BINDING WOOD

Binders and Wood Based Panels

Structure of the presentation

1. Introduction
2. Binders
   - Amino (UF, UmF, MUF)
   - Phenol (PF)
   - Isocyanates: pMDI / eMDI
3. Wood based panels
   - Plywood
   - Particleboard
   - OSB
   - MDF
   - LPL / HPL
4. Case Study

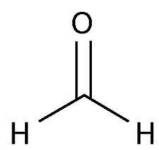
Introduction (1/2)

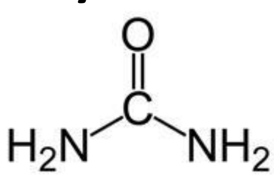
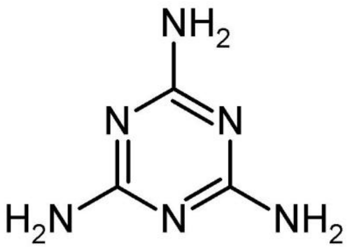
1) Wood (Lignin, Cellulose, Hemi-cellulose)
   - Trunks / logs
   - Green Chips
   - Sawdust / sander dust / plywood trim
   - Various forms of recycling (furniture, pallets etc.)
2) Wood preparation:
   - Veneers (Plywood, PW)
   - Strands (Oriented strand boards, OSB)
   - Chips (Particleboard, PB)
   - Fiber (Fiberboards, MDF, HDF . . .)
3) Resination
4) Hot pressing
5) Quality Control (QC)

Introduction (2/2)

Amino Binders (1/2)

- Aqueous solutions produced from:

Formaldehyde  and

Urea  or Melamine 

Methylolation stage:

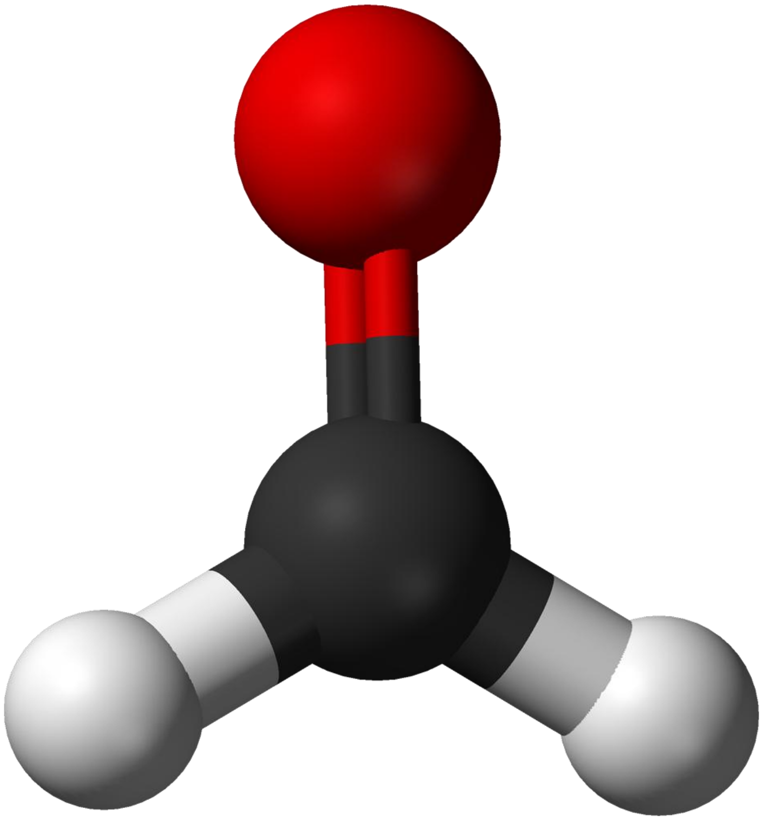
$-NH_2 + HCHO \rightarrow -NHCH_2OH$

Condensation stage:

i) $-NHCH_2OH + HOCH_2NH- \xrightarrow{H^+} -NHCH_2-O-CH_2NH-$ (ether bridge)

ii) $-NHCH_2OH + H_2N \xrightarrow{H^+} -NH-CH_2-HN-$ – (methylene bridge)

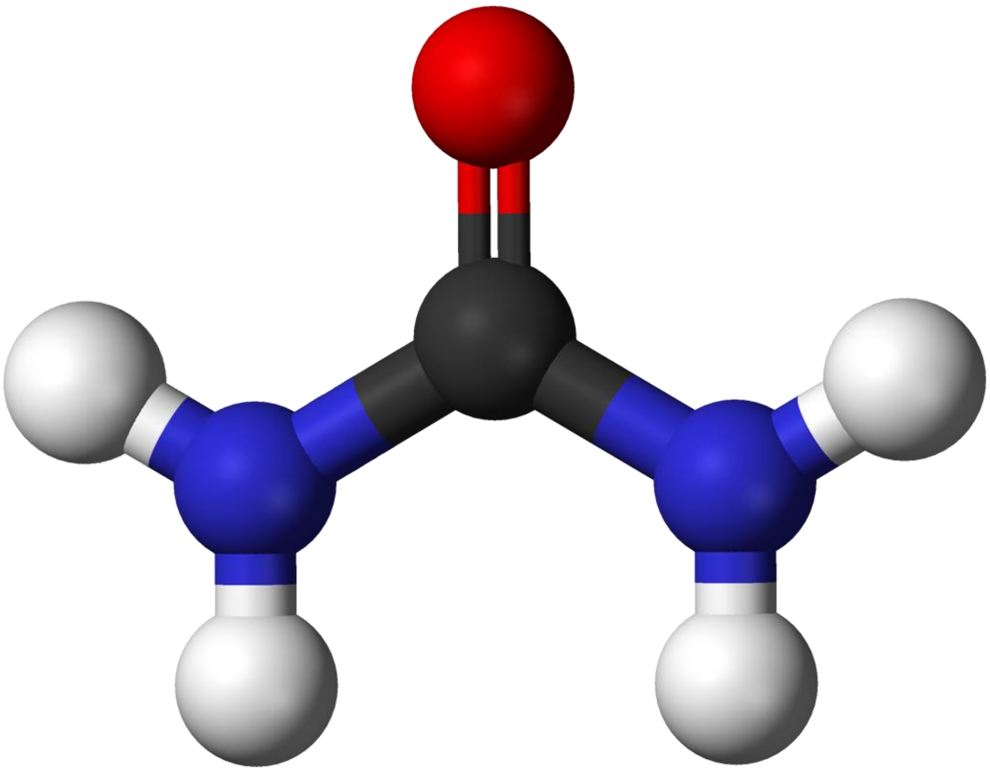
Formaldehyde



1	+	(12	+	16)	+	1	=	30		

- is a colorless gas with a characteristic pungent odor.
- is a naturally occurring substance in the environment. Natural processes in the upper atmosphere may contribute up to 90 percent of the total formaldehyde in the environment, other sources being forest fires, automobile exhaust, and tobacco smoke.
- is an important precursor to many other chemical compounds, especially for polymers.
- is easily soluble in water. Commercial solutions of formaldehyde in water, commonly called **formalin.**
- Has a Molecular Weight of 30.

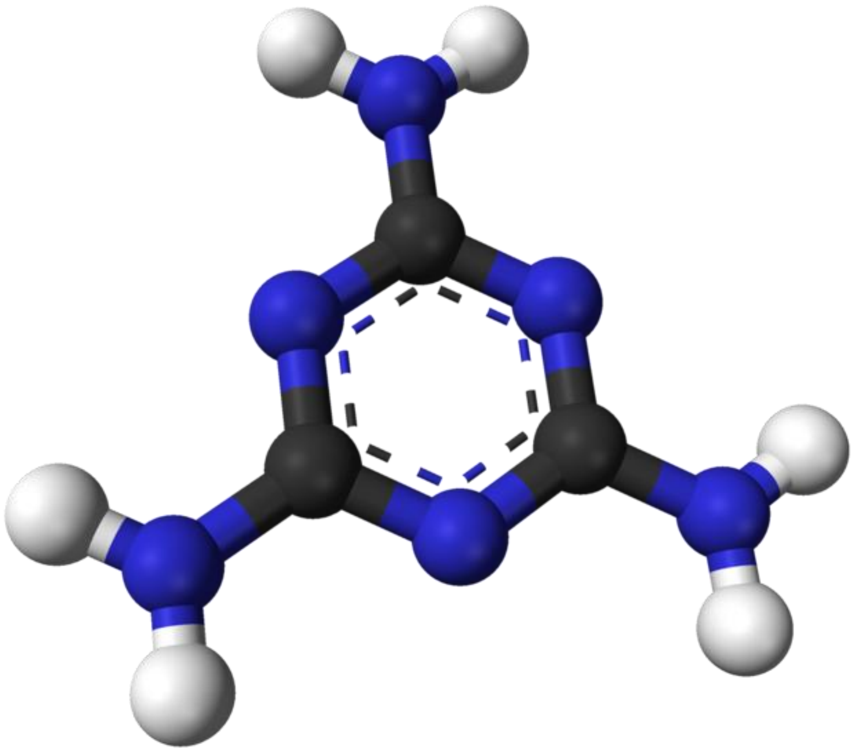
Urea



1 + 1 + 14 + (12 + 16) + 14 + 1 + 1 = **60**

- Is a colourless and odorless solid
- Is widely used in fertilizers as a convenient source of nitrogen (90% of world production)
- Is highly soluble in water and practically non-toxic
- Has a Molecular Weight of 60.
- It can react with formaldehyde on the hydrogen sides (theoretically 4)

