industrial applications of pinus pinaster
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This work has been developed in the frame of the project “Technical Co-operation for the Development of the Industrial Applications of Pinus Pinaster” (Atlanwood-59) co-financed by the Programme Interreg IIIB “Atlantic Area” (2000-2006) with ERDF funds.
Aquitaine, Central and Northern regions of Portugal and Galicia are prime forestland, covered with more than a half of the worldwide surface of Pinus pinaster. The main forest stand in Southern Europe, representing more than 2 million hectares, produces approx. 15 million m$^3$ of wood per year. This natural resource was traditionally the raw material for most woodworking industries located at the Atlantic Arc/Iberian Peninsula, and fostered the development of an economic activity that generated employment and wealth for several generations.

The world we live in today is strongly impacted by the worldwide globalisation of the economy. More than ever, innovation and cooperation should be the key drivers to sustaining and improving the current competition levels. In this sense, the “Technical Cooperation Project for the development of industrial applications for Pinus pinaster”, under the auspices of the EU Initiative Programme INTERREG III B “Atlantic Rim”, stands for an example of the opportunities brought by cross-border cooperation.

For the first time, the information from France, Spain and Portugal could be collected and integrated in a publication aimed at enhancing and promoting the use of Pinus pinaster wood in several applications. As the reader will notice, the aesthetic quality and technical features of this material together with technology progress in woodworking and preservation open up new and interesting perspectives, mainly for construction and furniture applications. The innovative examples included at the final part of this publication are a very good example of the aforesaid.

We believe that the outcome of this project will be a useful contribution to the appropriate development of these applications. The underlying idea is to reinforce the sustainable use of an indigenous and renewable resource with a great impact on the economy of these regions and on the environment preservation.

Jean Lesbats
FIBA Chairman

Ángel Hermida
CMA Chairman

Fernando Rolin
AIMMP Chairman
INTRODUCTION
The “Technical Cooperation Project for the development of industrial applications for Pinus pinaster” has been carried out under the EU Initiative INTERREG III B “Atlantic Area” 2000-2006 of the European Fund for Regional Development. This programme is aimed at reinforcing cross-border cooperation to promote a larger territorial cohesion and integration within the Atlantic rim, which consists of some regions of Ireland, United Kingdom, France, Spain and Portugal.

The Fédération des Industries du Bois d’Aquitaine, the Associação das Indústrias de Madeira e Mobiliário de Portugal and the Cluster de la Madera de Galicia, acting as header of the woodworking value chain have participated in the “Atlanwood” Project. The Centre Technique du Bois et de l’Ameublement of France (CTBA), the Centro Tecnológico das Indústrias de Madeira e Mobiliário de Portugal (CTIMM) and the Centro de Innovación y Servicios Tecnológicos de la Madera de Galicia (CIS-Madera) were also involved this project.

The purpose of this project is to update the knowledge and share experiences on the industrial processing of maritime pine (Pinus pinaster) within three regions (Galicia, Portugal and Aquitaine), which share common initiatives, they all have a significantly large forest stand covered by Pinus pinaster species, atlantic subspecies.

**Pinus pinaster at the Atlantic area: a common resource**

The worldwide area covered by Pinus pinaster is estimated to be approx. 4.4 million hectares, from which 4.2 million are located at its natural distribution area (Spain, Portugal, France, Morocco, Italy, Turkey, Greece and Tunes). The remaining 200,000 hectares are settled in other reforested areas (Australia, South Africa, New Zealand, Chile, Argentina and Uruguay).

Together Aquitaine, Galicia, Northern and Central Portugal regions represent almost 7 million hectares of forestland
The presence of Pinus pinaster in this forest area is of utmost importance, since it represents the main resource in the supply chain of the local and well-rooted wood-based industries. This influence is also disseminated in other Atlantic areas, such as British Islands and Northern Spain, which also show significant consumption of roundwood or Pinus pinaster-based products.

The following table shows figures regarding this species geographical distribution. Considering the previous data, there is clear evidence that Aquitaine, Portugal and Galicia together represent more than a half of the total area covered worldwide (4.4 million hectares).

<table>
<thead>
<tr>
<th>Geography</th>
<th>Forest stands (ha)</th>
<th>Maritime pine forested areas (ha)</th>
<th>Percentage over the total forested areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galicia</td>
<td>2,039,574</td>
<td>467,351*</td>
<td>23%</td>
</tr>
<tr>
<td>Portugal</td>
<td>3,349,327</td>
<td>976,069</td>
<td>29%</td>
</tr>
<tr>
<td>Aquitaine</td>
<td>1,796,918</td>
<td>921,805</td>
<td>51%</td>
</tr>
<tr>
<td>Total</td>
<td>7,185,819</td>
<td>2,365,225</td>
<td>33%</td>
</tr>
</tbody>
</table>

* Corresponds to a predominance of Pinus pinaster forests.
In Aquitaine, maritime pine (Pinus pinaster) represents 921,805 ha, 51% of the overall forest area. The largest forest stands are concentrated in the Landes and Gironde departments (counties), where Pinus pinaster amounts to 84% and 75% of forest area, respectively.

In Portugal, maritime pine represents 976,000 ha, and covers 29% of the overall forest area. The largest stands are mainly located at the Central, Northern, Lisbon and Tagus Valley (Vale do Tejo) regions (57%, 37% and 22% of forest stands, respectively).

In Galicia, there are 383,632 ha of pure maritime pine stands. Furthermore, it is also present in other forest stands with several other species, such as eucalyptus and other hardwood. Taking into account the forest area covered by mixed stands where pine has a predominant role, a total figure of 467,351 hectares is reached, representing 23% of the total forest area. The distribution of this species in Galicia is homogeneous. The covered areas in each province range between 94,041 ha in Pontevedra and 151,336 ha located in Ourense.

Economical relevance of Pinus pinaster industrial processing

Pinus pinaster is a crucial species to supply the outstanding wood processing industries located in Aquitaine, Portugal and Galicia. The estimated annual production of industrial maritime pine roundwood is approx. 14.6 million m³. As a reference, it should be highlighted that this figure is very close to the whole annual production of roundwood generated in Spain.
The following table shows the forest industry contribution for each geographical area. These figures highlight the relevance of both the forest and the woodworking industries in Aquitaine, Galicia and Portugal.

<table>
<thead>
<tr>
<th></th>
<th>Portugal</th>
<th>Galicia</th>
<th>Aquitaine</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total GDP (million €)</td>
<td>129,887</td>
<td>36,840</td>
<td>66,717</td>
<td>223,115</td>
</tr>
<tr>
<td>Forest industry GDP</td>
<td>4.146</td>
<td>2.395</td>
<td>3.336</td>
<td>9.876</td>
</tr>
<tr>
<td>Forest industry GDP (million €)</td>
<td>3.2 %</td>
<td>6.5 %</td>
<td>5 %</td>
<td>4 %</td>
</tr>
</tbody>
</table>

Sources: O bosque avanza. Consellería de Medio Ambiente (Galicia), INE (Portugal).

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<table>
<thead>
<tr>
<th></th>
<th>Years 2001/02</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coniferous</td>
<td></td>
</tr>
<tr>
<td>Europe (EU-15)</td>
<td>188.8</td>
</tr>
<tr>
<td>France</td>
<td>21.8</td>
</tr>
<tr>
<td>Spain</td>
<td>8.6</td>
</tr>
<tr>
<td>Portugal</td>
<td>3.1</td>
</tr>
<tr>
<td>France + Spain + Portugal</td>
<td>33.5</td>
</tr>
<tr>
<td>Pinus pinaster</td>
<td></td>
</tr>
<tr>
<td>Aquitaine</td>
<td>9.1</td>
</tr>
<tr>
<td>Galicia</td>
<td>1.9</td>
</tr>
<tr>
<td>Portugal</td>
<td>3.1</td>
</tr>
<tr>
<td>Total</td>
<td>14.1</td>
</tr>
</tbody>
</table>
Structure of the Forest property

In Portugal, 92.3% of the forest area is privately owned. Only 7% is communal property (normally, mountain areas or close to dunes in coastal areas) or state-owned (0.7%). Only 1.1% of forest explorations are larger than 100 hectares, and the most common size is in lower than 3 hectares (84.5% of the total figure).

In Galicia, the predominant property scheme is private ownership (68%), followed by municipal, communal woodlands (30%). The remaining portion comprises state-owned/public woodlands classified as public utility (1%) and state-owned/public woodlands, which are not classified as public utility (1%). Globally speaking, it is estimated that there are 673,000 forest owners, holding 1.5 to 2 hectares on average, normally divided into several portions. A reference should also be made to the presence of 2,700 woodland communities with an average forest area over 200 hectares.

In Aquitaine, forestland is mainly privately owned (91.3%). The communal property represents 6%, and public/state-owned woodlands only 1.3%. As a whole, there are 285,300 forest owners, holding on average areas slightly over 5 hectares. Contrary to Galicia and Portugal, where the average privately owned properties range between 1.5 and 3 ha, in Aquitaine 73% of the privately owned property belong to owners holding on average more than 10 ha of land.

Socio-economic context

Together the three regions total surfaces represent 159,927 km². From this global figure, 57% corresponds to Portugal, 26% to the Aquitaine region and 18% to Galicia. The total population is 15,528,394 inhabitants, with an average density of 97 inhabitants/ km².

Portugal is the region with higher number of inhabitants, 9,869,300 (63%), and also with the higher population density, 111 p/Km². Galicia has 2,751,094 inhabitants and a population density of 93 p/Km². Aquitaine counts with 2,908,000 inhabitants ans a population density of 70 p/Km².

In administrative terms, Portugal is divided into five NUTS II regions, North, Centre, Lisbon and Tagus Valley, Alentejo and Algarve; the first three regions represent almost 87% of the whole population. The larger population density is concentrated at the Atlantic coast. The population growth was 0.7% in 2001, although the Centre region, Algarve and Alentejo showed negative figures, with Alentejo achieving -5.8%. The largest population growth can be seen at the Northern region, with an annual 2.6% increase.
The Galicia autonomous territory is located at the Northwest of the Iberian Peninsula and, in administrative terms, is divided into four provinces: A Coruña, Lugo, Ourense and Pontevedra. The Atlantic coast provinces, A Coruña and Pontevedra, are the most industrialised and populated areas, with 141 and 206 inhabitants/km², respectively. One of its most striking characteristics is the multiplicity of small-sized communities. With approximately 30,000 communities, Galicia gathers almost half of all existing communities in Spain as a whole.

The Aquitaine region is divided into five departments: Dordogne, Gironde, Landes, Lot-et-Garonne and Pyrénées-Atlantiques, its administrative capital is Bordeaux. The Gironde department has the largest territory (44%) and population density (129 inhabitants/km²). The most part of the Aquitaine population lives in towns (70%). Since 1990, the average population growth is 0.4% per year, a figure higher than the French and the European Union average.

<table>
<thead>
<tr>
<th></th>
<th>Portugal</th>
<th>Galicia</th>
<th>Aquitaine</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>9,869,300</td>
<td>2,751,094</td>
<td>2,908,000</td>
<td>15,528,394</td>
</tr>
<tr>
<td>Surface (km²)</td>
<td>89,044</td>
<td>29,575</td>
<td>41,308</td>
<td>159,927</td>
</tr>
<tr>
<td>Forest area (ha)</td>
<td>3,349,327</td>
<td>2,039,574</td>
<td>1,796,918</td>
<td>7,185,819</td>
</tr>
<tr>
<td>Agrarian surface (ha)</td>
<td>2,573,069</td>
<td>843,657</td>
<td>1,713,754</td>
<td>5,530,480</td>
</tr>
<tr>
<td>Quercus suber (ha)</td>
<td>712,813</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quercus robur (ha)</td>
<td></td>
<td></td>
<td>187,789</td>
<td></td>
</tr>
<tr>
<td>Quercus rotundifolia (ha)</td>
<td>461,577</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eucalyptus globulus (ha)</td>
<td>672,149</td>
<td></td>
<td>174,210</td>
<td></td>
</tr>
<tr>
<td>P. pinaster and E. globulus (ha)</td>
<td>159,414</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population density (inhab./km²)</td>
<td>111</td>
<td>93</td>
<td>70</td>
<td>97</td>
</tr>
</tbody>
</table>

Sources: IFN III (Galicia), CRPF-cadastre 1997 (Aquitaine), Direcção Geral das Florestas (Portugal)
FOREST RESOURCE
General characteristics of *Pinus pinaster*

The natural distribution of *Pinus pinaster* (*Pinus pinaster* Ait.) is: France, Spain, Portugal, Italy, Morocco, Algeria and Tunes.

In the Iberian Peninsula, two subspecies can be found: the Atlantic and the Mediterranean. The first one grows in Galicia and Northern Portugal (Galician pine, maritime pine) and the second in the remaining Iberian Peninsula (Autrian pine, maritime pine). In France, there are two different genotypes, classified according to their original location: Landes pine and Corsea pine.

In Portugal, it is called pinheiro bravo and/or maritime pine. In Aquitaine, it is called maritime pine and/or Landes pine.

One of the reasons that helped the development of this species here was its strong resilience against sandy and scarcely fertile soils, an obstacle to other species growth, together with its fast growing capacity. The capacity of *Pinus pinaster* to grow in poor soils is related to its well-developed radicle system and its remarkable capacity of drawing nutrients from the soil.

This species can endure seasonal drought, but it shows a poor resistance to cold temperatures, wind and/or snow. The best qualities are located at the coast with an average maximum growth of 20 m³/ha per year and cutting periods of 30 years.

Although they can reach 40-meter height, normally they do not grow over 20 or 30 meters. At the first stage of the tree development, its top is pyramidal, and afterwards becomes rounded and irregular. The top of the oldest specimen is too much reduced when compared to the tree height, what favours the presence of dense underbrush, often a thicket.

