. wood

b. glue

c. the process itself

a. Various kinds of wood differ considerably, and even the same species varies with regard to the structure (specific weight, porosity, oil and resin content, acidity, hygroscopic properties, difference between spring wood and summer wood, difference between heartwood and sapwood etc.) Besides, there are differences in the state of wood (e.g. moisture content).

Light porous wood takes up too much glue: a thicker glue must be used. Resins and oils make adhesion more difficult (e.g. teak). In summer wood adhesion is weaker than in spring wood. The closed cellular web and thick resin of the heartwood cause difficulties.

The fibre direction in the piece to be glued is important because of different shrinkages. Butt joints, moreover, have a small gluing surface. Hence, both pieces must have the same fibre direction.
Gluing together heavy and light woods must be avoided.
The moisture content of the wood is important: different glues require optimum moisture content in service. Suitable moisture content is generally 10...15 per cent. In the case of dry film glues it is lower, 8...10 per cent, and the moisture range is smaller in this case.
The surface of the wood must be smooth. In certain cases, a pre-treatment must be applied in order to remove oil and resin.
Many glues are adversely affected by wood preservatives.

b. The amount of dry substance has a considerable effect on the result of gluing. The solvent is usually water, which is removed from the seam in due course. At the same time, the seam shrinks. The amount of shrinkage is inversely proportional to the amount of dry substance, it is also dependent on the thickness of seam. Shrinking causes stresses in the seam. Of these reasons, increasing the amount of dry substance makes the result better.
The amount of dry substance and possible filler have an effect on the viscosity of the glue. Its range of variation in glues is very wide: 100...15 000 cP.[1] The viscosity to be selected also depends on the pressure. When great pressures are used, thin glues are too strongly absorbed in the wood, so thicker glue is better in this case. The choice of viscosity depends further on the specific gravity and moisture content: light wood - thick glue; moist wood - thick glue and vice versa.
The acidity of glue is an important factor. Strong acids and bases damage the seam. The reaction of the wood itself must also be taken into account: it is usually acid. As the catalysts used as hardeners are usually acids, the seam can in the worst cases become weaker, and the wood in the vicinity of the seam can be lightly hydrolysed (softened). Thick seams make the situation worse also in this respect.

1/ centipoise

c. A very important stage in gluing is the application of pressure on the pieces. In the gluing of softwoods (density 0.4) one uses lower pressures (15 kp/cm^2, 2200 lbs/sq.in.) than for medium density hardwoods (0.7) (0 kp/cm^2, 2900 lbs/sq.in.).
These values do not yet cause shrinking of wood (in the case of Finnish woods).
Very heavy hardwoods, of course, can tolerate higher pressures. High pressure is disadvantageous for light woods also in other respects, because the glue is pressed into the wood and the seam becomes discontinuous. Uneven pressure also leads to the same end result. Too low pressure easily leaves the seam open.
As for temperature, one has to watch the temperature of the working space and of the pieces beside the temperature of the press. All temperatures must correspond to the process requirements. Errors occur in this respect, especially in cold conditions.

2. Glues

2.1. General classification

Glues can be classified on the basis of many criteria. The most usual ones are ability to withstand environmental conditions and origin.
In the first case, the main division is made between indoor and outdoor glues. This division is generally used in technology. In this connection, the glues are divided on the basis of their origin, as usually is the case in theoretical treatment. First, the two main groups are

- natural glues
- plastic glues

The former are further divided into two sub-groups:

- vegetable glues
- protein glues

The latter can also be divided into three sub-groups:

- thermosetting glues (Duro-plast)
- thermoplastic glues (Thermo-plast)
- elastomers

In these main groups, the classification can be continued in more detail. The main features of this detailed classification appear below.

2.2 Natural glues

This old class of glues has become less important during the last 20 or 30 years. Yet one can say that certain natural glues are still important as such and in combination with plastic glues. There is no reason to expect natural glues to totally disappear from use.

Vegetable glues. This group comprises macromolecular carbohydrates, vegetable proteins and water-soluble glues containing lignin. They are used in easy gluing applications with modest requirements. As raw material for starch glue potato, wheat, rice, maize, etc. can be used. Tapioca starch, which is obtained from cassava roots occurring in Java, is worth mentioning.

Dextrin glue is a near relative to the former group. Dextrins are produced by hydrolysing starch. The range of application is gluing of paper in cases where high moisture content typical to starch glues must be avoided. (cigarettes, paper pads, cardboard etc.)