Melamine



1 x 6 + 14 x 6 + 12 x 3 = **126**

- Is a white odorless solid, most commonly in thin powder form
- to produce melamine, most industrial manufacturers use urea
- Is practically insoluble in water
- Has a Molecular Weight of 126
- It can react with formaldehyde on the hydrogen sides (theoretically 6, 50% more that Urea)

Molar Ratio

One important parameter of resin is the Molar Ratio

It is an indication of the number the molecules of Formaldehyde exist in the resin with respect to Urea (and/or Melamine) molecules

To calculate the Molar Ratio of a UF resin, one must divide the weight of pure Formaldehyde with the Molecular Weight (30) and the weight of pure Urea with the Molecular Weight (60) and take the ratio of those two

$$\text{UF Molar Ratio} = \frac{\frac{F}{30}}{\frac{U}{60}} = \frac{2 \times F}{U}$$

When Melamine exists in the resin system, by convention, the Molar Ratio calculation takes into account that there are 50% more reaction sides in Melamine

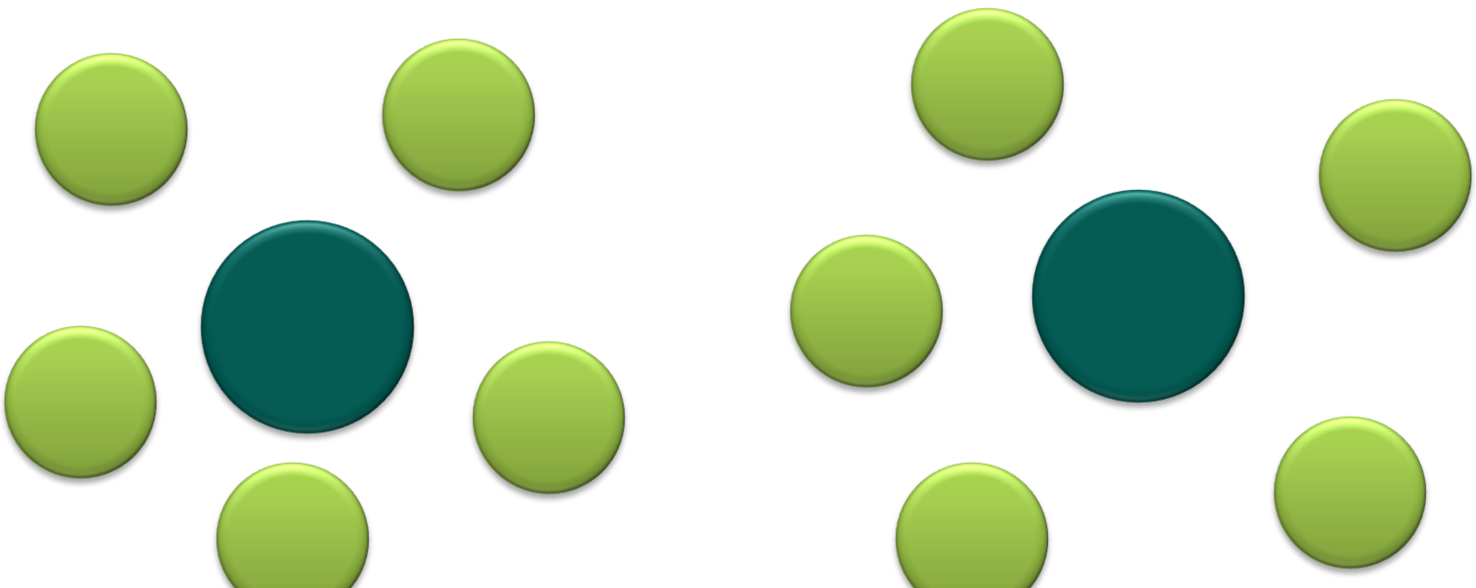
$$\text{UMF Molar Ratio} = \frac{\frac{F}{30}}{\frac{U}{60} + 1.5\frac{M}{126}} = \frac{14 \times F}{7 \times U + 5 \times M}$$

Making a Resin starts before the reactor

Formaldehyde Gas Goes Up the Absorber

Urea (in the form of water solution) is feed from the top of the Tower

Having the correct pH, some Formaldehyde will react with the Urea



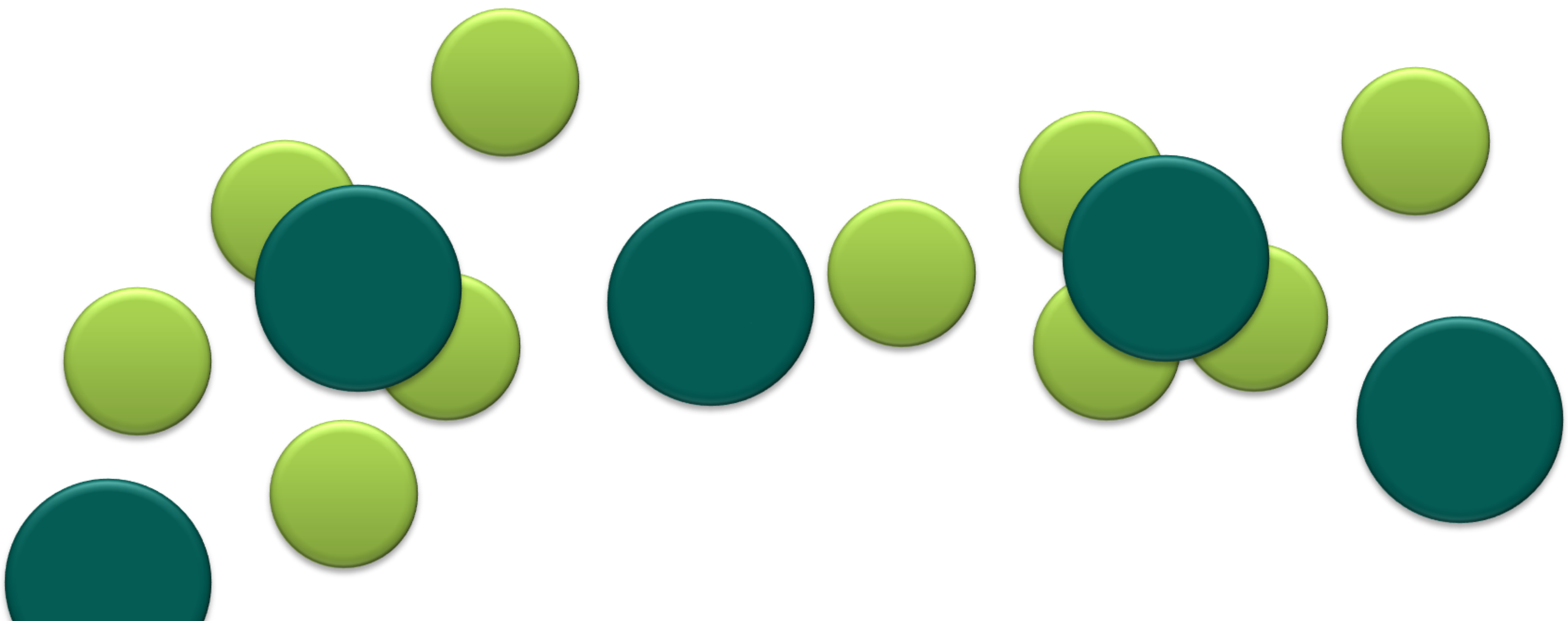
Q: What is the Molar Ratio of the above mixture?