Branches grow along the trunk and are grouped in verticils, each of these branches correspond to a growth period in height. Each year, pines can have one or two growths in height. If the second growth occurs, it will give rise to a verticil with
smaller-sized branches, as such, the age of the tree can be approximately estimated through the number of relevant small branches (this is not the case with old pines, since they may have already lost the branches of the lower part of their trunk).

In young pines, the bark stem is black and rough. After 15 years, it becomes thick and leaky.

Their thin sharp leaves (needles) are very long (15-27 cm) and thick (2-2.5 mm), and are grouped in two. Its colour is dark green and has strong and sharp points.

Blooming starts after 7-8 years, but without a regular shape until 10-15 years. The male flowers appear in ears, their colour is yellow and have 1 to 2 cm long. The female cones are small, their colour ranges from red to violet and they bloom in groups of 2 or 3 at the upper part of the top of the tree. The pinecones, which take two years to mature, are very large and have sharp points at the end of the scales. Once opened as a result of heat, they can resist for a long time in the tree. Pine nuts are brown-grey and show a large and dark wing.

**Historical evolution**

*Pinus pinaster* is an indigenous species both in Portugal, Galicia and Aquitaine. There were findings of its existence already at the end of the Glacial Period (8000 BC).

Its current distribution is the outcome of a long evolution process, which underwent climate changes, genetic evolution, and human modelling action over the nature. This last dimension was a decisive influence both in the distribution and composition of the current forest stands.

In the 18th century, the expansion of this species began by human action. Peasants who planted in their farms seeds from Portugal often together with cereal or gorse used this tree in reforestation.

From the 19th century on, *Pinus pinaster* is disseminated to the coast, although the total area did not exceed 20,000 hectares (0.7% of the Galicia territory). As of the second half of the 19th century, a relevant expansion of pine woods began led by private initiative. The continuous and remarkable sharp rise of wood prices since 1890, together with campaigns promoting pine reforestation explain the private proprietors interest in reorienting their forest exploration.
At the same time, in the 19th century, Galicia reached the maximum levels of deforestation, due to several factors, such as: demographic increase that intensifies the soil use for agrarian and cattle purposes (a phenomenon that close to the middle of the century decreases, as a consequence of emigration), the strong demand for firewood and charcoal/vegetal coal to be used as fuel for domestic and industrial purposes (mainly, at smithies), the demand for bark from the tannery industry, the development of the naval construction, the use of wood in buildings and the wood exploration activity.

In the 20th century and until 1939, the private sector invested in most forestlands, leading a spontaneous expansion process. Later after the civil war (1936-1939), a massive forest plantation programme begins, and in 35 years by public initiative, more than 9% of the Galician territory could be reforested, mostly communal lands, and Pinus pinaster was the most used species in more than a half of the replanted area. With regard to the forestland quality, these initiatives achieved different results, since there were cases where the plantation was made in seasonal limit conditions and in others the original seed was inadequate. The developed forestry activity kept pace with the development of a flourishing sawmilling industry, often as family business. In the 50’s, there were 250,000 hectares of pinewoods in Galicia and the sawmilling industry represented the third wealth source, after the agriculture and the cattle business.

At the same time, as of the end of the 50’s, there is a strong development of the wood-based panel industry, which is currently one of the most robust sectors in the Galician forest sector. The most striking growth in the production capacity was felt in the 70’s.

A similar trend was followed by the pulp and paper industry, whose activity is dated back to the 50’s. However, in this case, the use of pinewood as raw material was gradually replaced by eucalyptus.

In Portugal, the forest potential and relevance was recognised and promoted through several initiatives aimed at preserving and fostering forest and hunting heritage, since there had been long periods of constant reduction of forestlands. For instance, during the 15th and 16th centuries, hundreds of vessels were built to be used for the colonisation of conquered territories. Maritime pine was mainly used in masts, wooden rods and other accessories.

Although during the 17th and 18th centuries laws were passed to foster and protect forests, their impact was not enough to preserve forestlands. In the middle of the 18th century, during the reign of D. João V, Portugal reached the highest deforestation level, as a consequence of vineyard and cereal plantations and woods import from Brazil.

In 1824, the creation of the General Administration of Forests of the Kingdom, integrated in the Ministry of Navy, set the
beginning of a new era of solid forestry progress with the development of specific legislation, promotion and protection programmes, introduction of forestry ruling and management techniques, publication of papers on forestry issues and the establishment of the Forestry College (1865).

The 19th century witnessed the beginning of the works to fix coastal dunes and the first reforestation works at the inland mountains. In this century there is, therefore, a steady increase of the forest area, mainly due to the maritime pine expansion, to the regeneration of cork oaks and to the recovery of pastureland. In 1886, the creation of the Forestry Service within the General Directorate of Agriculture is a stepping-stone on the strategy of the public administration that was mainly concerned with coastal stands until that moment and then extended the forest development to the mountainous inland of Portugal.

In 1888, the establishment of the two first Forest Administration Services located in the country’s inland (Manteigas and Gerês) sets the beginning of the mountain range reforestation, which underwent a vigorous development with the Reforestation Plan in 1938. This Plan brought a forest increase at the inland areas located in the North of the Tagus river; its purpose was to conclude the reforestation of coastal dunes, to reforest uncultivated land located in the North of the Tagus river, with a 420,000 hectares surface to be reforested, the creation of vegetation reserves (33,000 ha) and the creation of pastureland in almost 60,000 hectares.

Dunes reforestation was another relevant chapter in the history of forestry in Portugal.

From a forestry perspective, the 20th century is characterised by the organic consolidation of forestry public administration and by the significant increase of tree-planted areas, as a result of a systematic replantation initiative implemented by several institutional plans and programmes.

In 1945, the creation of the Fund for Forest and Agriculture Promotion sets the support of the Forestry Public Administration to the private sector. Like in Galicia, this century witnessed the expansion of maritime pine in Portugal, mainly as a consequence of many reforestation programmes promoted by the State. The Pinus pinaster characteristics were a suitable alternative to reforest coastal dunes and inland mountains that had plenty of clearings. The good adaptation to soils degraded by an intensive use for many centuries, led to its expansion to almost the whole Portuguese territory.

Many products (e.g. firewood, mining wood, resin, and so on) could be obtained from pinewoods, which were the basis of the rural economy, mainly in the Central and Northern areas of the country. As of the 70’s, the rural exodus and the growing economic development at the inland of the country changed this situation and there was a gradual abandonment of pinewoods. The progressive eucalyptus plantation in areas where climate and soil conditions were favourable also reinforced this circumstance.
Aquitaine

As in Galicia and Portugal, the current predominance of maritime pine in Aquitaine is due to a great extent to the low productivity and fertility of soils. The most common ones are strongly acidified and with low fertility. Besides, the accumulation of humic acids (compressed at a 0.2 and 2 meter depth) in these soils tends to contribute for floods during most part of the winter.

Originally, Pinus pinaster occupied land that was much less affected by the superficial accumulation of water. Only at the end of the 18th century, this species started gradually to colonise the whole Landes territory, which was permanently threatened by sand and water.

The determinant reason for the maritime pine expansion is related to human action. In this sense, the following should be highlighted: the progress achieved in sanitary techniques (performed during the first half of the 19th century) that was responsible for the development of a collecting network for water discharge, as well as mastering the techniques for stabilising coastal dunes (managed at the end of the 18th century).

Both facts had a decisive influence on the progress of Pinus pinaster plantations, since they helped to recover/valuate a large amount of land, improving significantly the life of local populations. Nevertheless, there were riots related to the land use between cattle breeders and forest owners.

In 1857, a law was passed requesting all municipalities to clean and replant their territories/land. This rule also demanded from all Town Halls that could not (by economic reasons) or did not want to carry out the investments to sell or auction these areas to private investors.

In the statement of the reasons for this law, it was defined that the purpose of the pine reforestation was to clean the Landes territory and promote a later agrarian use of the land. In this sense, it must be taken into account that the 19th century witnessed a steady development of infrastructures, mainly in the
railways, which enabled the development of several, relevant agrarian and cattle-related projects, although some of them could never be materialised.

On the other hand, resin recovery was one main reason for the maritime pine development and one of its first applications. The writer Camille Jullian, in his essays on the Roman Empire, states resin as one of the main merchandises in trade exchanges (together with the Pyrenees marble, Spain metals and French Midi olive oils), since they were indispensable to caulk wooden ships and preserve their riggings.

Besides since the Middle Ages, candles manufactured with this product replaced the torches what brought a strong demand increase. The relevant decrease in the extraction of resin started after the World War II. The few explorations left in 1960 vanished in the 80’s. This sector recession is explained by its labour-intensive activity and the strong competition from other producing countries. Today, although there are interesting programmes for resin recovery, the areas allocated for this purpose are very small.

In the beginning of the 60’s, the maritime pine situation in Aquitaine underwent a remarkable change, with the dissemination among private foresters of innovative labour techniques, oriented to the seed selection and certification, as well as to the optimisation of techniques for soil preparation and stands preservation. These forestry improvements helped to multiply the average productivity of Landes woodland (from 4 m³/ha/year in 1960 to 10 m³/ha/year in 1999).

In the 20th century, there were four events affecting significantly the evolution of the forest management in Aquitaine. In the 40’s, there were several fires devastating 40% of forest stands. This led to the creation of communal associations of defence against forest fires. To facilitate the quick intervention of fire brigades, foresters improved the access to the woodlands and provided them with water collecting spots. These actions were financed by a specific tax paid by forest owners, and by public aid.

During the strong snowfall in 1985, there were tree falls in 60,000 hectares, from which 30,000 ha were severely affected with breaks in their tops. Almost all masses affected went back to the replantations performed after the 1940/1950 fires. This issue was sorted out with a policy of seed certification.

The storm on 1 and 2 December 1976, affected severely the Southern area of the Aquitaine woodlands, falling approx. 2 million m³ of trees.

The storm on 27 December 1999, with winds blowing at 200 km/h at 30 meter from the ground, was another great catastrophe for the Aquitaine woodlands. More than 120,000 ha were affected and almost 27 million m³ of wood fell down.

Considering the outcome of this last storm, the Development Authorities started heightening the awareness of foresters to consider the effects of their forestry initiatives in storm situations. Furthermore, this storm brought a remarkable decrease of the wood price. The experience acquired after this event helped to improve wood preservation techniques and, particularly, the warehousing with irrigation.

Finally, a reference to the development of other industrial processes for the use of Pinus pinaster wood. The first one to be developed was the paper manufacturing industry.

The first paper mill, held by a group of foresters, was established in 1925 in Mimizan. Today, there are three major paper-manufacturing mills in Aquitaine that use maritime paper wood. More recently, the wood-based panel industry started developing in the region and now there are 6 industrial plants. Since 1990, these industries have shown an intensive investment drive and some industrial groups underwent an internationalisation process.
Current status of maritime pine

Currently, the existence of this species in the three regions totals more than 300 million m$^3$, which represent 54% of the overall existing wood.

The region with a larger quantity is Aquitaine with 158 million m$^3$. Within this region, the countries/districts of Landes and Gironde are those with the largest quantity of Pinus pinaster (81 and 55 million m$^3$, respectively).

### Galicia

Approx. 11 years after the two last national forestry inventories (IFN - Inventarios Forestales Nacionales), there has been a slight increase (+8%) in the maritime pine existences, until totalling 49 million m$^3$ with bark. However, in the whole Galicia, the accumulated figure for classes with diameters lower than 35 cm is reduced by 17% in the same period. Instead, the existences of classes with higher diameters increased by 55%. In these conditions, if demand is kept at the current levels, a significant deficit of Pinus pinaster wood might be expected in the medium, long term.

### Wood volume increase by species between inventories

On the other hand, it must also be considered that the lack of a generally used optimal forestry management for the Pinus pinaster stands has notably limited both productivity and the
possibility of obtaining wood of quality. This process was aggra-
vated by the promotion of an inappropriate natural regenera-
tion, as a result of the application of traditional cutting
methods that tend to eliminate the better quality trees.

Traditionally, private Pinus pinaster forests had been managed
through selective cuttings of the better trees. Thus, the pro-
prietor could occasionally obtain some more revenues to add to
its normal income.

With this practice, smaller and thinner trees that had been
dominated by others of better growth and larger size were kept
in the field. As Pinus pinaster is a species with great light
needs, these trees have inadequate quality characteristics for
their utilisation (curve-shaped branches, and so on). On top of
this, this kind of management promotes a negative genetic
selection, by producing the natural regeneration from less vigo-
rous growth trees. Consequently, the resulting forest is very
irregular and characterised by the co-existence of young and old
trees. All this reduces the productions obtained and is an ob-
stacle to the right utilisation operations.

Currently, although there has been an important development
in the use of forestry techniques over Pinus pinaster, it is still
quite common to find stands where no kind of intermediate
forestry labour has been performed, such as: thinnings, pru-
nings and clearings.

In Galicia, when it is necessary to perform an artificial regene-
ration (either in case of a new plantation or due to difficulties
with a natural regeneration) it is common to opt for a planta-
tion. If a plain rooted plant is used the most appropriate sea-
son is between November and March. Although when a plant
with covered roots surrounded by soil is used the plantation
season is quite extended, the middle summer month should
be avoided, in any case.

In the last times, the most used plantation spacings are 2 x 3,
2.5 x 3 or 3 x 3 meters, which correspond to initial densities of
1,670 1,330 or 1,110 stems per hectare.