Polyvinyl acetate glue (PVAc) has in many cases superseded dextrin glue.

There are two main types of cellulose glues

- cellulose ethers (methyl cellulose)
- cellulose glycolates (carboxymethylcellulose, CMC).

Both are made from sodium cellulose. The main field of application is wallpaper paste. These glues can also be used on wood, leather, metals and almost any other material.

Carbohydrate glue (gum arabic) is used in stamps and envelopes.

Protein glues

The glues of this group are usually made from animal residues (hides, leather, bones, fish residues). The protein (collagen) contained in these residues decomposes into glutine on applying heat. It is easily dissolved in hot water and it easily forms a jelly. Glutine glue is suitable for indoor use: main field of application is furniture. The glue seam is colourless, elastic, chemically inactive and in all respects excellent in indoor conditions. The glue sets very quickly and is easy to apply, only simple equipment being needed. Glutine glue must be protected against micro-organisms. Resistance to moisture can be increased through the use of formaldehyde (in cases where the relative humidity of the environment is high). Oxalic acid is also used for this purpose.

Casein glues are also very old in application. Casein is a milk protein which is precipitated from milk whey by means of enzymes or acids. The latter kind - acid casein - us the actual raw material for glues. Casein is dissolved in alkaline water. The usual base in this connection is calcium hydroxide $Ca(OH)_2$.
The durability of this glue is very short but it can be lengthened by means of chemicals (phosphates, fluorides etc.).
Casein glue has several advantages:

- casein powder can be stored for many years in air-tight packages
- the use is simple (cold water)
- the seam can be rather thick without serious effects (gluing of sawnwood)
- the strength is good, tolerates exposure to water
- temperature resistance is very good
- suitable for gluing resinous or oily woods

The disadvantages are

- colour defects in the case of woods containing tannic acid (oak, mahogany etc.)
- the mineral components (calcium) in the glue cause tool wear.

Casein glue is still used especially in the case of large pieces (glued girders).
Albumine is a constituent of blood. Albumine-based glue has formerly been used widely in plywood industry. Today, albumine only occurs in certain combinations for instance in combination with phenol (FENALB glues).
Certain oily plant seeds yield an extraction residue containing proteins, which can be used for glues. The best-known of these seeds is soybean. Soybean glue is much used in Japan and in the U.S.A. Its properties are comparable with those of casein or albumine.
All protein glues can be combined with varying mixture ratios, also with certain plastic glues (phenol, carbamine).

2.3 Plastic glues

This is the main group of glues due to its good properties:

- good resistance to water, even boiling
- good resistance to chemicals and micro-organism

- the setting process can be made very rapid

Plastic glues have brought many new applications and uses with them. The development is still rapid in this respect.

The plastics used in gluing wood are divided into

- thermosetting resins: can be used only once, non-reversible
- thermoplastic resins: can be used many times, reversible

This is a physical division. Chemically, the division goes further:

- polycondensates
- polymerates
- polyadditives

In this connection, only the most important plastic glues used in woodworking are treated.

Polycondensates

When plastic monomers combine to form polymers, a substance is split off from the point of adjoining molecules; usually this is water (polycondensation). In the glue manufacturing process, the reaction is carried halfway through. In gluing, the reaction continues to the end and a hardened irreversible group of macromolecules is formed: the glue seam.

This group contains four important basic glue plastics, which have in common a reaction with formaldehyde. These are:

a. phenol-formaldehyde resin
b. resorcinol resin — phenolic resins
c. carbamide resin
d. melamine resin — amino resins

a. Phenol is a reddish substance with the odour of carbolic acid. It is manufactured from coal tar by means of distillation, or synthetically starting from benzene. It is easily dissolved in hot water (+65° C, 150° F). Phenol reacts easily with formaldehyde. The reaction has three stages, and it is interrupted at a certain stage. The solvent is evaporated or the solution is absorbed in paper, which, in turn, is dried. In the former case, a powder is obtained, in the latter case, a dry film.

Phenol can be used as a cold glue, but this is restricted by the high acidity (pH around 1.0).