Starting a batch

UFC is pumped in the reactor

Then, it is diluted with water

Having the correct pH, more Urea is added



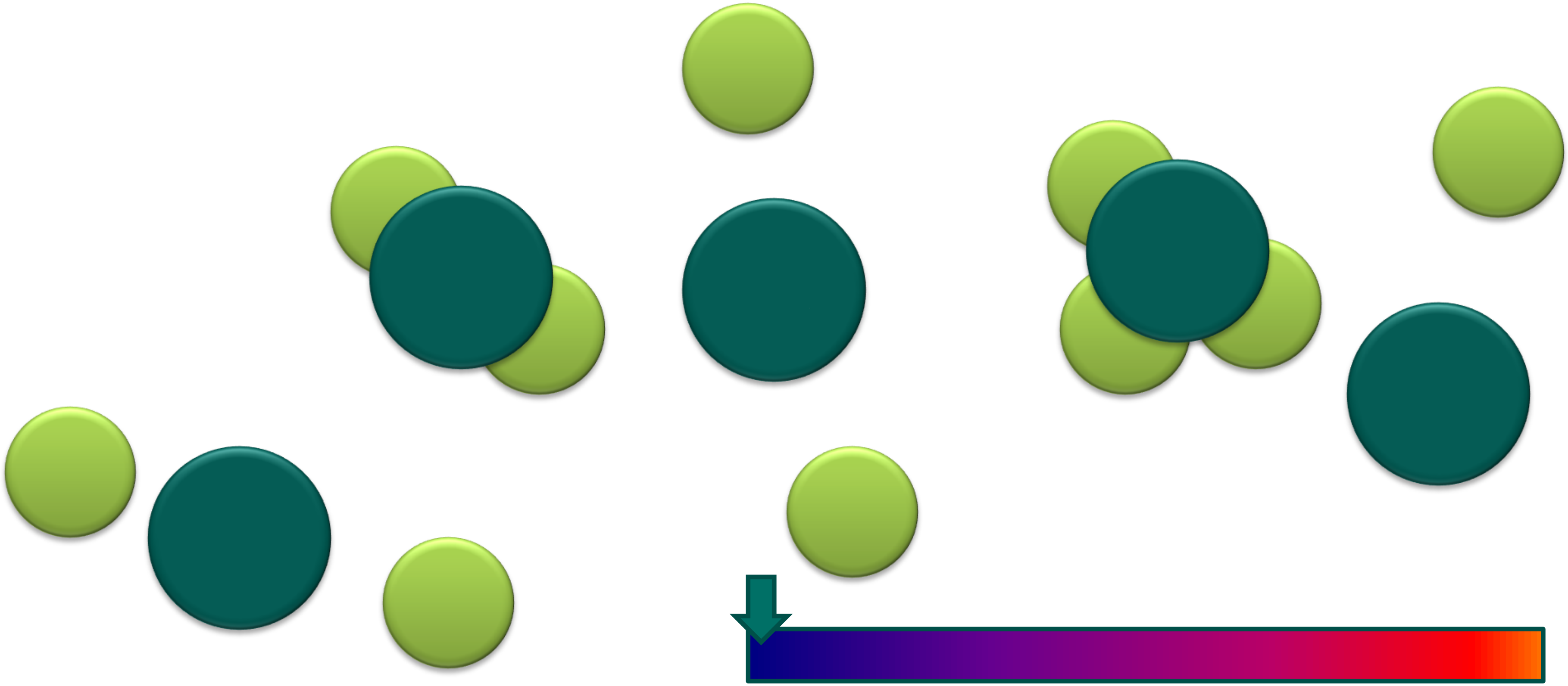
Q: What is the Molar Ratio now?

Taking it to polymerisation temperature

Heat is supplied to the mixture and the temperature rises

The molecules start reacting with each other

Reaction has to be completed (waiting time)

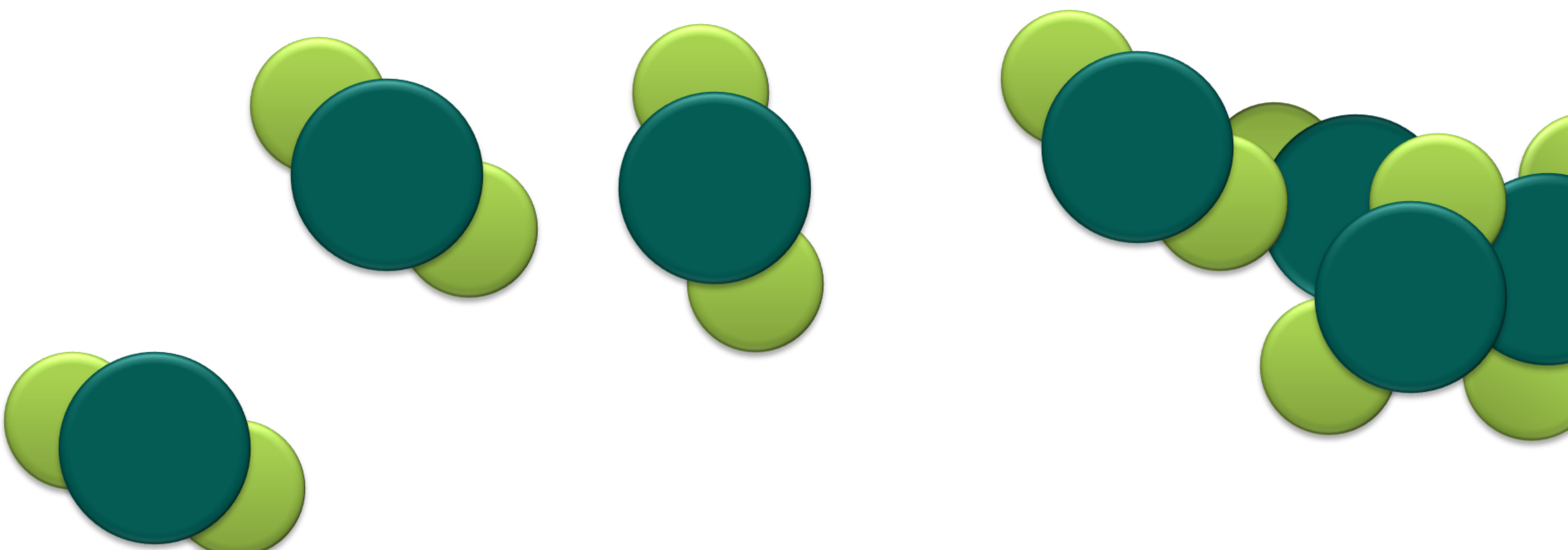


The polymerisation stage (1)

Upon acidification, the monomers will start to react with each other

Chains are formed…

… which react with other chains to form long & complex chemical molecules

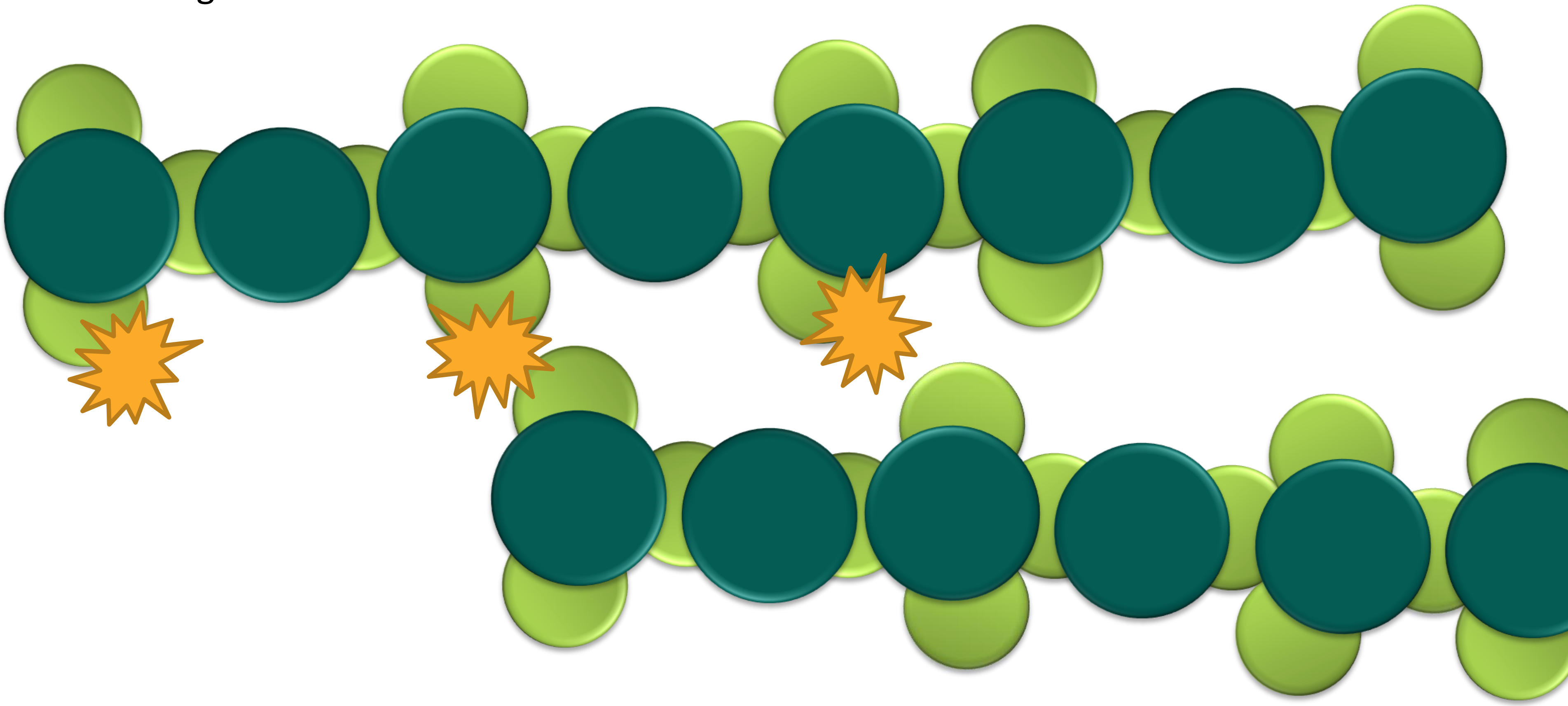


The polymerisation stage (2)