In case of high-density plantations (1,600 - 2,000 plants per
hectare), it is recommended to perform a first cutting at 8 or
10 years to reduce the competition between trees. In case of
low-density (1,000 - 1,350 plants per hectare), it is necessary
to carry out a careful replantation to prevent the occurrence of
excessive clearings. In this case, it is necessary to carry out
a replacement to keep the required density. Nevertheless, it is
convenient to perform an early pruning to avoid and excessive
thickening of the branches.

Trimmings are indispensable when pines are young. Once the
brushwood is mastered, after ten years, these operations are
no longer performed, unless to facilitate pruning operations or
prepare the pinewood for cattle utilisation, what will contribute
to reducing fire risks.

During too many years, Pinus pinaster forestry in normal
forests was characterised by keeping high densities, trying to
use the whole forest production capacity. Thus, high quantities
of small-sized wood could be obtained, mostly for the pulp and
wood-based products industries.

Almost until 2-3 decades ago, the cutting periods used to be
from 25 - 30 years. Currently, the market conditions advise on
a forestry oriented to the preferred production of high diame-
ter pines, whose wood is employed at sawing or veneer indus-
tries. For that, periods of 30 to 40 years are used to ensure
that trees’ diameters reach 35 and 40 cm at their final cutting.
For that, it is necessary to perform large clearings and keep
lower densities. Wood obtained from clearings can be used by
the pulp and WBP industries and in sawmilling, as well (in case
of lower trunks of trees cut down in the last clearings).

The following table includes a typical scheme of clearings
carried out on a Pinus pinaster regular forest. Since the
moment when the last clearing is carried out until the age
required to perform the final cutting, it is advisable that a su-
fficient number of years occurs (preferably 10 years), so that
the selected trees can adequately develop their diameter.
One of the characteristics of the Galician Pinus pinaster is that its lower branches die quickly while growing and moving away from the trunk, this happens even in those with low densities, although the branches remain dead attached to the trunk for a long period of time. This leads to the formation of dead knots that may depreciate significantly the wood.

Pinus pinaster pruning is aimed at avoiding the formation of knots in thick wood pieces fit to the production of sawnwood or veneers. If this operation is adequately performed, it will not have a negative effect on the growth in height of the tree.

The optimal situation is pruning pines with normal diameters of 10 to 15 cm, following the method below:

- When the height is about 5-7 metres and the normal average diameter is approx. 10 cm, the pruning should be made until 2 meters height in all trees.

- When the average diameter is about 18 cm, the pruning should be made until 3 metres height. Only the best 400 - 600 stems per ha should be pruned. This should coincide with the first clearing.

In this way, it can be guaranteed that the first timber/log will be free from knots, except for the inner 10 cm diameter cylinder.

<table>
<thead>
<tr>
<th>Year</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Plantation of 1,670 plants per hectare.</td>
</tr>
<tr>
<td>15</td>
<td>Clearings of 670 plants per hectare.</td>
</tr>
<tr>
<td>20</td>
<td>Clearings of 300 plants per hectare.</td>
</tr>
<tr>
<td>25</td>
<td>Clearings of 250 plants per hectare.</td>
</tr>
<tr>
<td>35</td>
<td>Final cut of 450 trees per hectare.</td>
</tr>
</tbody>
</table>

**Portugal**

From the analysis to the forest inventories carried out in 1982 and 1995, we can see relevant structural changes to the forest stands in Portugal. Traditionally, maritime pine was the most representative species, now it is decimated both by forest fires and the increase of eucalyptus plantations. Between 1982 and 1995, the extension of this species has decreased by 22% (-276,000 ha). On the contrary, during the same period, eucalyptus forestations grew by 74% (+286,000 ha).

The substantial increase of forested area with eucalyptus was carried out to replace maritime pine, above all in coastal areas (North and Centre) and at the Tagus area. This eucalyptus
expansion, a very fast growing species (12-30 m³/ha/year), is proceeding and it is not expected to change in the coming years.

Like in Galicia, the implementation of unsufficient or inadequate forestry measures (like felling larger production capacity trees) favoured a degenerative process that after several generations led to the current situation of low productivity and quality of the produced wood.

The decrease of Pinus pinaster forest area brings a fall in the volume of standing wood, mainly in pure stands, which is explained by fellings and fire rates higher than the reforestation rate.

With regard to existences by age classes in pure stands, there is a clear decline in those lower than 39 year classes (see figure), but in the higher class (>60 years) there is a solid increase until achieving a 10 times higher level than the one in 1983.

The massive reduction in the existences of the 20 to 39 year class can be explained by the impact of forest fires and the growth of wood consumption. This fact led to felling volumes higher than growth rates. Besides, the trend of the “older” classes indicates a progressive aging of masses, what can bring a potential reduction of the regeneration capacity and production at the medium, long-term.
Normally, reforestation is performed through plantation, with initial densities between 1250 and 1670 plants/ha, dependent on the season quality. The minimum distance between rows is 3 metres to allow forestry mechanical operations.

The best plantation season in the areas of Minho, coastal Douro and Northern and Central mountains from November to May, using plain rooted plants. In the Centre and South, the plantation should be carried out from November to May, but using plants with covered roots surrounded by soil.

Reforestation with seeds is only used if the purpose is to protect the stands.

During the first 10 years, 2 to 3 fellings of small-sized thinning are carried out, using normally mechanical equipment through the lanes (a tractor with a cutting saw or similar). Between trees, the felling of small-sized logs is manually carried out.

In cases of high density areas (more than 1667 trees per hectare), it is recommended to carry out a selection with variable intensity, depending on the starting point. This treatment is carried out in a systematic way (opening lines or rows) and/or in a selective way (by felling those trees with worse quality).

In any case, it is advisable to carry out clearings to improve the quality of wood obtained at the final cutting. These treatments to be held in autumn should follow the structure shown in the table below:

| Clearings | 15-20 years | Clearing of 20 - 40 % of standing trees.
|           | 25-30 years | Clearing of 20 - 30 % of standing trees.
|           | 35-40 years | Clearing of 20 - 30 % of standing trees.
|           | 40-50 years | Final cut (300 - 500 trees per hectare).

Pruning determines the production of wood without knots and prevents vertical propagation to the top of the trees in case of fires. This operation is carried out in autumn or winter.

The first pruning is normally carried out in all trees (until an average height of 2 metres) at 10-15 years of age, when the average height ranges between 5 and 7 m. The second pruning is only carried out to the selected trees with 3-4 m height and with 15-20 years of age.

In areas lower than 10 hectares and moderate slope (< 5%), the normal utilisation is the “clear cuts” (matarrasa). In mountain areas, it is carried out by tracks (or rides) with a width (or diameter) equivalent 1 to 3 times the average height of the mass.

**Aquitaine**

The forest area in Aquitaine was extended 2.5 times within a century (1861-1961), mainly because many areas traditionally used as pastureland were reforested with maritime pine. Between 1861 and 1979, the forest area increased constantly, despite the big fires in the 40’s. After World War II, the forest area/surface stabilised in 1.2 million hectares, mostly distributed in the regions of Gironde, Landes, and Lot et Garonne.

Considering the data from the last inventory (IFN 1998/2000), there is an overall 151 million $m^3$ of standing wood, from which 92% correspond to maritime pine. Twenty years after the last inventory dated 1976/1979, maritime pine stands have increased by 28 million $m^3$, achieving 138 million $m^3$ (a 25% growth).

The updating of this data after the storm on December 1999 shows a 27 million $m^3$ decrease in Pinus pinaster existence. This figure corresponds to the overall production of 3.4 years.
Originally, maritime pine plantations were fundamentally oriented to resin collection. This changed with the growing visibility of wood production. From 1960 on, the cultivation of maritime pine was technically improved in the Aquitaine region, with the development of specific techniques of reforestation and forestry.

Traditionally, (in 80% of the cases), soils were reforested by artificial sowing. Once prepared, cleaned, fertilised and ploughed, the piece of land was sowed in lines with approx. 2-3 kg of seeds by hectare. As of the 80’s, there was a change in the plantation habits, with tree nursering production from genetically improved seeds. Currently, both techniques are used.

In both cases, the soil must be well drained. If that is not the case, drainage channels must be prepared with a minimum depth of 30–40 cm, at least 6 months before planting. The land is prepared by ploughing to allow a better rooting of the tree and the penetration of organic material in the soil. Normally, there is a first fertilisation with phosphoric acid.

Sowing is normally performed in spring, from February to May, and in the autumn, from August to October. The plantation is performed between November and May, using a separation between plants of 1.5 and 2 metres and separations between rows of 3 to 4 metres. Initial densities range between 1,200 and 1,500 plants per hectare.

Modern forestry applied to maritime pine requires trimmings to fight against other plants competition and favour the development of young plants. Therefore, when the regeneration is performed through seeds, a clearing plan should be used during the first years to reduce the plants density. Normally the first one is done in the third or fourth years, keeping 2,500 to 3,000 trees per hectare. This implies a 0.8 - 1 m space between trees. The second clearing is carried out between the fifth and the seventh year, eliminating one of each two plants until reducing the density to 1,250 - 1,500 trees /hectare.

As a general rule, the first clearing is carried out when the normal diameter is around 16 cm, what normally occurs between 10 and 15 years. Clearings are carried out each 4 or 5 years, removing in each occasion between 25% and 30% of trees.

The last clearing before the final cutting is held when trees reach a normal diameter of almost 30 cm (approx. at 30 years of age). At this point, the final mass density is about 300 to 350 trees /ha. The final cutting is normally performed when trees reach a diameter between 40 and 50 cm (50 - 65 years shift).
Currently, there is a trend towards shortening growth shifts, as a consequence of the increasing demand for medium sized wood (0.6 to 1.2 m\(^3\)/tree).

Aimed at achieving good quality wood at the final felling, intermediate prunings should be performed only to those trees selected for final felling. The first pruning should be performed when the tree has a 11-14 cm diameter. The second one before it reaches a 20 cm diameter, pruning the 300-350 trees that constitute the final mass until five metres and a half in height.

The provisioning mechanisation has increased considerably after the 1999 storm. Today it is around 65% (2004) and is progressively growing. This situation brings changes in forestry characteristics, such as rows separation or the plantation mark. Considering the aforesaid, the first clearings must be mechanised by competitiveness reasons.

The purpose of this forestry is to produce the maximum quantity of quality wood within the shortest period of time, keeping a sustainable ecological balance. Considering this, the genetic improvement of the plant and the strengthening of forestry’s quality aspects (mainly pruning) are key factors to be taken into account.

Forest fires

In Galicia, in the 80’s, fires consumed a total amount of 659.000 hectares, from which 283.000 hectares corresponded to tree’s cultivated land. During that decade, more than 195.000 hectares were burnt in only one year (year 1989), from which approx. a half was from tree planted areas.

In the 90’s, with the development of a fight plan against forest fires, the affected area could be reduced until reaching average figures of 25.000 ha/year, despite the sharp rise of the number of fires during those years. Moreover, a special highlight to the drastic reduction of the percentage of tree planted area affected (from the affected areas, only 6.000 hectares corresponded to tree planted areas).

Although the efficiency of the operations against fires is getting higher, the number of fires is extraordinarily high (more 9.000 fires every year). Currently, several preventive initiatives are fostered to improve this situation.
In Aquitaine, although the woodland at Landes de Gascogna went through big fires periods, like those occurred in the 40’s when almost 400,000 ha were burnt, the development of preventive and control measures could decrease the burnt area per year, by increasing the fire extinction efficiency. Nevertheless, the number of fires is still growing every year, mainly in suburban areas, tourism related or located along the large communication axis. It should be highlighted that natural phenomena (flash of lightning) are one important cause for fires; they start several simultaneous fire spots, which are difficult to extinguish.

1991 stood for the year with more affected surface – 182,486 ha, besides the proportion of tree-planted area was especially high (69% - 125,488 ha).

2003 was a catastrophic year for the Portuguese woodland, as well. Although the number of fires decreased compared to previous years, a total amount of 423,276 hectares were burnt, what represented a 13% of the total forest area. Almost 82% of the tree-planted area was affected, due to 59 very big fires (more than 1,000 hectares affected). The difference between previous years (1998-2002), where the burnt surface of tree-planted area recorded an average figure of 53,572 hectares, and 2003, where 283,063 hectares were burnt, should be highlighted, since it represents a 429% increase of affected area.

In 1987-2003, fire burnt globally more than 2 million hectares, from which almost 50% corresponded to tree-planted areas.
SUSTAINABLE FOREST MANAGEMENT
Today in every aspect related to the society there is a growing concern with environment preservation. In the forest management case, the public opinion awareness towards the development of mechanisms that could guarantee the sustainable development of woodland started in the 80's with the announcement of the deforestation consequences in tropical areas.

As of 1990, several world conferences were held to analyse and debate measures to be adopted, in order to find a balance between investment protection and industrial development. In line with this, for instance, the sustainable forest management was established in 1992 at the Earth Summit in Rio de Janeiro (Brazil) and its first definition was: “Forest resources and forest lands should be sustainably managed to meet the social, economic, ecological, cultural and spiritual needs of present and future generations”. In the Helsinkii conference of 1993, the Western European countries adopted the principles defined at the Rio Summit, adapting the definitions to the European forests with a 6 criteria sustainable forest management.

Finally, at the last years of the 20th century, the first certification systems for sustainable forest management were created.

The purpose of the certification schemes is to guarantee to the consumer that the acquired products are the outcome of a sustainable forest management process.

Certification systems

Forest certification is a voluntary process where the independent third party organisation (auditor) certifies that wood comes from sustainably managed forests/woodlands.

Among all forest certification systems developed worldwide, the following are highlighted due to their broader dissemination:
**FSC (Forest Stewardship Council) SYSTEM**

Created in 1993 by a group of non-governmental organisations of investment protection (from which WWF is the oldest organisation), FSC sets its priority in equatorial and boreal forests, and is supported in the following principles:

- Compliance with laws and FSC principles.
- Tenure and use rights and responsibilities.
- Indigenous people’s rights.
- Community relations and workers’ rights.
- Benefits from the forest.
- Environmental impact.
- Management Plan.
- Monitoring and assessment.
- Maintenance of high conservation value forests.
- Plantations.