The main use of phenol is not gluing. The powder is dissolved in water so that the content of dry substance is 40...50 per cent. The glue sets by means of a hardener under pressure and heat. Suitable hardeners are resorcin, para formaldehyde and hexamethylentetrammin. The process data are roughly as follows:

p = 18 kp/cm^2 (200 lbs/sq.in.) hardwoods

t = 120...160^{0}C (250...320^{0}F)

Phenol seam is very dark. It is resistant to water (even boiling) and is more heat-resistant than wood.
The use of phenol film is very simple. The moisture content of the wood must in this case be very even, between 5...10 per cent.
Phenol glue is suitable in joining together wood and metal, but not suitable in joining metal to metal without additional measures.

b. Resorcinol is a close relative of phenol. It is also made from benzene which is sulphurated with sulphuric acid. Resorcinol reacts very eagerly with formaldehyde. This requires some caution. Resorcinol glue is in many respects similar to phenol glue (dry substance, hardeners etc.). The difference is that the seam sets readily at room temperature. The price of this glue is high due to manufacturing costs but it is widely used in exacting jobs: aeroplane construction, boatbuilding, glued girders etc.

c. Carbamide or urea belongs to the amino compounds. It is made from carbon dioxide and ammonia in a simple way, so its price is relatively low. Carbamide also reacts with formaldehyde.
It is a white crystalline substance and soluble in water.
The content of dry substance in a glue ready for use is 50...60 per cent. It sets under heat and/or acid hardeners (free acids or their ammonium salts, like ammonium chloride).
Carbamide can be used in cold or hot gluing. In the former case, the hardener must be quick-acting. The dry strengths of the seams are good (comparable with phenol) but the wet strengths are considerably lower (below 50 per cent after prolonged immersion). Alternate wetting and drying is harmful because the seam cracks rapidly. Cracking with age is a negative property of carbamide. The situation can be improved by means of suitable additives. Such additives are caolin, vegetable powders, wood dust and some alcohols. The seam must also be very thin. Carbamide glue can be made into a foam mechanically or chemically. Thin and even spreading can be achieved in this way.

The properties of carbamide glue can be considerably improved by adding melamine, but this makes the price higher. Carbamide glue or urea is widely used for instance in board manufacture (all kinds of boards).

d. Melamine is also an amino compound. It is manufactured from limestone, carbon and nitrogen in a many-staged process, which means a high price. Melamine is also a colourless crystalline powder. Its condensation requires much formaldehyde. The glue sets under application of heat only, so the gluing method is hot gluing. The content of dry substance in the glue solution is 40...50 per cent. The process data are

$p = 8...20$ kp/cm^2 (115...280 lbs/sq.in.)

$t = 110...120^{o}C$ ($230...250^{o}F$)

The wide pressure range is applied according to the specific gravity of wood.

Melamine seam is colourless, strong, elastic and water-resistant. This glue is particularly suitable for high-frequency gluing. Its advantage is the possibility of drying the surfaces after spreading glue. This facilitates the working process very greatly.

Polymerates

In the polymerizing process, nothing is separated from between the monomer molecules, as in the case of the polycondensation process. The most important glue of this group is polyvinyl acetate which belongs to vinyl plastics. It is manufactured from acetylene and acetic acid. The polymerization is easy, and the price is cheap. As a solvent, water is used when gluing wood. When gluing other materials other solvents with low boiling points are used, like alcohols, esthers and ketones. The setting of polyvinyl acetate glue is a purely physical process. The solvent is absorbed into wood. The seam is colourless. The biggest advantage of the glue is the simple use - no hardeners - easy to spread - easy to clean - rapid setting - low pressures needed. The seam is very elastic, and it can be made thick. This glue is suitable for assembly gluing of furniture. The dry strength in good, but a long continuous load causes creep. Wet strength is poor. This glue is mostly used as a cold glue. Hot gluing is also possible but in this case cooling must be done under pressure to below $50^{o}C$ ($120^{o}F$).

The process data are

p = 1...3 kp/cm^2 (15...45 lbs/sq.in.)

t = 20 ^oC (70 ^oF)

PVAC glue begins to soften when heated to above 60 ^oC (140^oF). If the relative humidity in the air is high, the seam becomes somewhat more resistant to heat.

Polyaddition resins

Polyaddition is a variant of polymerization: when monomers are combined, some bindings are opened and new reacting groups of atoms are added to the chain.