The longer the molecules, the higher the friction between them

The higher the friction, the more viscous the mixture becomes

The more viscous the mixture, the longer a constant volume will take to go through a hole

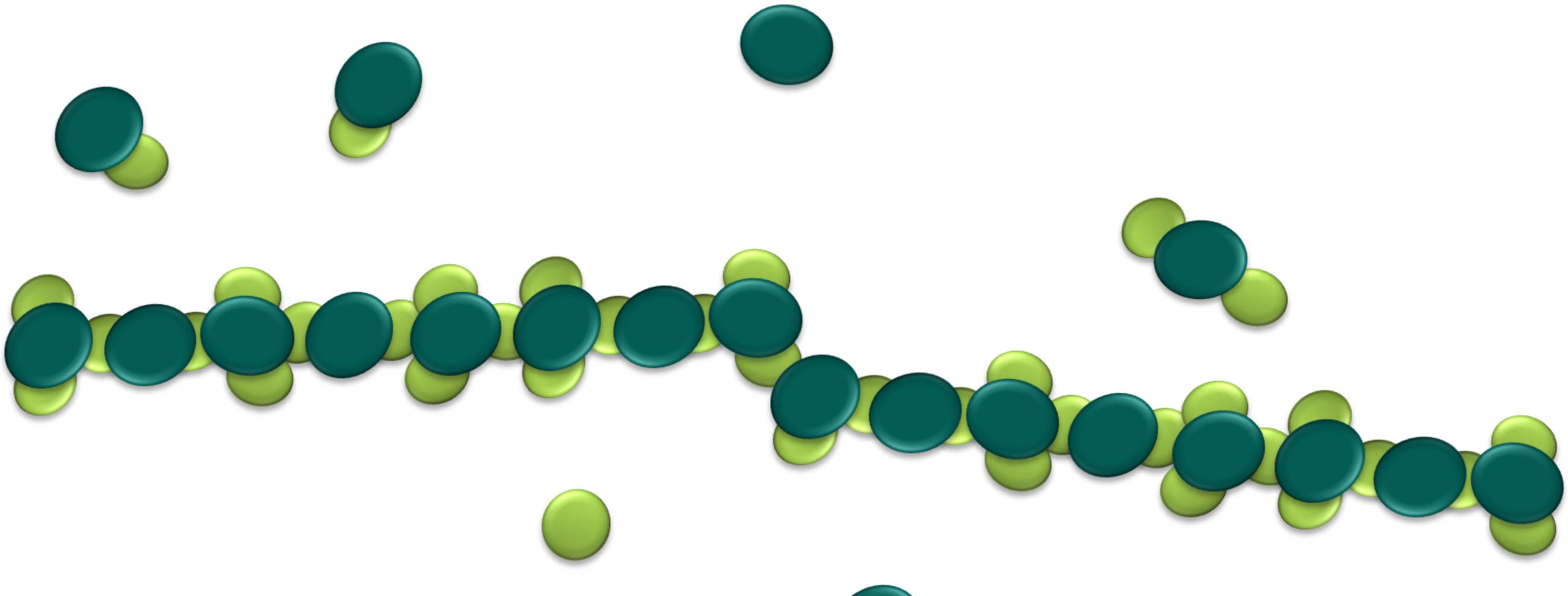


Finishing Off

By changing the pH, the favorable environment for reaction is discontinued

It is true that not all of the formaldehyde has participated on the polymerisation

It is left out intentionally, to make more monomers (again)



These monomers, will be used as quick links for the long chains

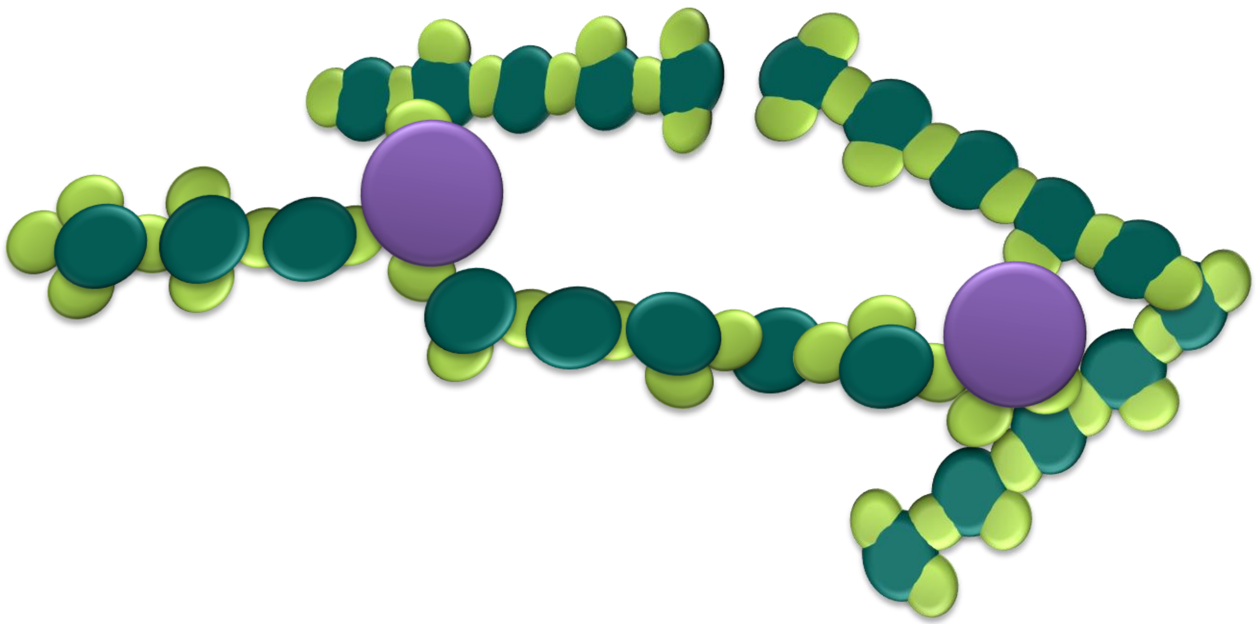
The melamine effect

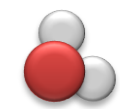
As already said above, melamine has 6 reactive sides vs. 4 of urea

It is true that melamine is highly hydrophobic (water- repellant)

Those two abilities make melamine a good partner for better resins as:

1. They increase the density of the polymers (Higher cross-linking)
2. They protect the polymer from water – deterioration (hydrolysis)