**PEFC (Programme for the Endorsement of Forest Certification Schemes) SYSTEM**

The Pan-European Forest Certification Scheme was launched in 1999 in Europe by federations of private forest owners.

Although this system is developed in Europe, its impact is worldwide disseminated through the mutual recognition (ongoing and final agreements) established with systems developed in other continents:

- North America: CSA internacional (Canada), SFI (United States).
- Latin America: Certfor (Chile).
- Africa: PAFC (Gabon).
- Southeast Asia and Oceania: AFS (Australia).
- Europe: enlargement to countries outside the European Union (Russia).

This system is supported on the “six Helsinki criteria”:

- Maintenance and appropriate enhancement of forest resources and their contribution to global carbon cycles.
- Maintenance of forest ecosystem’s health and vitality.
- Maintenance and encouragement of productive functions of forests (wood and non-wood).
- Maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems.
- Maintenance and appropriate enhancement of protective functions in forest management (notably soil and water).
- Maintenance of other socio-economic functions and conditions.

Furthermore, this system aims to be consistent with national forest policies and also to be adaptable to the small-sized privately owned forests/woodland.

**Certification process**

The certification systems acknowledge two complementary parts:

- *Sustainable forest management (SFM) certification*
  The use and management of forests and forest land must respect its biodiversity, productivity, regeneration capacity, vitality and potential, now and in the future, without jeopardising other ecosystems.

- *Chain-of-custody (CoC) certification.*
  This mechanism checks if the wood used by the woodworking industries comes from sustainably managed forests. This is the subsequent stage of the sustainable forest management certification and stands for a necessary procedure to trace back the origin/source of the product.
This double certification is an assurance to the final consumer that the purchased product was manufactured by companies whose raw material supply comes from sustainably managed forests.

Wood from certified forests is controlled along its value chain until the final product.

Forest certification is a voluntary procedure where an independent third party (certification body) assesses and grants by writing that the forest management conforms to sustainability criteria (SFM certification), and that there is a reliable trace down from the forest products origin until the final product (CoC certification).

The general forest certification systems are: single/individual (for private owners or privately-owned companies) and group (for a group of small and medium-sized companies under one certificate).

Furthermore, the PEFC system covers another possibility, the regional certification which is most efficient in large privately owned forest areas. The FSC system also includes the SLIMF (Small and Low Intensity Managed Forests), which covers areas of less than 100 ha, or with less than 5,000 m³ of annual profitability and with annual profitabilities lower than 20% of average growth.

The possibility of group certification offered by the PEFC system was broadly accepted and represents more than 70% of the certified forests in Europe. In some countries, such as, Germany, Finland, Austria, Belgium and France, this possibility represents 100% of certified forests.

Chain-of-custody certification

The chain-of-custody certification is performed to assure wood tracking from forest until the end consumer. This procedure is carried out as follows.

The PEFC system has several possibilities available for the chain-of-custody certification:

**Physical separation method**

It should be guaranteed that certified wood is separated, in other words, is clearly identified in every stage of the manufacturing or trading process.

**Percentage method**

The company will be allowed to use the label “Origin from sustainably managed forests” on the portion of its products that corresponds to the amount of certified raw material. This system is checked through inventory records kept in each process stage. When the company uses more than 70% of certified wood, its whole production can be labelled with the PEFC label.

### Sustainable forest management

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
</table>
| 1    | Request for certification  
- Individual certificate  
- Group certificate  
- Regional certificate |
| 2    | The certification entity requests for the necessary documents and send a previous query for the audit. |
| 3    | Auditor’s visit. Audit. |
| 5    | Emission of Sustainable Forest Management certificate. |

After irregularities correction, second visit  
Extraordinary audit

Not in favour report
In favour report
Forest certification status

**Galicia**

The last available data of 2006 show that in Spain there are 393,498 ha of forests with the PEFC sustainable forest management certificate and 105,560 ha certified by the FSC system. Additionally, there are 38 companies with their chain-of-custody certified by PEFC.

With regard to Galicia, there are 119,681 ha certified by the PEFC system (30% of the overall figure in Spain) and 9,492 ha certified by the FSC system (9% of the overall figure in Spain). In 2005 in Galicia, 511,000 m$^3$ of wood certified under PEFC system were produced from forests managed by the Xunta de Galicia (Galicia Autonomous Administration) (74%), and from forest industries with certified forests.

In Galicia, there are currently 11 companies with their chain-of-custody certified under the PEFC system. Besides, the “Grupo Galego de Cadea de Custodia” (Galician Group of Chain-of-Custody) offers a group certificate, that currently includes 17 small and medium-sized companies.

**Portugal**

The last data available (December 2005) show that in Portugal there are 50,012 ha of forests with the PEFC sustainable forest management certificate and 50,253 ha with the FSC sustainable forest management certificate. This data basically corresponds to the same area, mostly covered with eucalyptus plantations. There are several ongoing projects to certify pine
plantations. It is estimated that pine forest stands amount to approx. 10,000 hectares until the end of 2007.

There are 5 companies with their chain-of-custody certified by PEFC and 11 with FSC chain-of-custody certificate. Additionally, there are several forest management certificates (from FSC and PEFC).

Aquitaine

Data reporting to September 2004 shows that almost 600,000 ha and 3,500 land owners hold the sustainability certificate accredited/granted by the PEFC system. Reporting to the same date, the chain-of-custody of 70 companies was certified by the PEFC system.
WOODWORKING INDUSTRIES
In Aquitaine, Portugal and Galicia, Pinus pinaster wood felling amounts to 14.6 million m$^3$, what represents approx. 60 % of wood for industrial purposes within this sector. Aquitaine holds the largest production (9.1 million m$^3$), followed by Portugal (3.1 million m$^3$) and Galicia (2.4 million m$^3$).

*Pinus pinaster* primary processing consists basically in sawn timber production (with a consumption of approx. 10 million cubic metres of roundwood with bark), as well as in the pulp and wood-based panel industries.

![Diagram showing maritime pine industrial wood production and *Pinus pinaster* consumption sawmill industry for Aquitaine, Portugal, and Galicia.](image)

*Sources: CIS-Madeira 2001 (Galicia), FIBA 2002 (Aquitaine), AIMMP 2001 (Portugal).*
Sawmill industry

The sawmill industry is a relevant economic activity for the Pinus pinaster processing, on the one hand, due to its high consumption level of raw material (67% of the total amount), and on the other, because it is a supply source of products and by-products for other sub-sectors (secondary processing, panels, and others.). Currently, this sector is under a restructuring process, and there is a gradual reduction in the number of companies. Data on this sector trend and characteristics in Aquitaine, Portugal and Galicia are included ahead.

In Aquitaine, especially the sawmill industry is strongly dependent on Pinus pinaster wood consumption (93% of total supply). In Portugal, although in smaller proportion, the sawmill industry is also mostly based on this species consumption, both from domestic source (75% of the total amount) and from imports (1.2%). The remaining consumption corresponds to other hardwoods (9.1%), tropical wood (8%), other coniferous (3.1%) and eucalyptus (3.4%). In the Galicia case, although the consumption percentage is lower (63%), maritime pine remains the principal raw material to be used. The remaining supply comes from eucalyptus (8%), other hardwoods (10%), and other coniferous (19%), mainly Monterey pine (Pinus radiata).

At the present time, estimates point to 1,000 sawmills companies split by Galicia (37%), Portugal (35%) and Aquitaine (28%). In the last years, there was a drastic reduction in the number of sawmills. This trend is expected to proceed in the near future, until achieving a balance where the company structure and the average production capacity are adapted to both the raw material availability and the conditions of a globalised market.

The following figure shows data on the current distribution of the companies according to their annual production capacity.

In Aquitaine, the sector restructuring originated the development of a large-sized group of companies (25 sawmills that represent 60% of the production) using the state-of-the-art techniques in sawmill and drying process. This promoted a quality improvement of products and helped to increase productivity and reduce variable costs. Since 2000 and despite the aforesaid, there is evidence of a decrease of approx. 20% in the annual production volume until stabilising around 1.5 million cubic metres.
In Portugal, the decrease in the number of sawmill units is also closely related to the competition pressure, resulting from the technology evolution and the need to develop processes of secondary processing units (wood drying process, pallets assembly, glue/adhesive products manufacture). Significant progress was, therefore, achieved that helped the sawmill industry to evolve its average productivity of maritime pine from 68 m³/man/year in 1975 to 350 m³/man/year twenty years after. Nevertheless, there are still a high number of traditional companies that lack technical capacity to improve its competitiveness.

In Galicia, although there was an improvement in the production capacities, excepting a few cases, there were no intensive investments in sawmill units. According to the available data, there are 19 companies that process more than 20,000 m³ of pine roundwood with bark. The consumption of this group corresponds to around 37% of the total amount.

There are also 38 medium-large-sized companies with consumption between 10,000 and 20,000 m³ with bark (24% of the consumption). The remaining portion (clearly larger in number) corresponds to small premises, mostly family business with a reduced production capacity.

The costs structure in Aquitaine, Portugal and Galicia is strongly related to wood costs, employed technology and labour costs. Some data is included ahead to show cost differences in raw material, amortisations and labour.

In Aquitaine, it must be stressed that 75% of sawmills are active in forest exploration and, therefore, can buy directly standing wood. In Galicia and Portugal, this percentage is lower, since there are several intermediates in wood supply to plants. In Portugal, the sawmill industry buys from intermediates approx. 60% of its consumption.

In Aquitaine, the average income/revenue of sawn products is estimated to be ranging between 42 and 48% (2.1 - 2.4 m³ with bark of trunk by m³ of product). In Portugal, the profitability lies in 2.3 tonnes of roundwood with bark by m³ of sawn
timber. In Galicia, the estimated average profitability is between 2 and 2.3 tonnes of roundwood with bark by sawn m³.

**Products**

Another most interesting point is added by the offer of products developed from Pinus pinaster. Here differences are remarkable. Due to their relevance, the furniture and carpentry sector in Portugal and the planed products manufacture in Aquitaine should be highlighted.

In Galicia, production is mostly boards and planks for construction and carpentry, as well as wood for pallet manufacture, packaging and food containers. Boards and panels for construction and carpentry are mainly used in construction for auxiliary works, such as: wooden surfacing structures, scaffoldings and closing devices. The best qualities are sent to carpentry and furniture.

In Portugal, it is relevant to highlight that a significant quantity of wood (22%) is used in value added products by carpentry and furniture. In quantitative terms, pallets and wooden packages production together with civil construction applications (wooden structures and others) constitute the main destinations of maritime pine sawn timber. The quantity of wood used in the manufacture of posts, rods and locking/closing devices is also relevant.

From the 1,757,000 m³ of sawn timber produced in Aquitaine (2001), only 58% is traded. The remaining amount (42%) corresponds to wood processed by sawmills themselves to manufacture other products, such as: pallets, boards or wainscots. Among the product range, the significant quantity of wood used in boards, wainscots and other planed products (31%) should be highlighted. 12% of the production is exported.
In the last years in Aquitaine, the container and package (mainly pallets) manufacture share has increased significantly, from 38.9% to 48% between 1993 and 2001. The market trend for planed products is to remain stable around 30%, after the decrease felt between 1993 and 1997.

Pulp and wood-based panel industries

The wood-based panel industry located in Aquitaine, Galicia and Portugal consists of 26 companies that altogether have an annual turnover over 1,000 million euros, employing directly around 6,000 people. In Galicia alone, it is estimated that indirect employment bound to this sector may amount to 13,500 people.
Although, mainly as of the 90’s, the consumption of alternative species was significantly fostered (above all eucalyptus in Galicia and Portugal), the prime raw material is still Pinus pinaster wood. Currently, there is a strong trend towards the use of recycled wood (from products, such as: containers and packages at the end of their life cycles), replacing the traditionally used roundwood.

This kind of industry started developing at the end of 50’s, beginning of the 60’s, with the installation of the first chipboard and hardboard lines. In the 70’s, there was a strong expansion of this activity which proceeded through the 80’s with the installation of the first medium-density fibreboard lines. Currently and in general terms, this is an industrial sector that thanks to intensive investment carried out in the last years, was capable of maintaining efficiency levels required by a highly competitive market that demands permanent innovation needs in developing new products and improving costs and processes efficiency.

The products range includes chipboard, MDF, hardboard and plywood. There is currently a trend for vertical integration of value-added processments, such as: melamine surfacing, veneers or wood-based products as laminate floorings or postforming.

With regard to pulp production, it must be referred that there are 3 mills in Aquitaine. In Galicia and Portugal, the use of pine wood was gradually replaced by eucalyptus as of the 70’s.

<table>
<thead>
<tr>
<th></th>
<th>Number of plants</th>
<th>Number of employees</th>
<th>Annual turnover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquitaine</td>
<td>6</td>
<td>1,137</td>
<td>260</td>
</tr>
<tr>
<td>Portugal</td>
<td>12</td>
<td>2,530</td>
<td>324</td>
</tr>
<tr>
<td>Galicia</td>
<td>8</td>
<td>2,133</td>
<td>470</td>
</tr>
<tr>
<td>TOTAL</td>
<td>26</td>
<td>5,800</td>
<td>1,054</td>
</tr>
</tbody>
</table>

Sources: CIS-Madeira (Galicia), AIMMP 2002 y MTS 2001 (Portugal).
In Galicia, panel manufacture represents approx. 60% of the total domestic production.