From this group, two excellent glues are mentioned here:

a. polyurethane glue

b. epoxy glue

a. Polyurethane is made from a suitable isocyanate and a di-valent alcohol. The seam has a good cohesion strength and a good ahdesion to various substances. It is very elastic, and fully resistant to boiling, chemicals, oils and micro-organisms. The seam does not shrink, so it can be made thick. Polyurethane glue begins to set already at room temperature. Carbamide or ammonium chloride can be used as hardeners. Rising temperature quickens the hardening. The top limit here, however, is 60 ^oC (140 ^oF) because after exceeding this limit poisonous substances are evaporated. The moisture content of wood must not exceed 10 per cent. The process data are

p = 3...kp/cm^2 (45...120 lbs/sq.in.)

t = 10...60 ^oC (50...140 ^oF)

Polyurethane glue has many uses in exacting jobs.

b. Epoxy glue is manufactured in a complicated process. Phenol, acetone, chlorine compounds, hydrochloric acid and sodium hydroxide are needed.

The price is high; however, epoxy glue has excellent qualities. It has all the advantages of polyurethane glue, and it is suitable for gluing almost any substance. (smooth glass, for instance). In cold gluing, triethylentetrammin is used as hardener. The setting time is long in this case (12 hours). Hot setting is achieved by means of phtalic acid anhydride, for instance.

If temperature is elevated to above 220 ^oC, the setting time is lowered to under ten minutes.

Elastomer

Neoprene contact glues are rubber-based glues with a mixture of ketones as solvent. Another possibility is to use a rubber emulsion in water. The former alternative is to be preferred however. Application of pressure is not absolutely necessary, but a pressure of, say, 5 kp/cm^2 makes the strength 6- to 8-fold. The pressure can be applied by means of rollers because no appreciable time is needed for the application of pressure.

The glue is left to dry after spreading before the surfaces are put together. This is particularly necessary when gluing porous materials such as metals.

Neoprene contact glues have a good resistance to water.

All glues mentioned above are the most important examples in their groups. Together they represent the majority of glues now in use. The glues not mentioned here have a small significance in the gluing of wood.

Some data on various glues as well as a comparison between different glue types used in Finnish industry are given in tables 6.1 and 6.2.

3. The gluing process

The manufacturer usually gives instructions for use. They are to be carefully observed.

When ordering glue, all factors affecting gluing must be stated (machines, tools, working method) as well as the final service conditions. On the glueing location, storing is of prime importance. Powder glues are easier to store than liquid glues. Both must be protected from heat and oxidation (airtight storing).

When preparing glue for use, all constituent parts must be accurately measured or weighed so the proportions are right.

The prescribed order of mixing and stepwise stirring time must be observed. Viscosity and acidity must be continuously controlled. The time for gluing · must be known as well as the amount of glue needed for this, so the batch size can be determined.

The "pot life" indicated by the glue manufacturer presupposes an ambient temperature of 20 ^{o}C. If the temperature is higher, the pot life decreases very rapidly with increasing temperature. The following examples give a picture of this phenomenon:

Temperature, ^{o}C	Pot life Glue A minutes	Glue B hours
15	70	40
20	40	24
25	25	15
30	15	10

Glue A is a carbomide glue for cold gluing , and glue B is a carbomide glue for hot gluing.

The glue must be spread in a suitable manner determined by the glue, type of joint and scale of production (manual work, roller spreading, spraying, pouring etc.) Even spreading and thin layers are to be sought after. The wood must be optimally moist and at the same temperature as the working space. The surfaces must be clean and smooth. The evenness of spreading. the glue layer must not be left exposed for too long periods.

A <u>pressure programme</u> must be provided for each gluing job. This indicates the times needed for pressing, heating, cooling and curing.

<u>Pressure</u>: increasing the pressure, time for constant pressure and lowering the pressure

<u>Temperature</u>: see pressure

<u>Cooling</u>: need for continued pressure, step-by-step stages

<u>Curing</u>: allowed times for starting handling and machining.

If a multilayer press is used, all openings should close at the same time.

Evenness of temperature and pressure throughout the working area is important. In continuous gluing continuous process control is needed. The basic tasks and means are the following:

Measuring moisture content of the wood before and after gluing. Instruments needed: scales, drying cabinet. Electrical instruments are not reliable enough.
Measuring viscosity and acidity of the glue. Instruments needed: a viscosimeter and a pH meter.
Measuring seam strength with standard test pieces. Instrument: testing machine (shear strength, tensile and compression strength, bending strength).
Inspecting seam structure and absorption of glue to wood. Instruments: microtome and microscope.
Spot checks to inspect adhesion by means of knife test. Instrument: chisel.