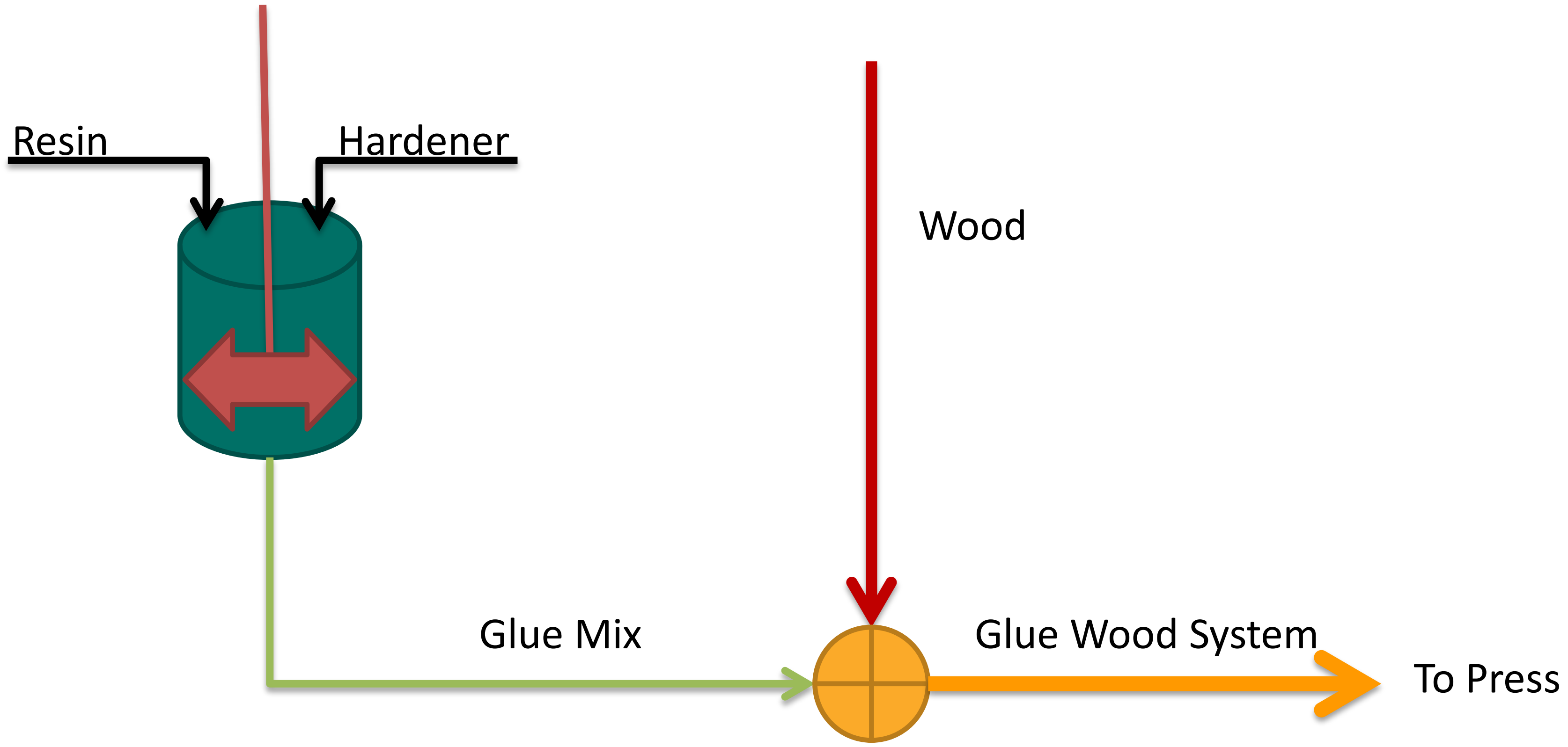




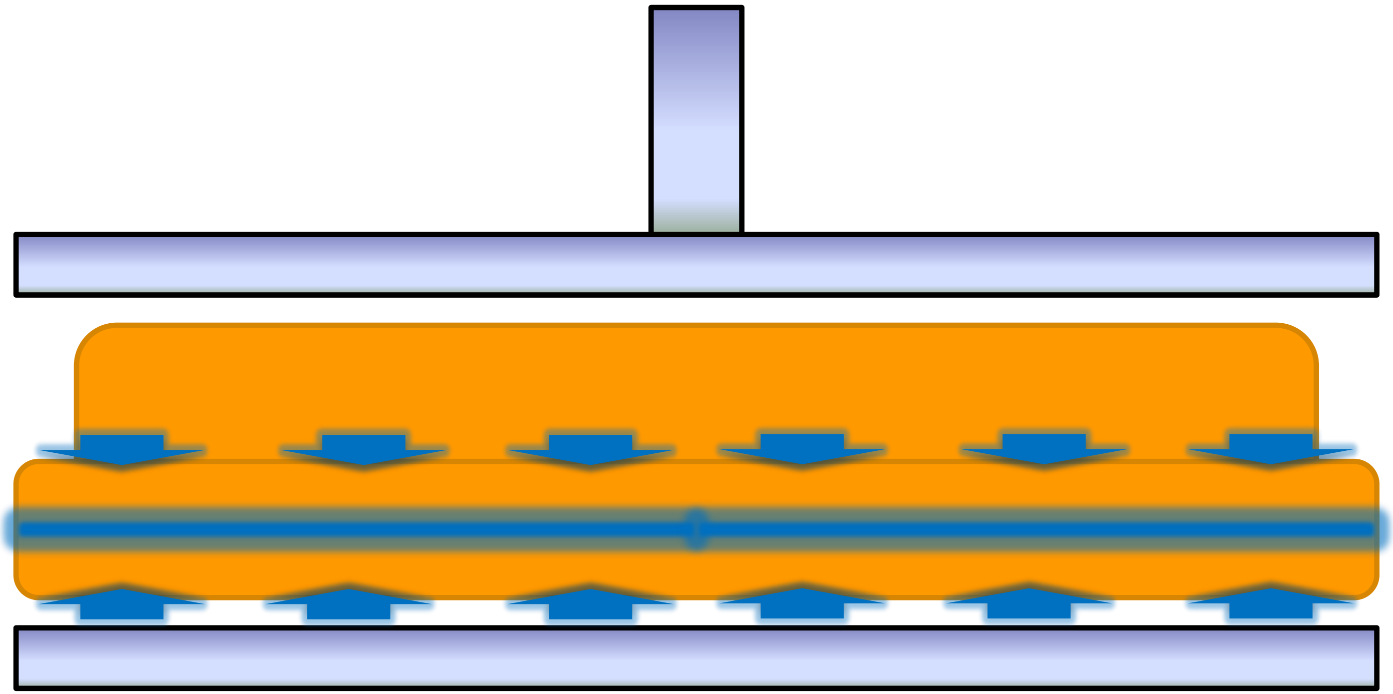
Setting the Resin

- The polymerisation is favoured by low pH and high temperatures
- In the press, the temperature is high enough but the pH is on the alkali side
- One could add acid in the resin to lower the pH, but that will set the resin on the spot.
- Ammonium-based compounds-hardeners are used (e.g. Ammonium Chloride, Ammonium Sulfate, etc).
- These are the salt of the corresponding acid with ammonia.
- When mixed with the resin, the ammonia reacts slowly-enough with the free formaldehyde, liberating the necessary acid.
- The amount of hardener has to be carefully selected to avoid resin setting prior to the press (“precuring”)

Resination



In the press



Mat is entered in the press and Pressure is applied

Press-plates are hot, so water from the top and bottom of the mat, is turned into steam

Steam is flowing from the surfaces to the core where he can leave the mat

Steam heats up the path is following, providing heat for the resin to set

Amino Binders (2/2)

A 3D cross-linked structure is formed!

- Condensation reaction is acid catalyzed.

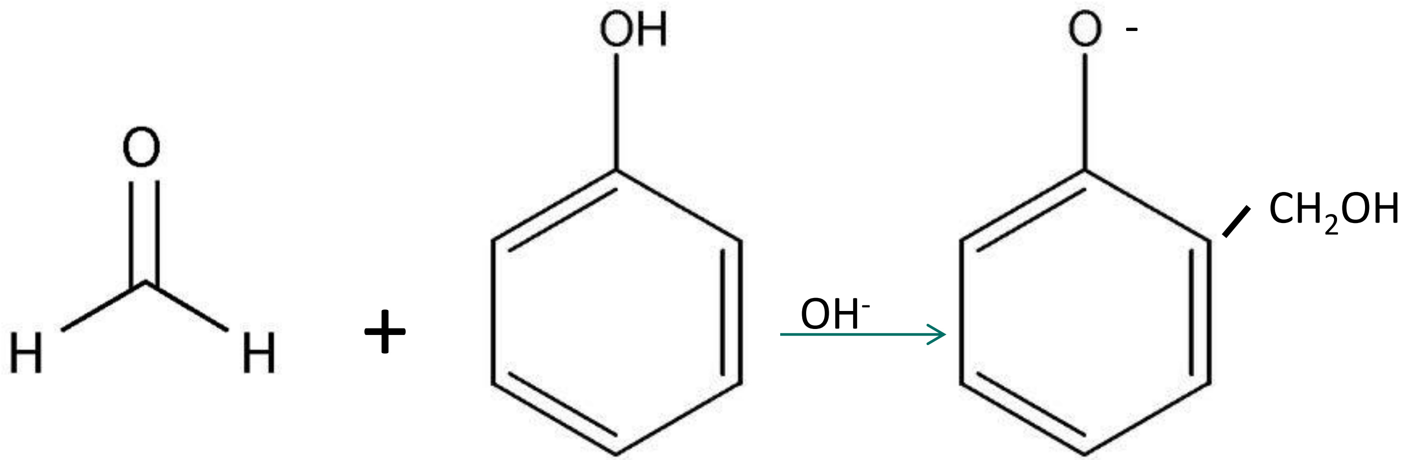
Advantages	Disadvantages
Low cost High Reactivity Acceptable panel properties With melamine (expensive additive) specialty panels can be produced like low formaldehyde emissions, moisture resistant.	Formaldehyde release from set polymer Carbon footprint Without Melamine poor moisture resistance Need of catalyst, low pot life

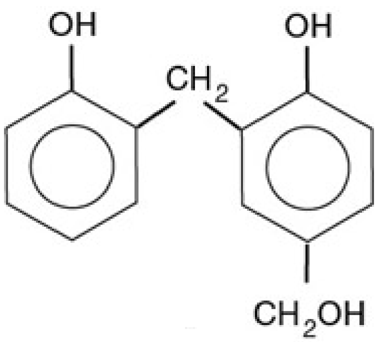
Applications	**Interior grade PW, PB, MDF, OSB (face) , HPL, LPL**

1) Melamine increases cross – linking density due to three non linear amino groups
2) Due to the quasi aromatic ring it resists hydrolysis better than UF link.