Since the very beginning, this industry has backed its growth on maritime pine wood consumption from Galician forests. However, the consumption growth was higher than the supply and it became necessary to import coniferous wood. For instance in 1999, 0.5 million m$^3$ of coniferous wood had to be imported to complement supply.

In what concerns chipboard, progress achieved in the manufacturing technology enabled the use of by-products from other industries as main raw material supply, for instance small-sized pieces of wood (branches and slabs) and recycled wood, it further allowed the introduction of a mix of different species, such as pine, eucalyptus and other hardwoods (oaks, sweet chestnut, alder, birch, and others).

In medium density fiberboards, the characteristics of the process have limited the incorporation of lower quality materials. However, the development of new manufacturing Technologies from white eucalyptus wood (Eucalyptus globulus) led to an increase in the production capacity of the sector, with the creation of new manufacturing lines, without increasing the pressure over pinewood stands.

Concerning plywood, the trend to work with white eucalyptus is kept, since it offers broader supply possibilities. Likewise, in the case of flat ply production plants, although pinewood was traditionally used as raw material, in the last years, the lack of an adequate quality and stable supply forced companies to seek for imported woods.
In Portugal, this industry started up in 1957 with a small industrial plant of chipboard production. Taking as a reference 2002 data, there are 12 wood-based panel manufacturers in Portugal: 5 produce chipboard, 3 MDF, 4 plywood and/or wood panels, 1 hardboard and there is a company dedicated to the manufacture of a mixed particleboard with cement.

Maritime pine constitutes the main supply source to the chipboard production industry (98% of total consumption) and to MDF panels (95% of total consumption). On the contrary, its use by the wood panel and plywood industries is very low, with percentages around 6% of total consumption.

MDF was the product with the highest growth in the last years. Turnover in this sector is about 325 million euros; it is strongly driven to export, almost half of its production is exported. The key markets are Spain and the United Kingdom. In the last few years, there was a reduction in exports to Spain, which was replaced by Switzerland, the Netherlands and Finland.

In Aquitaine, the panel sector comprises 6 industrial plants, whose production corresponds to 20% of the total domestic production. There are plants of chipboard (3 units - 1.2 million cubic metres), MDF (1 unit - 200,000 cubic metres), plywood (1 unit - 120,000 cubic metres) and insulating panels (100,000 cubic metres).

It should be highlighted that this plywood plant is the European unit with the largest development in coniferous wood production.

Unlike Galicia and Portugal, where cellulose pulp is fully supplied by eucalyptus wood, in Aquitaine there is also a relevant use of pine as raw material in pulp and paper manufacturing processes.

Specifically, there are 3 industrial groups that produce Kraft pulp (530,000 tonnes) and Fluff pulp (165,000 tonnes).

Altogether the panel and the pulp industries have an annual consumption around 2.6 million tonnes of wood from tree felling and 1.6 million tonnes of sawmill by-products.

The supply flows include almost the whole existing amount of wood for pulp and wood-based industries in Aquitaine, as well as other resources from boundary regions, such as: Limousin, Midi-Pyrénées and País Vasco, and other imports.

Before the 1999 storm, estimates pointed to an additional need of 1 million tonnes of wood every year.

These companies are much larger than the others of the sector (more than 150 employees per company), and, despite their reduced number, their contribution represents more than 50% of the overall turnover of the sector.
Secondary processing of wood

The secondary processing helps to explore the whole economic potential of wood resource. The following chart shows some reference figures on the multiplying factor obtained from wood processing during its various stages and processes.

For this reason, although absolute values achieved may be lower in terms of turnover, wealth creation is especially relevant for this kind of companies. Here the distribution of the value-added obtained by the Portuguese wood industry is relevant, since this industry uses above all domestic woods including the furniture industry.
With regard to the impact on employment creation, again Portugal is taken as a reference. In this country, the furniture subsector employs approx. 41,000 people; this figure represents 5% of the overall pulp and wood-based panel industries and 60% of the employment in the wood processing chain. In terms of turnover, the density of this subsector is clearly lower. Only pulp manufacturers achieve 54% of the total production figure in the processing chain.

While analysing Pinus pinaster processing in south-western Europe from a global perspective, one of the most interesting and striking aspects are the existing differences in the development achieved by Aquitaine, Galicia and Portugal in the various subsectors. These differences are responsible for a divergent value-added figure obtained with a resource, which is basically a common one.

For instance, considering the wood portion for value-added applications, it can be confirmed that, in the presence of utilisation levels of approx. 22.4% of Pinus pinaster sawn timber in furniture applications (Portugal) and by 31% in boards, wainscots and other planed wood products (Aquitaine), in Galicia these applications exist but not in large quantities.

Main contributing factors for this situation:

- The quality of the maritime pine sawn timber: The insufficient use of appropriate forestry techniques (genetic improvement, treatments, and so on) determines the quality of both standing wood and sawn timber. This fact is promoted by the strong wood demand from pulp and wood-based panel industries and, above all, to the large dispersion of forest property. Normally, a medium-sized sawmill can only achieve 5-8% of best quality wood (clean and semi-clean board) fit to be used in the manufacture of carpentry and furniture components. As a consequence, the roundwood characteristics do not help to achieve enough quantities of sawn timber adequate for industrial use in sectors other than packaging.
- In Galicia and Portugal, the lack of a uniform use of quality standards applicable to the Pinus pinaster wood classification represents a strong disadvantage against the coniferous wood competition from other sources. This effect is increased by the use of a grading system according to “continuous width”.

- The inexistence of marketing initiatives enhancing the knowledge of the characteristics and technical qualities of Pinus pinaster wood used in value-added applications. Here a special reference to the Aquitaine example, where planification and development of promotional concerted actions has been carried out since the 80’s, and fostered decisively the market share of products, such as: parquets (floorings) and wainscots. To help to understand this effort, it should be added that in television advertisement alone, investments amounted to approx. 3.2 million euros.

**Galicia**

In Galicia, this subsector comprises about 2,400 companies (including individually-owned companies), from which 1,360 correspond to carpentry and joinery activities and 1,046 to furniture and wooden objects manufacture.

From the total employment created by the wood processing industry in Galicia estimated in 17,000 workposts, the largest part is related to carpentry and furniture activities (10,000). Turnover amounts to 421 million euros.

This subsector is preponderantly composed by micro-companies (9 out of 10 are craft companies) with a much reduced average number of workers. There are 3 distinct groups:

- Small-sized companies with insufficient production capacity and less than 10 workers (corresponds to 90% of the sector). Almost all are individually-owned or limited liability companies, with strong family ties among workers and a commercial activity addressed almost exclusively to the local market. The annual turnover of most of these companies does not exceed 300,000 euros.

- Medium-sized companies, with 10 - 20 workers, mostly individually-owned or limited liability companies (6.2% of the sector). The annual turnover of approx. 92% of these companies does not exceed 1,200,000 euros.

- Industrialised companies incorporated as public limited company or limited company, with a number of employees varying between 20 to 100 workers (3.5% of the sector). This group of companies posts an annual turnover higher than 1,250,000 euros and operates in the domestic and international markets.
Specialisation and automatisation of the productive process is much reduced, except in some activities, such as: kitchen and bathroom furniture and, at a lower extent, in home furniture. Moreover, tailored production overcomes line production, except in the case of medium and large-sized companies where larger standardisation can be found.

Chipboard and MDF (medium-density fibreboard) are the most used materials. Solid wood comes in the second place with a 30% of total consumption. 88% of this solid wood is imported from abroad and 6% from other Spanish areas. Only 6% of solid wood comes from a Galician source.

Paradoxically however, it is estimated that only 10% of sawn timber produced in Galicia is subject to processing in this region (1999 data). Current applications are reduced to:

- Use in furniture frames of three-piece livingroom suites, sofas and armchairs.

  - Manufacture of floorings, wooden surfacings and frames. One of the traditional uses of maritime pine in Galicia is the production of boards and wainscots. In many cases, these processing works were performed at sawmills, using wood dried in the open air. Nowadays, although there are some specialised companies in manufacturing this kind of products, the use of Pinus pinaster can be considered much less relevant, because the use of other wood species is broadly predominant.

  - Use in food containers, mainly in the production of bottle cases. For logistics reasons, normally the final assembly is performed at the destination.

  - Manufacture of pallets and other industrial packaging. Most part of the wood for these applications is also delivered ready-to-assemble and the final assembly is performed at destination to optimise transportation. Currently in Galicia, there is an industrialised company exclusively active in pallets assembly and several sawmills manufacturing manually pallets, normally non-recoverable, mainly for the local market.

Finally, it should be refered that today the best maritime pine wood qualities, used in furniture manufacture, are mostly delivered to industries and warehouses located in other regions of Spain, e.g. Valencia, Andalucia and Catalonia.
Portugal

In Portugal, the carpentry and furniture industry comprises approx. 7,000 companies. Data included in the following table shows the main indicators of this subsector.

<table>
<thead>
<tr>
<th></th>
<th>Carpentry</th>
<th>Furniture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of companies</td>
<td>2,075</td>
<td>3,676</td>
</tr>
<tr>
<td>Number of employees</td>
<td>11,000</td>
<td>40,950</td>
</tr>
<tr>
<td>Sales volume (million €)</td>
<td>538,7</td>
<td>1,247</td>
</tr>
<tr>
<td>Imports (million €)</td>
<td>64,3</td>
<td>122,2</td>
</tr>
<tr>
<td>Exports (million €)</td>
<td>75,3</td>
<td>113,2</td>
</tr>
</tbody>
</table>

*Source: AIMMP, 2002 y MTS 2001*

As it can be seen by analysing the average turnover and number of employees, especially in carpentry, the business community is mostly composed of very small organisations. Taking as a reference the furniture subsector, it can be observed that only around 500 organisations have more than 5 workers. The most part are family businesses.

With regard to technology use, there are very different situations that should be split into the following groups:

- Craft industries delivering works performed with manual mechanisation and in many cases without any decorative finishes.
- Standard companies with some automatisation degree and finishes departments.
- Intermediate companies well structured in terms of safety and environment and other basic aspects, but, in general terms, with improvement needs in the overall management of the company, for instance in areas, such as: design and commercial strategy.
- Modern companies with updated and complete equipments, as well as appropriate production and commercial managements.

In terms of geography, furniture companies are concentrated in the North of the Douro River (almost 69%) and in the districts of Leiria, Viseu and Setúbal. 81% of the companies that altogether produce 90% of the turnover and 89% of employment are located at the districts of Porto, Lisbon, Braga, Aveiro, Leiria and Setúbal.

As it can be observed in the following products distribution chart, bedroom and sitting room furnitures are predominant, representing almost 50% of the total sales volume. The market growth of modular kitchen furniture should be highlighted.

From a commercial and investment viewpoint, this subsector in Portugal shows a low internationalisation degree. Although the larger part of the production is addressed to the domestic market, export destinations are France (33.4%), Germany (20.5%) and Spain (12%), mainly for bedroom and dining room
furniture. Although imports (which exceed exports) correspond to the same type of furniture, there is a difference related to the inclusion of design or of an associated trademark. The most part of imports come from Spain (57.3%), Italy (16.2%) and France (5.4%).

During the last years, there was a large increase in furniture consumption, closely related to the peak felt in the real estate business, as well as to changes in interests and consumption habits. Besides, company’s technological investment was fostered, resulting in the increase of the installed production capacity. Nevertheless, at the first signs of economic crisis in 2002-2003, there was a relevant fall in domestic consumption. This fact was accompanied by some instability in the international distribution channels, due to the strong competition from furniture produced in other countries. As a consequence, there was a significant reduction in the number of active companies.

Among the main wood species used, we can find cherry tree, oak, sweet chestnut, walnut tree, European beech and Pinus pinaster. These are the most used woods, not only due to their decorative dimension and their engineering/shaping possibilities, but also by traditional reasons, since they are indigenous species. Naturally and above all in what concerns hardwood, the raw material supply is complemented by imported wood from other countries.

With regard to Pinus pinaster, Portugal stands out undoubtedly in the development of this kind of furniture applications based on the use of solid wood of this species. Currently, there are examples of companies that with the use of this raw material could achieve the highest quality and efficiency standards and could successfully trade their products both in the domestic and international markets.

Aquitaine

In Aquitaine, the application of forestry techniques for several decades helped to obtain a significant volume of good quality sawn timber. Considering the SERFOB data (1997), the average grading by qualities is split as follows:

- Qualities OA, OB e 1: 25%
- Qualities 2 e 3A: 70%
- Qualities 3B: 5%

As it can be checked on item visual grading criteria, the first group corresponds to wood free of defects or with small specificities. The following table shows some data on the uses assigned to each quality:

<table>
<thead>
<tr>
<th>Application</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>First quality frames</td>
<td>OA</td>
</tr>
<tr>
<td>Frames, floorings and surfacings</td>
<td>OA-OB</td>
</tr>
<tr>
<td>Furniture and indoor components (staircases, …)</td>
<td>OA-OB</td>
</tr>
<tr>
<td>Carpentry and kit furniture</td>
<td>OA-OB-1</td>
</tr>
<tr>
<td>Outdoor furniture</td>
<td>OB-1-2</td>
</tr>
<tr>
<td>Structural components</td>
<td>2-3A</td>
</tr>
<tr>
<td>Packages and pallets</td>
<td>2-3A</td>
</tr>
<tr>
<td>Wine cases</td>
<td>2-3A</td>
</tr>
<tr>
<td>Crosspieces</td>
<td>3A</td>
</tr>
<tr>
<td>Non-reusable packages</td>
<td>3A-3B</td>
</tr>
<tr>
<td>Wooden surfacing structure</td>
<td>3B</td>
</tr>
</tbody>
</table>

These conditions of raw material availability enabled the development of an industry, currently with 30 industrial units producing significant quantities of value-added products, among them floors (parquet) and panellings (lambris). There is an annual production of 3,800,000 m² floors (670,000 m² are exported) and 12,000,000 m² wainscots (290,000 m² are exported). All these products are manufactured with maritime
pine. Around 75% of the production holds quality labels issued by certification bodies. Most companies also produce decoration components, such as: frames, skirtings and others.