This equipment is sufficient for essential tasks in the control of glue joints.

Note

Effect of wood preservatives on gluing

The gluing process can be considerably affected by the use of wood preservatives. Is oily substances such as creosote oil are used as preservatives, the gluing can be very difficult indeed. The wetting properties of the glue can be improved by adding 2 to 4 per cent of weight of formaldehyde to the solution. A low glue viscosity also facilitates spreading.

Wood preservatives tend to slow down the hardening process. Therefore, a gluing temperature of about 10 degrees higher than that for non-treated wood is recommended.

Boron-containing preservatives have the least effect on gluing.

Standards for glues

BS 1203:1954 (Plywood Glues)
BS 1204:1956 (Countr. Work in Wood Adsives)
BS 745:1949 (Animal Glues)
BS 1417:1948 (Synthetic Glues)
BS 1455:1956 (Chisel Test)
BS 1444:1948 (Casein Glues)
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Glues

Fig. 6.1 Distribution of stress in glued joints (comparison)

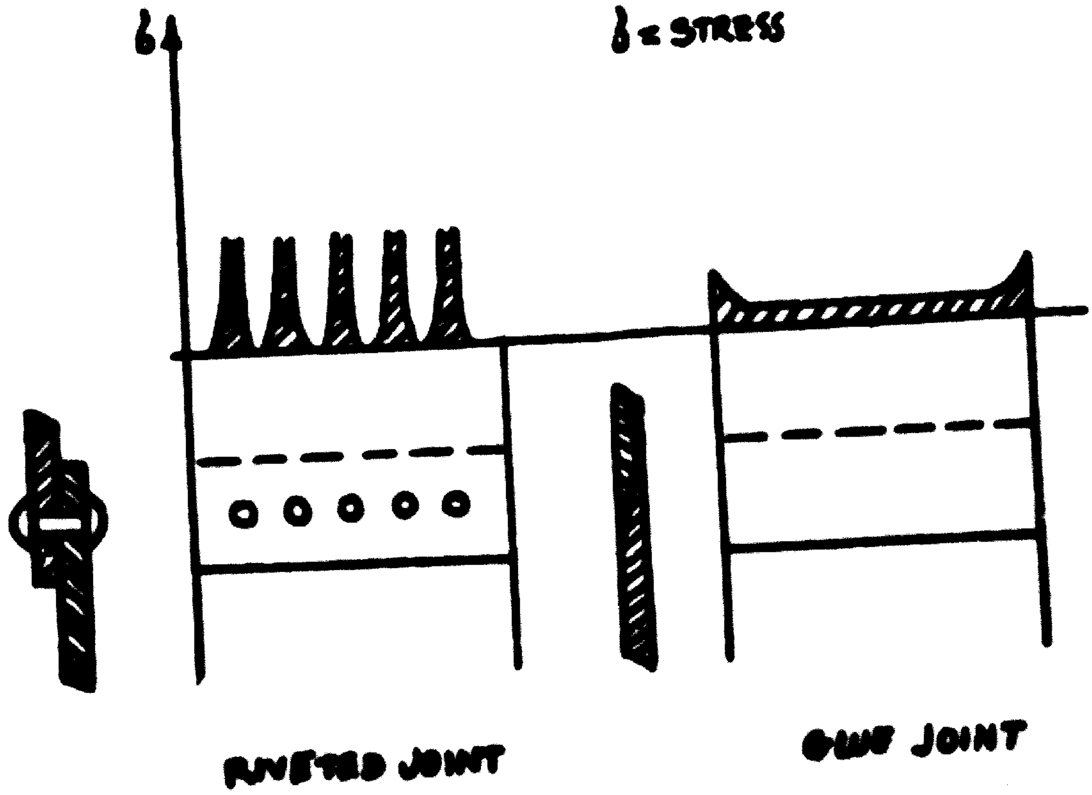


Fig. 6.2 The principle of glued joint

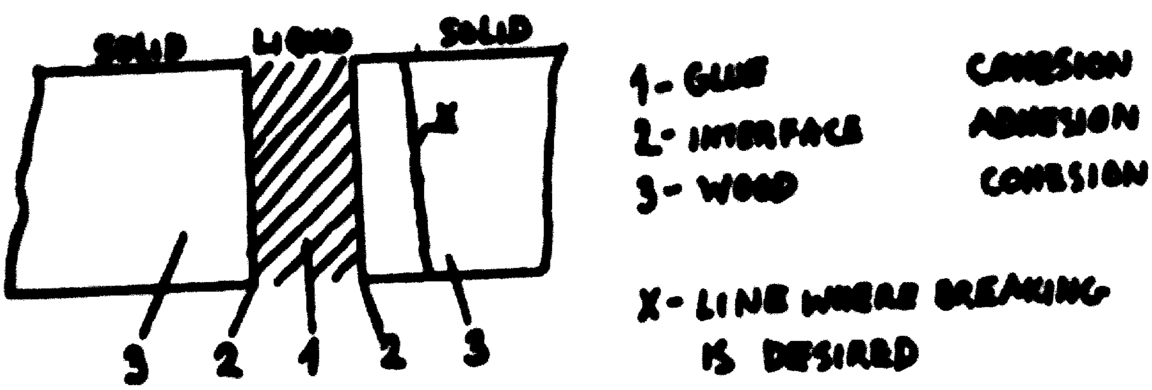
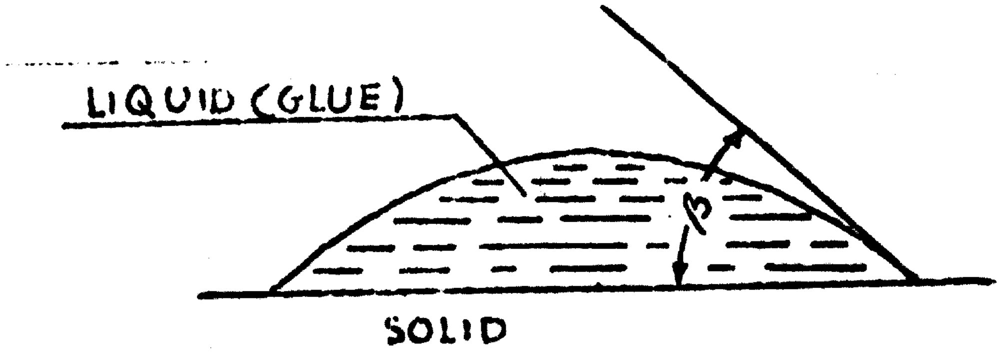


Fig. 6.3 The spreading of glue



β= contact-angle

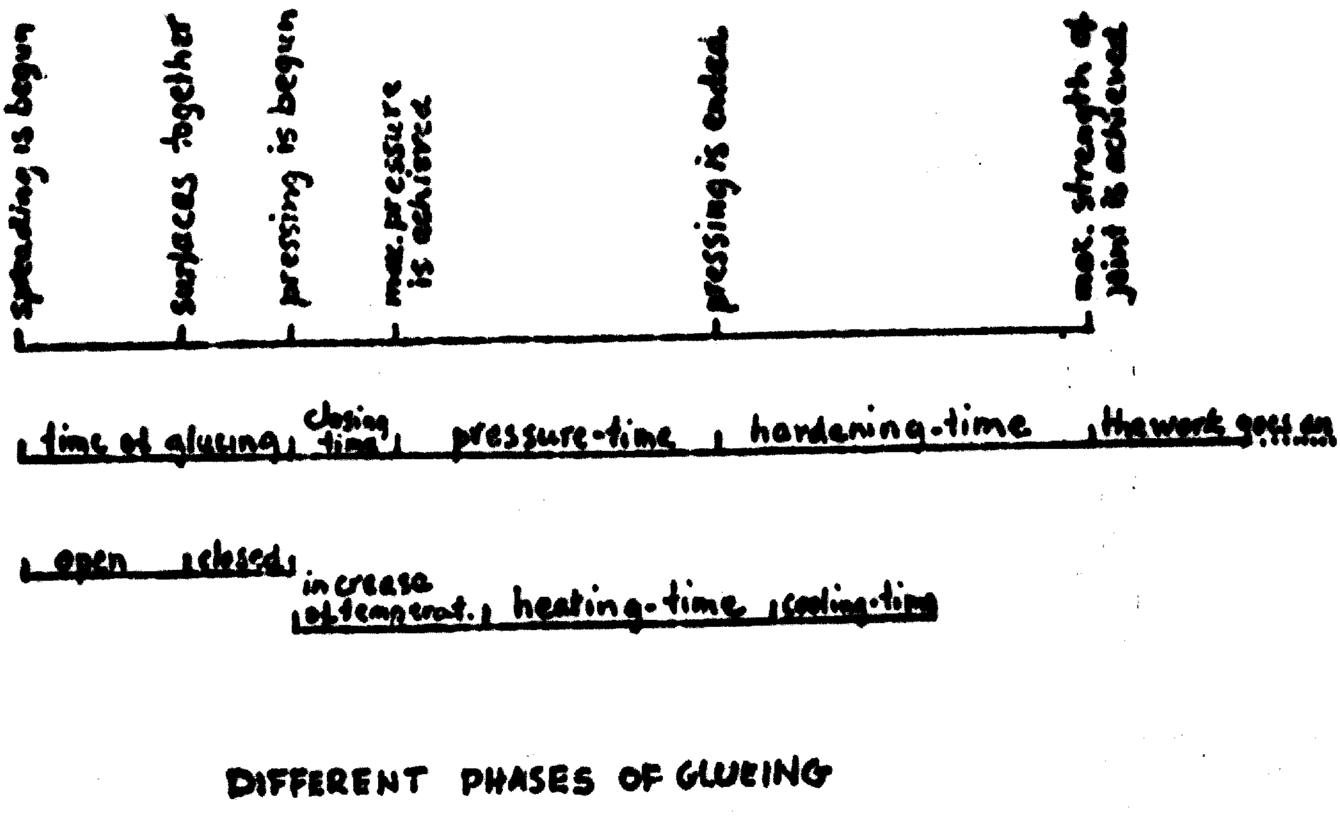
can vary between 0....180° (theoretical ultimate values)