Phenol binders (PF, 1/2)

- Aqueous solutions produced from:





A 3D cross-linked structure is formed!

Phenol binders (PF, 2/2)

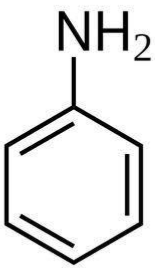
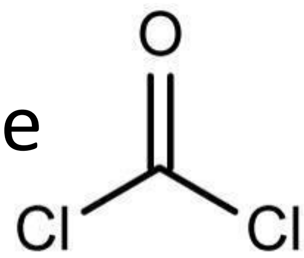
Advantages	Disadvantages
Relatively Low cost Can be used without hardener i.e. long pot life Low formaldehyde emissions Good panel properties, withstanding boil tests	Carbon footprint Low reactivity Toxic, corrosive RM (Phenol) Color

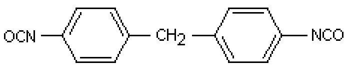
Applications	**Exterior grade PW, OSB (face) , HPL + many other non WBP**

Isocyanates (pMDI, eMDI, 1/2)

Polymerized or emulsified Methylene diphenyl diisocyanate,

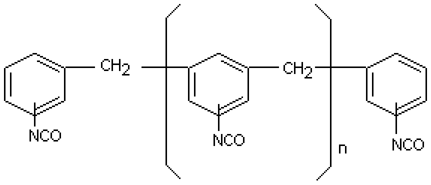
Not miscible with water, produced from:

Formaldehyde, Aniline  and Phosgene 



Chemical structure of MDI

A 3D cross-linked structure is formed!



Chemical structure of PMDI

Isocyanates (pMDI, eMDI, 2/2)

Advantages	Disadvantages
Low addition rates Low formaldehyde emissions High reactivity Compatibility with Amino and phenolic binders Good panel properties, withstanding boil tests	High cost Carbon footprint Handling Health and safety Adheres to press platens

Applications	**OSB (core & face less frequently) , Special grades PB, MDF**

Binders Summary

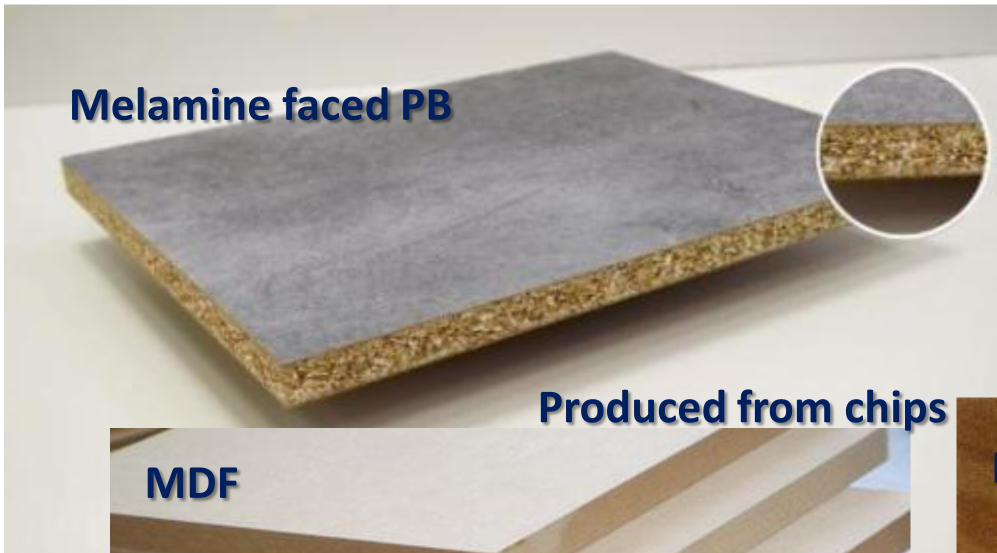
- Three main categories:

1. Amino
2. Phenolic
3. Isocyanates

- All have advantages / disadvantages and are selected for suitable applications
- Very competitive market
- Cost is an important factor that can change the preferred binder
- All come from fossil fuels

A 3D cross-linked structure is formed!

WOOD BASED PANELS



PLUS BINDER!!!!!!!!!

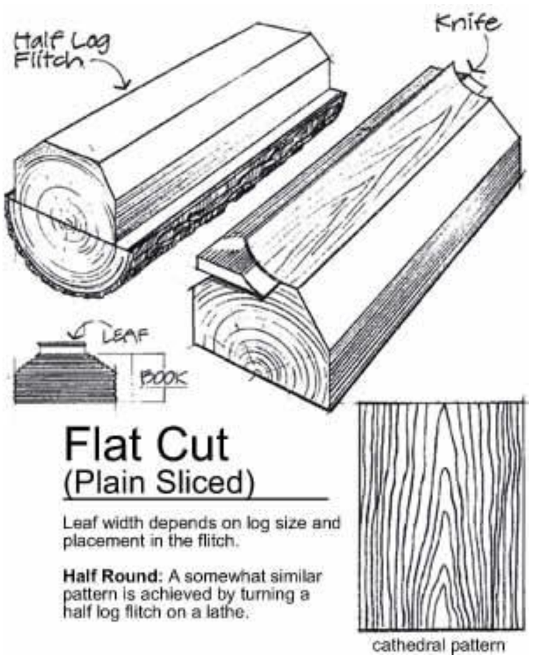
Plywood (1/4)

- Process flow:

1. Cutting steamed logs into veneers
2. Selecting and drying veneers
3. Gluing veneers and forming piles
4. Cold pressing (pre-press)
5. Hot Pressing and stacking
6. Quality control

Plywood (2/4)

Produced ONLY from logs that are cut into veneers (expensive)



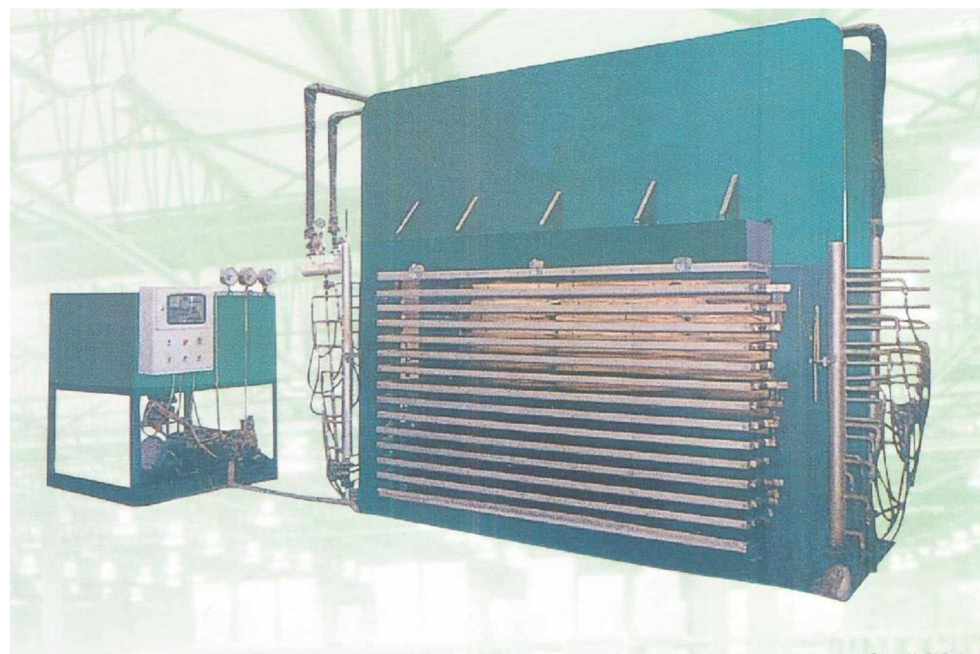
•Once the veneer is prepared and DRYED the binder is applied
•In the lab it is done by a spatula or a small roller
•Industrially by:

1. Roller
2. Curtain
3. Foam
4. Spray

Plywood (3/4)

Cold (Amb. Temp, 10min various sp. pressures) and

Hot pressing (130^{o}C, 1min/mm, various sp. pressures)