Package production is also relevant, considering the high level of maritime pine consumption (corresponding to 60% of the domestic production of softwood in Aquitaine). This sector comprises 80 companies, half of them employing less than 5 people. The development of high productivity techniques and integrated logistic services was decisive to help maritime pine wood achieving a dominant position in the pallets sector.

In Aquitaine, there are also almost 200 companies that produce structural and carpentry components (doors and windows). Half of them employ less than 50 people. There are approx. 20 sawmills dedicated to the manufacture of structural components.
WOOD CHARACTERISATION
Morphology

A common defect associated with Pinus pinaster is the absence of an upright trunk. The origin of this circumstance might be the uneven diameter growth and the presence of compressed wood in most part of the trunk. These shape defects, which are strongly influenced by environmental and functional factors of the tree, can be corrected by the use of a plant genetically improved and/or through specific forestry techniques.

The curvatures occurrence in the tree generates compressed wood at the compressed part of the trunk, in order to reorient the tree to the upright position. This wood is easily recognised, due to its strong coloration, uncommonly large rings, unusual aspect and abnormal high densities. Once dry, this kind of wood decreases longitudinally. This defect conditions its use in construction applications.

The presence of curvatures in trunks impacts on the revenue of wood industrial sawmills. For this reason, one of the most common uses of Pinus pinaster wood is in containers, packages and pallets manufacture. In these applications, wood is cut into short length pieces, minimising, thus, the impact of trunk curvatures. The difference with other European coniferous species lies on the fact that those species can be processed until a 6 metre length, whereas, generally, maritime pine cannot exceed a 2.5 m length.
Macroscopic description

The Galician pine wood colour is white-yellowish in the phloem and reddish-yellowish in the heartwood. The proportion of the heartwood is related with the tree age and its growth level. The slightly circular pith’s colour is «wine red» or brown.

The annual (age) rings are quite visible, due to the contrast between spring and summer zones, bringing to this wood a singular characteristic grain.

The number of rings by centimetre varies between 1 and 4 (average: 2.2). As a consequence of the uncommon characteristics and annual climate variation, its distribution is quite irregular within the same trunk. In general terms, the texture is thick.

If the stands were not pruned, knots will appear in large numbers and without an even distribution. They are relatively large, dark greyish-brown coloured, and in general, are loose or dead. This happens, because Pinus pinaster has a trend to let branches under the tree top die, so that, while expanding in diameter, the tree keeps generating knots from dead branches. The presence of knots devalues the wood, since it constitutes one of the main criteria of wood grading, both in decorative and structural utilisations. Another characteristic of this wood is the presence of well located resin pockets/bags. Fiber is straight.

Microscopic characteristics

Tracheids have a polygonal cross section, with large aerolar pits, generally placed in a single row, although sometimes double series can be observed at the radial walls extremities. There are no pits at the tangential walls of the summer tracheids.

Wood rays are uniserial and fusiform. The first ones include 10 to 15 height cells by average term. Extreme values with regard size are 26 cells with a 500 µ. thickness and 2 cells with a 38 micras thickness. Normally, they are heterogeneous with marginal, spread, serrated tracheids at the inner part of the ray.

Pits at the intersection fields of cells of radial parenchyma with longitudinal tracheids are pine-like type with small flanges. Normally they appear 2 or 3 per intersection. Radial tracheids are serrated with isolated teeth.

The radial parenchyma walls are thick and with the same thickness of longitudinal tracheids.
There is no vertical parenchyma.

Vertical resin ducts are numerous and with a 200 and 350 micras diametre, and have thin-walled epithelial cells. These channels are mainly located in the transition area from spring to summer. Horizontal resin ducts area much smaller, including their rays.

**Wood variability**

Wood is a natural material that results from the growth of a living being, and for that reason can show various anatomical characteristics. This fact promotes the variability, and should, therefore, be taken into consideration while assessing its behaviour and characteristics.

Wood is a natural material that results from the growth of a living being, and for that reason can show various anatomical characteristics. This fact promotes the variability, and should, therefore, be taken into consideration while assessing its behaviour and characteristics.

The wood formation is due to an activity performed by a series of cells integrated in the vascular cambium. This process includes three phases: cellular division, differentiation and maturation. During this development process, a number of internal and external factors contribute to the variation of type, number, size, shape, physical structure and chemical composition of the constituent elements of wood (summer wood, spring wood, reaction wood, juvenile wood and adult wood). All this is conditioned by the genetic data, soil and climate characteristics, forestry treatments ( spacings, fertilisation, thinnings and clearings, prunings) and biological agents or natural events that may have impact on the tree development. As a consequence, there are morphological and structure changes.
Aimed at controlling the natural variability of maritime pine wood, important efforts were carried out in the genetic selection and improvement, as well as in the development of specific forestry.

Due to genetic factors, it is possible to find almost 50% differences in similar samples (drawn from trees of the same age and quality season) (Desh y Dinwoodie, 1996). Soil-related climate factors are also significantly responsible for wood variability, mainly in terms of mechanical properties, as a consequence of efforts demanded by land slopes, weather phenomena (wind and snow) and the tree weight.

A study carried out by LNEC (Portugal) to assess the suitability of Pinus pinaster Ait. wooden structures from several different sources could prove the relationship between wood variability and its source.

To this variability among distinct individuals of the same species can be added a second variation level within the wood of the same individual. This variation can be divided into three levels:
- Horizontal variation (from the pith to the bark).
- Vertical variation (from the trunk base to the tree top).
- Variation in the growth rings (pronounced in the case of maritime pine).

In these cases, variability lies in the variation of the cellular elements characteristics. As such, in the horizontal direction there are three different main zones: pith, juvenile wood and adult wood. Mechanical properties increase, from pith to adult wood, while the tracheids length grows (main anatomical element bound to wood resistance). Juvenile wood found in the first rings next to the pith correspond to wood formed under the direct influence of the top of the tree. This wood shows larger retraction, less durability and much less resistance/resilience, for that this wood has poor quality for carpentry and furniture applications, and mainly for structural uses.

The growth rings arrangement helps indirectly to understand the tree growth variations, since summer wood shows larger density than spring wood. According to some studies (Castera et al., 1999), the module of elasticity in traction for summer wood shows 1.2 times higher values than spring wood for a changing age of 2 to 4 years. In a changing age between 8 and 10 years this disproportion is even higher (almost 2). For this reason, normally structural grading standards establish limits to the rings width, by considering that the ring width increase brings a reduction in wood density (because it carries a lower percentage of summer wood) and, consequently, a lower mechanical resistance.
Physical-mechanical characteristics

Taking as a reference the bibliographical sources stated in the lower part (separate), the following table is included summarising the average figures corresponding to the main physical-mechanical characteristics of Pinus pinaster in Galicia, Aquitaine and Portugal. This data should be considered as a simple guiding reference.

From the previous data, it can be gathered that maritime pine wood can be classified from "light" to "semi-heavy", with a volumetric shrinkage from "average" to "high", "medium/average nervous", and with a "high" ratio between linear shrinkage coefficients in radial and tangential directions. The hardness mean is "average", higher than the one found in other pine varieties in the Iberian Peninsula.

Properties of maritime pine juvenile wood

Juvenile wood evolves during the first years of the tree changing growth, concentrating in a spiral area around the pith. In maritime pine, normally the differentiation area between juvenile and adult wood can be found between the tenth and the twelfth growth rings.

Juvenile wood shows anatomical and chemical characteristics different from those of the adult. It is characterised by short fibres with large lumens and thin cellular walls, a large fusiform axis, relevant quantity of compression wood, low density, high lignin rate, poor mechanical resistance, high longitudinal shrinkage and reduced cross shrinkage. As a consequence, wood is nervous and, in general, shows worse characteristics for industrial processing purposes.

Considering the above, the juvenile wood characteristics cause a lower mechanical resistance (subject to an elasticity module for Pinus pinaster wood free from defects of 9,000 N/mm², juvenile wood can only achieve 3,000 - 4,000 N/mm²). Besides problems resulting from deformations caused by a larger dimensional instability can also occur. This fact is influenced by the fibre deviation and is more noticeable in the centre of the trunk. All this can have an impact during the manufacturing process (irregular drying, problems in decorative finishes applications, need of a higher adhesive consumption, and so on). In case of wooden veneers, juvenile wood causes vibrations in the blade and cut failures. Furthermore, plates made of juvenile wood dry quicker, increasing the occurrence of cracks.

<table>
<thead>
<tr>
<th>Physical characteristics</th>
<th>Galicia</th>
<th>Aquitaine</th>
<th>Portugal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (green wood) (kg/m³)</td>
<td>-</td>
<td>-</td>
<td>1,000</td>
</tr>
<tr>
<td>Anhydrous density (kg/m³)</td>
<td>1,055</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>12% density (kg/m³)</td>
<td>576</td>
<td>564</td>
<td>510</td>
</tr>
<tr>
<td>Saturated volumetric dry weight (kg/m³)</td>
<td>398</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Basic density (kg/m³)</td>
<td>-</td>
<td>480 [350-645]</td>
<td>-</td>
</tr>
<tr>
<td>Hygroscopicity</td>
<td>0.45</td>
<td>0.52 - 0.57</td>
<td>0.52 - 0.57</td>
</tr>
<tr>
<td>Fiber saturation point (%)</td>
<td>34</td>
<td>-</td>
<td>28 - 30</td>
</tr>
<tr>
<td>Linear shrinkage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Tangential</td>
<td>7.59</td>
<td>7.7 [4.2 - 9.9]</td>
<td>7.2 - 10.1</td>
</tr>
<tr>
<td>b) Radial</td>
<td>4.94</td>
<td>4.6 [2.5 - 6.6]</td>
<td>4.1 - 6.0</td>
</tr>
<tr>
<td>Monnin hardness</td>
<td>2.6 - 3.1</td>
<td>2.2 - 4.2</td>
<td>3.6 - 3.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical characteristics</th>
<th>Galicia</th>
<th>Aquitaine</th>
<th>Portugal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression parallel to grain: strength (N/mm²)</td>
<td>39.9</td>
<td>47.8 [34 - 68]</td>
<td>30.0 - 68.5</td>
</tr>
<tr>
<td>Static bending: bending strength (N/mm²)</td>
<td>79.7</td>
<td>90 [62 - 139]</td>
<td>50.0 - 151.9</td>
</tr>
<tr>
<td>Modulus of elasticity in static bending (N/mm²)</td>
<td>7,378</td>
<td>10,200 [6,000 - 16,000]</td>
<td>6,800 - 11,500</td>
</tr>
<tr>
<td>Tension parallel to grain: tensile strength (N/mm²)</td>
<td>49.5</td>
<td>82.7 [48 - 162]</td>
<td>83.0 - 11,500</td>
</tr>
<tr>
<td>Dynamic bending I/J</td>
<td>15.9</td>
<td>11.8 [5 - 22]</td>
<td>-</td>
</tr>
<tr>
<td>Shearing strength (N/mm²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tangential</td>
<td>10.0</td>
<td>7 [2 - 12]</td>
<td>-</td>
</tr>
<tr>
<td>Radial</td>
<td>8.4</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Sources: A. Remacha 1987 (Galicia), CTBA (Aquitaine), Albino de Carvalho 1997 y CTIMM 2003 (Portugal).
Understanding the properties of juvenile wood is quite relevant, since there is a growing trend to reduce the cutting periods in plantations. In France, it is considered that the current rotation cut of maritime pine between 45 and 50 years can be reduced with the application of new techniques until reaching a figure around 30 years. For this reason, the knowledge of the percentage of processed juvenile wood and its impact on the characteristics of the manufactured product constitute crucial aspects to guarantee the process profitability and the final product quality.

Resin pockets in maritime pine

Resin pockets are part of the singular characteristics that can affect in a decisive way the quality of coniferous sawn timber, mainly in carpentry and furniture applications. In the Pinus pinaster case, sometimes this kind of defects are recurrent and their cause is not well-known.

In this species there are 3 different morphological types of bags:

- **Type I** is formed as an inner crack that does not affect the tree further growth. This type of resin pockets/bags are the most common in maritime pine.

- **Type II** corresponds to a cicatrization reaction as a consequence of a wound that damages the vascular cambium and may reach part of the bark. Besides, this type of pockets disturb the tree growth for several years and devaluate wood.

- **Type III** is formed as a consequence of thin longitudinal cracks which become full of resin. In the case of Monterey pine, this kind of pockets have mechanical strengths/stresses that cause lesions to the wood and cracks in the bark.
The geometry study of pockets Type I and III (carried out through the development of the pieces) shows evidence that sizes vary a lot; they have lengths from 20 and 120 mm, widths from 10 to 50 mm and thicknesses between 1 and more than 12 mm. It seems there is a good correlation between length and width. Besides, the analysis of the relationship between height and pockets/bags existence (carried out considering the first 3 trunks from 5 different sources) shows evidence that wood located at a lower height is more sensitive to the occurrence of this phenomenon.

Currently and despite studies carried out, the reasons for causing the occurrence of resin pockets in maritime pine are not fully known. However, certain studies carried out to other species, such as Monterey pine, raise the idea that factors, such as growth speed and others affecting the tree stabilisation (land inclination, winds, injuries, clearings) are possible causes to originate this phenomenon.