β=0° complete spreading

β=180° zero-spreading

AIM IN THE SPREADING OF GLUE : βmin

Fig. 6.4 Different phases of gluing



DIFFERENT PHASES OF GLUEING

Table 6.1

Glue	Dry substance per cent	Pot life hours	Moisture content of wood, per cent	Spreading g of solution/m²	Pressure kp/cm²	Temperature °C	Pressing time	Water resistance	Acidity pH
Glutine	35-50	100	4-10	140-250	1/2-1-5	-70	1-3 h	poor	7-8
Casein	30-35	4-12	4-10	250-300	5-10	20-100	2 h	resists moist air	10-14
Soybean	20-22	4-8	4-10	250-300	8-10	20	5 h	poor	10-14
Albumine	14-20	2-4	4-10	200-350	8-10	100	5 min + 1 min/mm	resists moist air	10-14
Carbamide	60-70	2/3(cold) 24 (hot)	4-12	100-200	6-12	20 100-120	1/2-4 h 3-10 min	resists moist air	3-6
Melamine	60-70	12-24	4-12	100-150	5-15	100	3 min + 1 min/mm	good	3-[illegible]
Phenol (hot glue)	40-50	2-5	< 5	100-150	10-15	120-150		good	10-14
Resorcinol	50-60	5/20°C 2 1/2/30°C	8-14	200-300	10-15	10 60 100	10 h 20 min 5 min + 1 min/mm	good	6-8
Polyvinyl acetate	50-60	6-12 months	5-12	200	8-15	20-80	2/20°C 7 min/80°C	resists moist air	5-7
Epoxy	-	1/3	6-12	150-200	6-12	20-150	10 min-7 h	good	-
Poly-urethane	20-80	24	6-12	200-250	3-8	10-60 (max)	5/10°-3/20°-1/2/60°	good	-

Table 6.2 Information on glues used in Finland

Group of glues	Percentage share of total use	Relative price
Protein	5	1,5
Carbamide	60	1,0(=$ 0,1/kg)
Phenol	20	2,5
Resorcinol	2	15,0
Melamine	2	6,0
Polyvinyl acetate	10	3,5
Other plastic glues	1	-

Table 6.3

INTERNATIONAL STANDARD ABBREVIATIONS FOR PLASTICS

(ISO/TC 61)

CA	cellulose acetate
CMC	carboxymethylcellulose
CN	cellulose nitrate
EP	epoxy
KF	carbamide formaldehyde
MF	melamin formaldehyde
PF	phenol formaldehyde
PA	polyamide
PE	polyethylene
PS	polystyrene
PTFE	polytetrafluorethylene
PUR	polyurethane
PVAC	polyvinylacetate
PVC	polyvinylchloride
RF	resorcinol formaldehyde
SB	styrene butadien
UP	unsaturated polyesther

4. 4.74