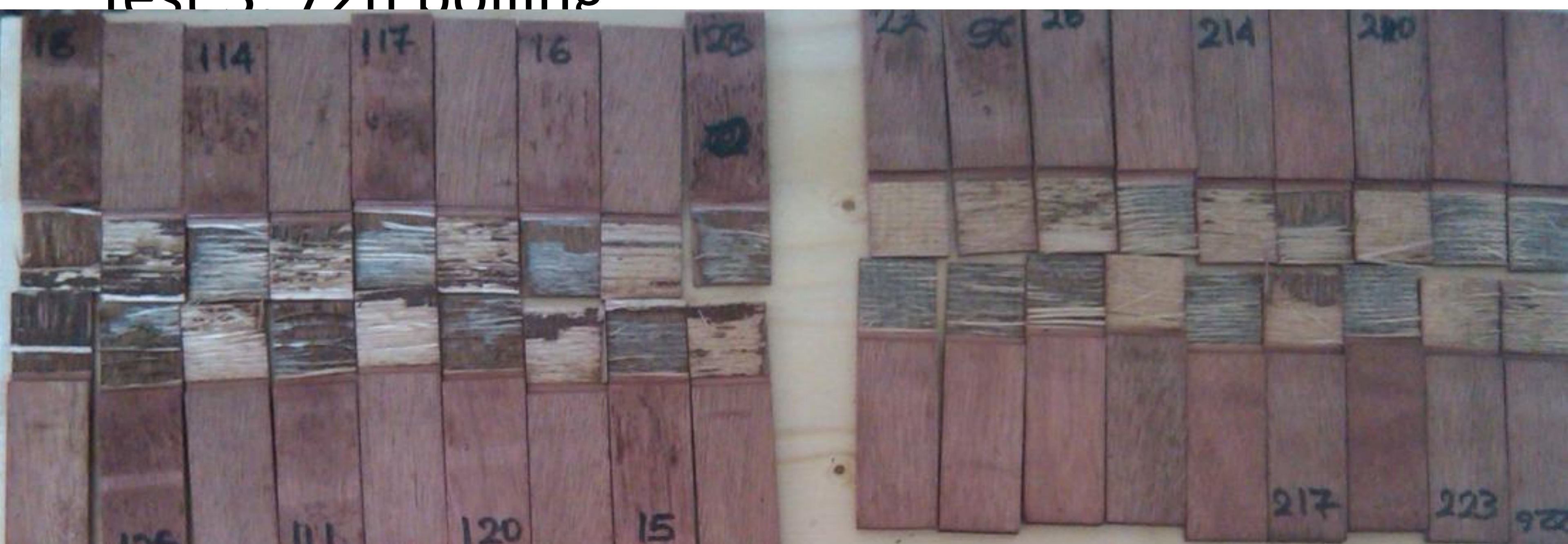
Plywood (4/4)

Plywood QC:

Test 1: 24h immersion in $20^{o}C$ water

Test 2: 6h boiling 18hdrying 6h boiling

Test 3: 72h boiling



Particleboard (1/5)

- Process flow:

1. Wood preparation into chips
   - Debarking, chipping, removing metal, flaking, drying, sieving
2. Preparing glue mix
   - Resin, Water, Hardener
3. Adding wax
4. Blending with resin
5. Forming a “mat” face and core layers
6. Pre-pressing
7. Hot pressing
8. Cooling star
9. Stacking
10. Sanding
11. Quality control

Particleboard (2/5)

Produced from every possible wood furnish, cheap solution

Blender

Particleboard (3/5)

Press infeed

Fastest production of all WBP, 3 - 6s/mm!!!!!
Temperature up to 245°C

Continuous press

- Mat is compressed and heated
- Heat is transferred by steam and convection
- Vapor escapes
- Binder sets (chemical formation of a 3D cross-linked structure)
- Board is released when it can hold itself together

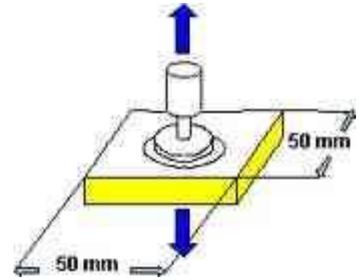
Cooling Star

Particleboard (4/5)

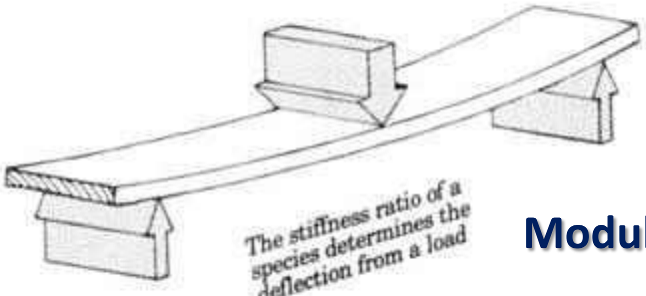
Quality control:	Measured in:
• Internal bond	N/mm^2 / PSI
• Modulus of rapture / elasticity	N/mm^2 / PSI
• Thickness Swell	%
• Formaldehyde release	ppm
• Screw pull	N/mm^2 / PSI
• Face pull	N/mm^2 / PSI
• Boil test	N/mm^2 / PSI
• Cyclic test	N/mm^2 / PSI

Particleboard (5/5)

Internal bond

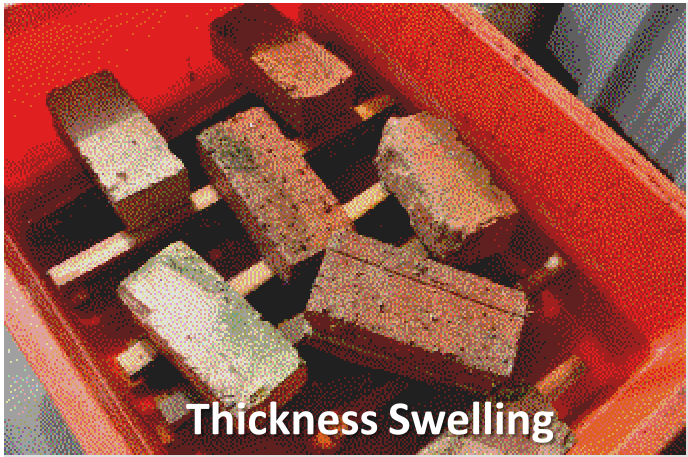


Face Pull



Modulus of rapture

Formaldehyde Release


Thickness Swelling

OSB (1/3)

- Process flow:

1. Wood preparation into chips
   - Debarking, chipping, removing metal, flaking, drying,
2. Preparing glue mix
   - Resin, Water, Hardener
3. Adding wax
4. Blending with resin
5. Forming a “mat” face and core layers
6. Pre-pressing
7. Hot pressing
8. Cooling star
9. Stacking
10. Sanding
11. Quality control

OSB (2/3)

Not all wood sources can be utilized, pressing factor above 10s/mm, cannot be laminated!!!

OSB (3/3)

Quality control:	Measured in:
• Internal bond	N/mm^2 / PSI
• Modulus of rapture / elasticity	N/mm^2 / PSI
• Thickness Swell	%
• Formaldehyde release	ppm
• Screw pull	N/mm^2 / PSI
• Face pull	N/mm^2 / PSI
• Boil test	N/mm^2 / PSI
• Cyclic test	N/mm^2 / PSI

MDF (1/5)

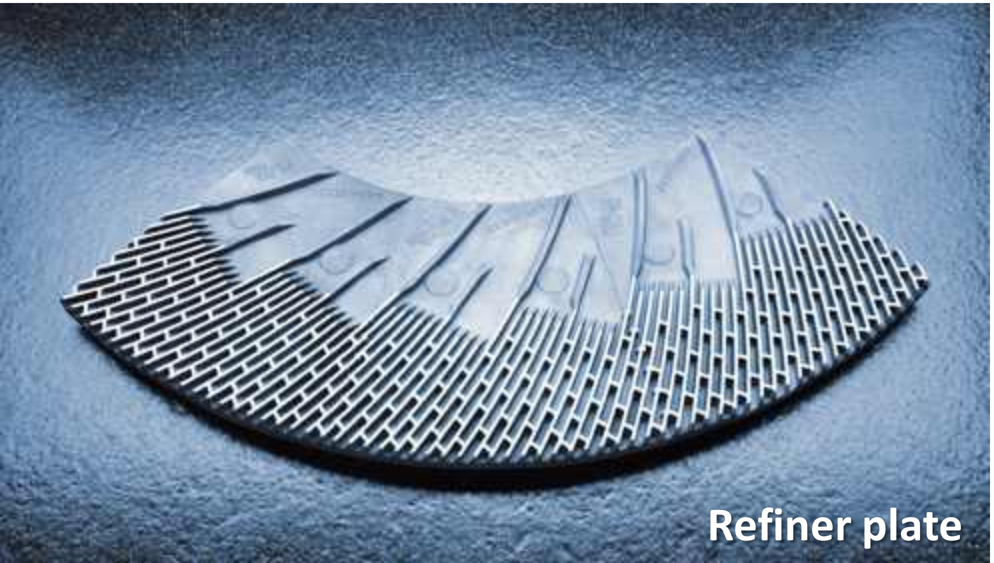
- Process flow:

1. Wood preparation into fiber
   - Debarking, chipping, removing metal, pre-steeming, digesting, refining
2. Preparing glue mix
   - Resin, Water, Hardener
3. Adding wax
4. Blending with resin
5. DRYING!!!
6. Forming a “mat” 1-layer most of times, 3-layer in some cases
7. Pre-pressing
8. Hot pressing
9. Cooling star
10. Stacking
11. Sanding
12. Quality control

MDF (2/5) refining

Open refiner

Open refiner



Refiner plate

MDF (3/5)

Produced from every possible wood furnish, cheap solution BUT wood refining is expensive, can be molded for doors and deep routed.