Finally, it should be mentioned that some studies carried out through electronic microscopy and other experimental techniques relate an abnormal ethylene release (normally present in association with other vegetable hormones) with a random proliferation of cellular cambium, that may originate the occurrence of resin pockets.
SAWING INDUSTRY
The sawing industry evolution kept pace with the plantations development during the 19th and 20th centuries. At first, this industry used water-mills operated saws. Later, with the industrial development many equipments and devices were adapted to work with steam machines, and in many cases, the sawing wastes/residues were used as fuel. By this time, timber/log carrying trucks were developed with mechanical systems to fix and position the trunks.

The most prosperous times were from the end of World War II until the beginning of the 60's. Wages growth as a consequence of the emigration led to a slight recession in the steady development trend, which can still be felt nowadays.

More recently as of the 80's, a reconversion/modernisation period began, bringing improvements both in company structures and production capacities, mainly in small and medium-sized companies. Nevertheless, there is still today a large smallholding.

Sawing systems

Contrary to other coniferous, where the entire timber/log is carried to the sawing premises for the longitudinal sizing of trunks, with maritime pine this is performed at the forestland. As such, timber/log is selected and classified according to its diameter and singular characteristics, and is cut in different lengths, normally between 2 and 2.5 metres.

This practice limits the usage of this species in structural applications, since these demand products with a larger length (normally above 2.6 m).

The reason for using this wood in short length logs has to do with the raw material losses caused by the trunk curvatures, its cone-shape (convex-shape) and other singular characteristics.
Traditionally, the maritime pine sawing industry was prepared to cover several sawing systems to obtain the utmost profitability from the raw material, even in those cases of standing wood with heterogeneous qualities. By considering as a priority the raw material profitability instead of the sawing plant productivity, many sizes and qualities were obtained. Thus, the processes automation and, above all, the grading and handling of sawn timber is more difficult. A clear example of this is the traditional Galician grading of "straight widths" ("anchos corridos").

In the last decades, there has been an increase in companies changing their classical sawing methods and specialising in the production of some products. This demands specific requirements for roundwood, according to the product type to be obtained. In this way, it is possible to increase productivity and automate the grading and stacking operations, although the plant becomes most dependent on raw material supply.

Installation types

The installation of production equipments in sawing premises is decided according to the following models: dowel layout and line layout.

By tradition, the dowel layout is the most common one, since it brings more flexibility to the production line. These installations are based on the use of band saws that allow the processing of trunks with different diameters and also continuous changes in the timber sawing. The cutting process is optimised manually piece by piece, (normally there is no automatic cutting optimisation system), according to its characteristics and quality. This allows great flexibility in production. This kind of installations normally correspond to sawing industries that consume roundwood with a 20 cm minimum diameter with bark, for the production of board and plank with "straight widths" ("anchos corridos") (without a grading by width). The purpose is to obtain the largest percentage possible of product for furniture and carpentry (clean, and semi-clean board and carpentry), besides a raw material profitable use.

Line layout was developed to obtain large production capacity and a high productivity level. To use this sawing system, it is necessary to turn to chipper-canter equipments placed in front of each other, combined with multiple cutting equipments with circular saws. In this way it is possible to achieve a high-speed feeding (100 m/min and even higher).

These line layouts offer low versatility and flexibility, and are only used by companies with a very specialised production for specific sectors. This layout is quite common in sawmills that produce splints and blocks for the manufacture of containers and packages from small-sized wood (normally with a 12 - 20 cm range), and sometimes wood cut in lengths lower than 1.25 metres.
Equipment and technologies

Roundwood preparation

Roundwood preparation, carried out in wood yards or stacking areas, can include cubing, grading, wood cutting, debarking and final grading. In maritime pine sawmills, these operations are limited to the debarking operation.

The most common procedure is to carry out the trunk selection by diameter and quality at the forest, and upon arrival at the sawmills the wood is already classified. The growing use of forest processing machines helps to improve the grading through a better control over wood sizes.

During the last years, the development of high production lines helped the integration of automatic timber grading lines (based on diameter, curvatures and cone-shape/fusiform measurements), aimed at improving profitability and productivity.

The knives with a circular ring device is the most commonly used equipment to debark maritime pine. This debarking process allows the possibility of working with a large diameter range (normally 10 - 60 cm) and at high speed (normally between 20 - 50 m/minute), and of obtaining a good debarking quality.

Sawing

Band saws

This is the most commonly used equipment in maritime pine processing. This device comprises an upright single-cut band saw with a side log-carrying truck. Its use is mainly based on its high flexibility (possibility of changing sizes cut by cut) and its adaptability to different cut patterns and wood sizes. The role of the operator is crucial while selecting the right cut, according to the raw material characteristics and also sizes and qualities of the products to be obtained.

In the last times, this technology has been evolving with the incorporation of the following equipment:

- Bi-cut saws. Help to increase production capacity approx. 20 - 40%, and can be fitted to already existing equipments without intensive investments.

- Tandem. This system consists of using cut equipments fed by the same log-carrying truck. Thus, it is possible to obtain 2 sawn products in each forward movement. This kind of equipment is seldom used, due to the difficulties arisen in separating the obtained products.

- Twin saws. This system consists of using two band saws in front of each other, which can be symetrically positioned in relation to the feeding axis. This technology shows advantages compared to tandem, because products can be easily separated. Feeding can be performed by a centralised feeding chain (which is much used while processing small-sized wood, although some problems arise to refeed wood) or by using a suspended central car (tele-twin version). This last system improves production around 30 - 40%.
Today there are ongoing developments on band saw equipments with log-carrying trucks that incorporate automatic cutting optimisation systems based on the trunk measurement/cubing and in programming values/figures. In this way, the operator has only to supervise the equipment running and validate the cut pattern calculated by the computer.

Besides their usage in this first stage, these equipments are often used at the resawing phase, mainly in unfolding slabs, with the purpose of increasing productivity and the line production. Unfolding equipments have been continuously improved, mainly in wood pieces feeding and refeeding systems. The most common layout of this equipment is an inclined band saw with a feeding table and a dragging/sliding roller.

In Galicia, it is common to find splint manufacturing lines for containers and packages, using band saw based cutting systems. These manufacturing lines are prepared to perform 3 faces to the wood piece, normally by using a group of twin saws and an horizontal band saw. Afterwards, the three-faced core is resawed by a tandem band saw equipment or by individual saws equipped with a refeeding device.

**Chipper-canters**

Chipper canters are cutting devices that convert directly residual material in chips, avoiding difficulties in collecting, transporting and handling slabs. Besides, this relatively recent technology enables high-speed feeding (50 - 100 m/minute, but 150 m/minute can also be reached), helping to obtain high production capacities.

These equipments are always associated with other cutting technologies. The most usual combinations are:
- **Twin band saws.** Allow working with higher heights and lower cut thicknesses than circular saws, although the production is lower (feeding speeds of about 40-60 m/minute).

- **Twin circular saws.** Can have one or two axes (higher cut height). 4 twin saws can be used to obtain 4 sawn pieces at each movement.

- **Circular multiple saws.** Allow the production of multiple pieces at each movement.

- **Band saw and log-carrying truck.** In this case, a header “cater” like located before the saw and aligned with it chips directly into the slab area. Production is limited by the cutting equipment.

In the most common case of line layout, these equipments can have two different labour systems:

- **Line grading.** Here, the cubing equipment installed at the line entrance measures the trunk to calculate the optimal cut scheme. As such, for each wood piece, the sawing equipment should be fitted to the selected cutting scheme.

- **Previous grading.** Wood is classified/graded by size and quality at the yard and is homogeneously delivered into the sawing line. Like this, time can be spared in two ways: with the computer calculation and with cutting tools handling and positioning.

With these very high productivity equipments, the operators’ work is almost limited to supervision and they almost do not intervene in the selection of the cutting scheme. This technology, however, is less used in maritime pine processing.

**Circular saws**

This is a very advantageous technology, due to its precision and cut quality. Its application in first cuts is limited to lower than 300 mm trunks. It is based on twin/parallel circular saws used to produce a core. In multiple cutting equipments (second cuts), it helps to improve the sawmill production capacity.

At first, these circular saw multiple equipments had fixed saws available. Now there are versions with mobile saws, which allow a greater flexibility in the use of these equipments.

Besides in multiple equipments, another important use is as edging equipments for width sizing of boards and planks. Although, traditionally, these equipments had two saws with one mobile at least, nowadays, there are equipments with 3 and 4 mobile saws available.

**Cutting tools**

Cutting equipments used by the maritime pine sawing industry are belt saws, also known by band saws. The most modern equipments have 1.4 to 1.5 metre diameter wheels and engine power of 75 and 90 CV.

To achieve high feeding speeds, these equipments have large saws, normally with more than 200 mm and a thickness of less than 1.4 mm; equipped with pronounced and single teeth. With this equipment and cutting speeds (saw speed) ranging between 40 and 45 m/s, it is possible to achieve feeding speeds of 50 m/minute. To achieve these speeds, it is recommended to work with saws with a cutting angle between 20° and 25°, in some cases even 28°, a tooth space of 45-50 mm and a height between 15 and 17 mm.
Grading and stacking

The purpose of wood grading is to group and stack wood according to its size and commercial quality. In some cases, it is common to see maritime pine sawmills working with a "straight width" grading.

The average production growth of plants, the trend for fixed width products and the technology development allowed the installation of automatic systems of grading and stacking. Despite the size grading being fully automatised, the quality grading, in general, is made by the operator who is responsible for taking decisions and selecting manually the wood.

There are two different automatic grading systems: lengthwise and crosswise. Lengthwise systems are used in smaller than 2 m wood or in dry wood. Crosswise systems that may be upright or horizontal are the most commonly used for lengthier wood. Automatic grading systems should be integrated and aligned by other devices, such as: automatic stacking, package and wood marking machines.

In large productions, wood marking can be performed by a device (normally, a paint injection spraying) integrated in the grading line. In smaller productions, marking is performed manually with a marking roller or plug/buffer.

Control auxiliary devices/means

The integration of information technologies in the manufacturing process was aimed at optimising wood processment, respecting the raw material characteristics (timber shape, wood singular features, among other).

This progress promoted the growth of the production rate into figures in the order of 20 logs/minute at the line input and even higher than 100 wood pieces/minute at the final stage of the process. Besides, the integration of these technologies enable a better quality control of the product.

The possibility of knowing the volume of each log is a crucial management element. For that, the diameter should be measured at least in two perpendicular axes. To optimise cuts, it is also necessary to know the diameters of the thinnest and the thickest points.
The logs length measurement is performed by measuring their displacement through a fixed sensor. So that measurements are reliable, the equipments used cannot be sensitive to climate variations and have to be capable of working at high rates.

Normally, two systems are used:

- **Luminous heat zone.** This system consists of passing logs by two luminous sources, measuring the shadow areas left on the sensors.

- **Infra-red rays network.** This principle consists of passing logs by a heat zone of rays emitted in parallell from an emitter to a receiver. Measurement is performed with a precision variation between 1 and 4 mm.

Whatever the system used, it is fundamental that the log displacement be carried out with a stable system, so that measurements can be reliable.

To optimise the cut, it is necessary to determine the wood shape, its curvature and cone-shape. This can be done through continuous diameter measurements, according to two perpendicular axes.

In a wood (timber) yard, these systems help to control the logs grading process by size, diametre and width. Data from the classified wood enable the selection of the most adequate cutting procedure and the achievement of large production rates (in the order of 20 wood pieces/minute). Sometimes, these optimisation systems are installed at the sawing line entrance, to facilitate the decision-making process of the operator, although in this case the production rate is slightly reduced.
**Laser-assisted positioning**

This system that may be quite simple consists of a laser emission device used by the operator to position the saw cut. This helps the operator to act faster and safer. The use of several laser rays connected to a calculation software optimises the cutting scheme, according to the pre-selected programmes.

**Artificial vision**

This device comprises several cameras grouped in a network and connected to a computer. This equipment determines the pieces profiles to control its positioning and placement on the log-carrying truck of the header saws. A similar device can be used in unfolding or resawing saws.

This data and its visualisation on screen enable the operator to select the piece in a safer and faster way, by using the pre-selected programmes.

**Grading automatisation**

Improvements achieved in industrial vision equipments made the identification of wood singular characteristics and defects reliable, with the purpose of achieving an automatic grading by wood quality.

Vision cameras are set on 2 perpendicular axes, so that the 4 faces of the pieces can be explored.
Length cut automatisation

The most widespread and reliable system consists of using a sensor that reads the markings made manually by the operators on cutting areas of the pieces. This procedure identifies the areas to be eliminated, by determining the defective areas. Afterwards, a programmable computer optimises the cut, executed by a retractable circular saw. The installation is normally completed with an automatic grading equipment. In this case, length classifying devices are used, although they need more space lengthwise, they are more sensitive and easier to manufacture than cross classifying devices, which are more compact but more complex to handle and build.

Length optimised system

1 - Defects marking area
2 - Measuring and cutting
3 - Automatic classification

1- Cuts
X1 X2 X3 X4 X5

2- Marking with fluorescent crayon
Sawmill production line for Pinus pinaster (board and plank sawmill)
Production reference: 14.000 – 20.000 ton/year/shift

Sawmill production line based on chipper canter and circular saws
Production reference: 35.000 – 50.000 ton/year/shift

1.- Chipper canter with four mobile circular saws and re-feeding system.
2.- Edger with cut-of saw
Drying Process
Natural drying process

The water content naturally existent in wood is much higher than the quantity allowed for its normal utilisation conditions. Greenwood moisture (expressed in relation to dry timber mass) can reach more than 100%. The following figure shows data on the final levels corresponding to outdoor and indoor uses.