Blow - Line

MDF (4/5) mat & pressing

MDF mat

Pressing time, relatively slow:
6 – 20s/mm
Press temperature up to 245°C

MDF press

MDF (5/5)

Quality control:	Measured in:
• Internal bond	N/mm^2 / PSI
• Modulus of rapture / elasticity	N/mm^2 / PSI
• Thickness Swell	%
• Formaldehyde release	ppm
• Screw pull	N/mm^2 / PSI
• Face pull	N/mm^2 / PSI
• Boil test	N/mm^2 / PSI
• Cyclic test	N/mm^2 / PSI

LPL / HPL (1/6)

Paper Type	Resin
Decor	UF and MF
Unicolor	UF and MF
Dark Unicolor	MF
Overlay (α-Cellulose)	MF
Kraft	PF or MF

LPL / HPL (2/6)

1. Glue mixes are prepared:

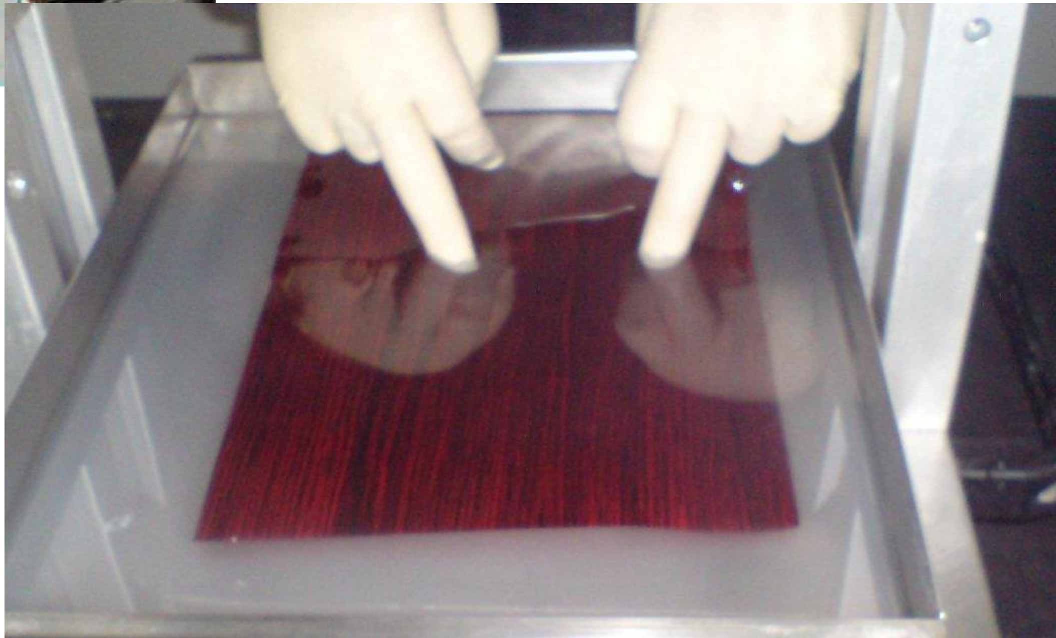
- Resin UF, MF, PF, water, hardener, wetting release agent and other additives (TiO_2, Al_2O_3 ….)

1. Paper is impregnated in the bath, then dried in the oven to reach about 10 – 12% volatiles
2. Then it is coated with another glue mix and dried again to ≈6% volatiles
3. Finally it is cooled and cut to size and stack packed or rolled

LPL / HPL (3/6)

Paper impregnation line,
up to 100m/s

Hand Impregnation bath



LPL / HPL (4/6)

LPL

The impregnated paper is thermally fused on to the substrate (PB or MDF)

Conditions:

Time = 14 – 40s
Temp. = 180 – 210^{o}C
Sp. Pressure = 25 – 40kg/cm^{2}
(400 – 700PSI)

HPL

Depending on final thickness kraft papers and stacked below a melamine décor paper and the whole sandwich is hot pressed.

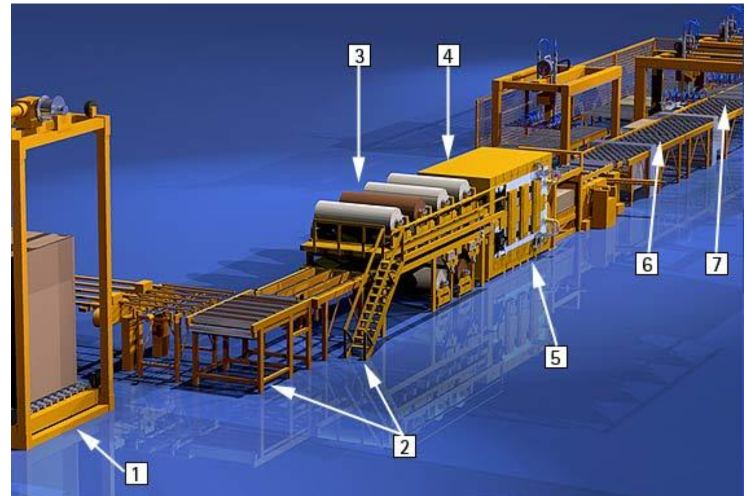
Then the HPL is cold set glued to the substrate

Conditions:

Time = minutes per mm
Temp. = 160 – 190^{o}C
Sp. Pressure = 80 – 120kg/cm^{2}
(1400 – 2100PSI)

LPL / HPL (5/6)

Short cycle laminating press



Continuous HPL and CL Press

LPL (6/6)

- Quality control:

1. Abrasion
2. Burn test
3. Scratch resistance
4. Resistance to staining

Even floorings can be produced if corundum is added in the overlay!

In all WBP production:

1. Wood is prepared
2. Binder is applied
3. Hot pressing follows

Key elements of hot pressing:

1. Moisture balance
2. Wood is compressed
3. Binder is set

Boards must:

1. Show resistance to deformation, rupture
2. Resist humidity to some extent in most cases
3. Comply with regulations regarding release of formaldehyde

Case Study (1/6)

Νέα και σύγχρονη μονάδα παραγωγής ινοσανίδας (MDF-HDF) στην κεντρική Ευρώπη ζήτησε την τεχνική βοήθεια της CHIMAR λόγω υψηλών ποσοστών μέσης κατανάλωσης ρητίνης κατά την παραγωγή, ακόμα και του πλέον συνήθους προϊόντος.

Case Study (2/6)

Η αυτοψία έδειξε ότι ο ξηραντήρας είχε σχεδιαστεί με μικρότερο μήκος για εξοικονόμηση κόστους αγοράς και εγκατάστασης.

Ως αποτέλεσμα, η θερμοκρασία λειτουργίας του ξηραντήρα έπρεπε να είναι ~12°C υψηλότερη από την ενδεδειγμένη (85 αντί 73°C), ώστε στον ίδιο χρόνο παραμονής της ρητινωμένης ίνας να επιτυγχάνεται η ίδια τιμή υγρασίας εξόδου της ίνας.

Case Study (3/6)

Καθώς η ρητίνη εκτίθεται σε αυτές τις θερμοκρασίες, ένα σημαντικό ποσοστό της «έπηζε» (πολυμερίζεται πρόωρα) πριν από το στάδιο της θερμής συμπίεσης με αποτέλεσμα να είναι αδρανές στην πρέσα.

Για να αντισταθμιστεί το ποσοστό αδρανούς ρητίνης, ήταν επιτακτικό να δοσολογείται μεγαλύτερη ποσότητα ρητίνης αυξάνοντας έτσι το κόστος της τελικής σανίδας.

Η χρήση όξινης ξυλείας (Radiata Pine) επιδείνωνε το πρόβλημα αυτό.

Case Study (4/6)

Μέρος της λύσης αποτέλεσε η προσθήκη χημικής ένωσης στη ρητίνη, η οποία ένωση καθυστερεί την ολοκλήρωση του πολυμερισμού και εξουδετερώνει μέρος των οξέων του ξύλου.

Αυτή η ενέργεια όμως από μόνη της θα είχε ως αποτέλεσμα την μείωση της παραγωγικότητας λόγω υστέρησης στην πρέσα.

Case Study (5/6)

Έτσι, προστέθηκε μια άλλη μία χημική ένωση, η οποία απελευθερώνει οξύ σε θερμοκρασίες λίγο μεγαλύτερες των 90°C.

Case Study (6/6)

Αποτέλεσμα:

- Οι ιδιότητες του τελικού προϊόντος παρέμειναν στα προδιαγεγραμμένα επίπεδα.
- Η παραγωγικότητα παρέμεινε στους στόχους.
- Η κατανάλωση της ρητίνης περιορίστηκε κατά 32%.
- Η τιμή της ρητίνης αυξήθηκε κατά 8%.


THANK YOU