Traditionally and due to its easy implementation, the maritime pine industry used to dry it on open air. This drying method only requires an available and appropriate place and no costs with energy consumption are involved. However, the main disadvantage of this drying method is its dependency on the warehousing climate conditions, what considerably limits the possibilities of reaching a moisture content compatible with its final use.
(especially in those applications that need a lower than 15% moisture content). Another disadvantage is the absence of any kind of control over the final quality of the obtained dry wood.

Although this technique shows great differences (depending on factors, such as the employed stacking system, wood thickness and environmental conditions) the Pinus pinaster mean/average natural drying duration (until achieving a moisture around 20%) is about 80 – 90 days in winter and 40 – 45 days in summer.

To obtain an adequate natural drying, it is important to guarantee a good air circulation and place the stacks in such a way that any quality loss by warping or any other defects are reduced. For that it is convenient to orient the wood in the perpendicular direction of dominant winds and place the piles as indicated on the figure. Furthermore, it is recommended to use stacking strips of coniferous or of clear hardwood (to avoid stains due to tannin washes).

The following table includes some reference values on the stack optimal configuration, depending on the wood thickness.

<table>
<thead>
<tr>
<th>Wood thickness (mm)</th>
<th>Stickers thickness (mm)</th>
<th>Stickers separation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-20</td>
<td>20</td>
<td>0.3-0.5</td>
</tr>
<tr>
<td>20-30</td>
<td>25</td>
<td>0.4-0.5</td>
</tr>
<tr>
<td>30-40</td>
<td>30</td>
<td>0.6-0.8</td>
</tr>
<tr>
<td>40-60</td>
<td>35</td>
<td>0.6-0.8</td>
</tr>
<tr>
<td>60-80</td>
<td>40</td>
<td>0.9-1.0</td>
</tr>
<tr>
<td>80-100</td>
<td>45</td>
<td>1</td>
</tr>
</tbody>
</table>

Considering that cold and humid air tends to go down, accumulating itself in the lower part of the stack, it is recommended to lift the stacks basis, avoiding the presence of vegetation or puddles formation. It is also recommendable to protect the upper part of the stacks. This benefits the drying process and prevents fungi attacks.

The vertical stacking system increases the drying speed (from 1.5 to 2 times). However, the warping risk is higher, therefore its use is not recommended for moistures lower than 30%.
Artificial drying techniques

Although the open air drying process is an advantageous option in some aspects (easy to handle, energy costs, maintenance costs, investment requirements, ...), nowadays there is a trend towards the incorporation of artificial drying in a chamber. This fact is motivated by the following factors:

- Need to guarantee that the final product obtained is compatible with applications that require low moisture contents (floorings, surfaces, ...).

- Need to improve the drying duration, reducing stocks of products under manufacture, to obtain relevant financial advantages and a larger organisation flexibility.

- Sawn timber transport optimisation, due to the wood weight reduction.

- Elimination of the possible degradation of sawn timber (by fungi or other causes).

Among artificial drying technologies, there are the following types:

**Acclimatised hot air dryers**

This system consists of collecting air from outside and impel it through ventilators into a heating accumulator and a moisturising system. The air is acconditioned at a determined temperature and relative moisture, according to the drying needs. The acclimatised air passes through the stack, absorbing water steam extracted from the wood. Through this process, this air becomes cold and humidity loaded, and has to be replaced by dryer air from outside.

**Medium temperature drying chambers (less than 100°C)**

This is the most commonly used drying process in maritime pine. Drying cycles obtained are relatively short (3-3.5 days for a 25-27 mm thickness board).

The chamber is normally manufactured from mixed isolating panels with a steel or aluminium coating, where a series of heating batteries/accumulators and ventilators are placed, these produce a hot air current that crosses the wood. The drying
control is made through moisture and temperature sounders, located inside the chamber. An electronic device performs an automatic regulation of the environmental conditions, according to the selected drying programme for each wood species and product thickness. In this kind of dryers, the air speed used inside the stacks is 1.5 to 3 m/second. The installation of speed variators helps to control the speed at each drying stage.

The most commonly used heating system is heat interchanger accumulators with hot water circulation, thermal oil or any other thermal fluid. Usually, heat is produced at cogeneration plants installed at the sawmill or at biomass boilers, which are supplied by wastes generated at the company.

Currently, a new system is under development, based on the use of a gas burner at the air direct thermal conditioning. This procedure allows the use of natural gas, propane or butane, as fuel.

In these dryers, the air humidity is regulated by moisture systems based on sprayed cold water injectors or low-pressure steam. To reduce air humidity, there are pipes or valves that can be regulated to enable air renovation. These devices can be equipped with extraction motors.

The useful capacity of this kind of dryers can reach 100 m³, although the most functional units have a capacity between 30 and 80 m³. Normally, the useful capacity corresponds to 20 - 25% of total capacity. Considering this, a 50 m³ dryer requires a chamber with a 200 - 250 m³ volume.

Normally, for pine drying the installed heat power recommended is around 400.000 - 500.000 kcal/h for a dryer with 80 m³ of real capacity.

High temperature drying chambers (more than 100°C)

High temperature drying chambers (100°C-120°C) have been developed during the last years, what allows a strong reduction in the coniferous drying time (in the case of maritime pine, the cycle is reduced between 2.5 and 3 times).

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>Wood moisture</th>
<th>Total time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial (%)</td>
<td>Final (%)</td>
</tr>
<tr>
<td>27</td>
<td>54</td>
<td>11</td>
</tr>
<tr>
<td>50</td>
<td>66</td>
<td>18</td>
</tr>
</tbody>
</table>

Reference values for the duration of high temperature drying with overheated steam

The operating system is similar to the medium temperature chambers. The main difference lies on the use of higher air speeds (between 5 and 6 m/s) and lower stacks width (< 2 – 2.5 m), to guarantee an homogeneous drying. This is why dryers have normally a reduced capacity (15 - 50 m³). Besides, to achieve this air temperature, it is necessary to use thermal fluids at a temperature in the order of 160 ºC (thermal oil or overheated water).

To reduce drying warplings, it is convenient to perform a very careful stacking and divide weights evenly at the upper part of the stack. The use of a load of 1,000 kg/m² is recommended.

The two main problems presented by these dryers are the process regulation and the determination of its final stage. The difficulties related to the first point arise from the determination of the air relative moisture at temperatures higher than 100 ºC and hygroscopic balance moistures lower than 5%. Among the existing solutions, the use of a pure water steam atmosphere (“drying in overheated steam”) is preferred. This system allows the process regulation according to the temperature of the dry bulb. Other methods consist of maintaining dry and moistured bulbs at a constant temperature and regulate the operation by time.
Nevertheless, there are several relevant constraints to be taken into account:

- Wood with high contents of resin shows problems due to the resin migration to the surface. This resin can crystallise and produce a dark coloration on the wood that later is difficult to eliminate.

- Dead knots tend to detach, what is aggravated when there is resin.

- When there are relevant differences at the initial moisture content of the load, this leads to relevant dispersions of the final moisture content of the wood. This system is appropriate for all coniferous drying process, including as greenwood.

- This drying process is recommended for thicknesses lower than 50 mm. With larger thicknesses and above all with square sections, normally there are internal cracks at the heads/headers that may extend until 20-25 cms.

The drying programme proposed by CIFOR-INIA for high temperature drying with overheated steam can be seen below:

<table>
<thead>
<tr>
<th>Dry temperature</th>
<th>T (ºC)</th>
<th>Tms (ºC)</th>
<th>HEHs (%)</th>
<th>T (ºC)</th>
<th>Tmi (ºC)</th>
<th>HEHi (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ts (ºC)</td>
<td>127</td>
<td>124</td>
<td>121</td>
<td>118</td>
<td>115</td>
<td>110</td>
</tr>
<tr>
<td>Hr (%)</td>
<td>42</td>
<td>45</td>
<td>49</td>
<td>53</td>
<td>59</td>
<td>65</td>
</tr>
<tr>
<td>HEH (%)</td>
<td>3.1</td>
<td>3.4</td>
<td>3.8</td>
<td>4.2</td>
<td>5.0</td>
<td>5.8</td>
</tr>
</tbody>
</table>

**T**: Dry temperature inside the dryer during the drying and equalisation phases. Tms, Tmi: Wood temperature at the final stage of the drying and equalisation phases (measured by a 3 mm thermocouple, T type, crossly introduced over the edge of the mark pieces until a 50 cm depth). HEHs, HEHi: Wood balance moisture corresponding to the temperature achieved by wood at the end of the drying and equalisation phases.

**Drying tunnels**

This type of large capacity dryers are mainly used at sawmills with large production of boards with thicknesses between 25 and 35 mm. This drying process is based on displacing wood stacks through a long chamber where wood is submitted to several conditions or drying stages.

This kind of premises have great advantages: a large production capacity, low energy costs and the possibility of automatic wood input and output. The major inconvenient is the difficulty in controlling the wood final moisture content. Besides, it is necessary to have an homogeneous wood load, both in species and initial moisture content, as well as in thickness.

The drying duration for maritime pine wood with 27 mm thickness and until moisture contents of 10-12% is about 3 days (at a maximum temperature of 85°C). With a high temperature drying process, it can be reduced to 1 day.
**Heat pump dryers**

This kind of dryer consists of a heat pump (similar to the ones used in refrigerating machines) to dehydrate the air contained in the chamber. The importance of this technology lies on the improvement of the process energy efficiency.

This kind of dryers operate at not very high temperatures (normally lower than 60-65°C). Often these dryers are equipped with heat accumulators and extractors what enables them to work as a standard dryer during the first stages when wood can easily lose moisture.

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**Close circuit heat pump dryer**

In this kind of chambers, the humid air from the stack goes through a dehumidifier that condensates the water steam extracted from the wood, which is then released outwards. The dry air goes through a condensator to be heated and it is necessary, mainly at the first drying process stages, to incorporate an auxiliary heating accumulator (usually an electric device). Normally, the air speed at these dryers is 1.5 to 2.5 m/s.

**Open circuit heat pump dryer**

In this case, dryers are equipped with air extraction and entrance check valves to regulate climate conditions inside the dryer.

**Vacuum drying system**

The vacuum drying method consists of applying pressure conditions that increase water circulation speed over the wood (wider spreading coefficient), decreasing, on the other hand, the ebullition temperature of water. Both facts help to achieve a faster drying process than in atmospheric pressure conditions.

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In general, this kind of chambers are less used by the maritime pine sawing industries, and are more commonly used for the hardwood drying process purposes. Normal drying circles of low thickness Pinus pinaster pieces are approx. 5 days. The chambers’ capacity usually is from 30 to 80 m³.

There are two types:
Water coming from the wood (in steam) is extracted from the dryer through the vacuum pump or collected in a condenser to be expelled outwards.

Among the most common methods, according to the means used to transfer heat to the wood, the following distinction should be made:

- **Discontinuous vacuum**
  Convection heating with vacuum periodically interrupted.

- **Continuous vacuum**
  Conduction heating.
  Metal sheets in direct contact with wood.
  Heating through overheated water steam.

The key advantage of the vacuum drying system is the reduction of the drying duration between 3 to 6 times against the traditional drying process, beside maintaining the same drying quality. Furthermore, it allows large thickness woods to be dried.

These dryers are normally used as auxiliary equipment to reduce drying time in those wood species hard to dry, mainly hardwood, such as European beech and oak.

### Drying cycles duration for maritime pine wood

The following table contains the normal drying cycles for various species subject to acclimatised hot air at a medium temperature (80º C), obtained in tests performed by CTBA in cooperation with other organisations:

<table>
<thead>
<tr>
<th>Wood thickness: 27 mm</th>
<th>Initial moisture (%)</th>
<th>Moisture final (%)</th>
<th>Drying duration (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maritime pine</td>
<td>80 - 90</td>
<td>10 - 12</td>
<td>3 - 3.5</td>
</tr>
<tr>
<td>Scotch pine</td>
<td>80 - 90</td>
<td>10 - 12</td>
<td>3 - 5</td>
</tr>
<tr>
<td>Oak</td>
<td>60 - 70</td>
<td>10 - 12</td>
<td>28 - 30</td>
</tr>
<tr>
<td>European beech</td>
<td>70 - 80</td>
<td>10 - 12</td>
<td>10 - 15</td>
</tr>
<tr>
<td>Poplar</td>
<td>170</td>
<td>10</td>
<td>5 - 11</td>
</tr>
</tbody>
</table>

If a high temperature drying process (120ºC) is used, maritime pine drying (for 27 mm thicknesses) can be reduced from 3 - 3.5 day cycles to a single day drying cycle.
- Drying process programme recommended by CTBA:

- Drying process programme recommended by Hilderbrand for thicknesses lower than 30 mm:

<table>
<thead>
<tr>
<th>Wood moisture</th>
<th>Dry temperature °C</th>
<th>Moistured temperature °C</th>
<th>Relative moisture %</th>
<th>Hygroscopic balance moisture %</th>
<th>Drying process gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>75</td>
<td>72,5</td>
<td>90,5</td>
<td>16</td>
<td>-</td>
</tr>
<tr>
<td>60 – 45</td>
<td>75</td>
<td>70</td>
<td>80</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>45 – 30</td>
<td>75</td>
<td>66,5</td>
<td>67</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>30 – 20</td>
<td>80</td>
<td>65</td>
<td>49</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>20 – 11</td>
<td>80</td>
<td>56</td>
<td>31,5</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

- Drying process programme recommended by Hilderbrand for thicknesses between 30 and 60 mm:

<table>
<thead>
<tr>
<th>Wood moisture</th>
<th>Dry temperature °C</th>
<th>Moistured temperature °C</th>
<th>Relative moisture %</th>
<th>Hygroscopic balance moisture %</th>
<th>Drying process gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 60</td>
<td>70</td>
<td>67,5</td>
<td>89,5</td>
<td>16</td>
<td>-</td>
</tr>
<tr>
<td>60 – 45</td>
<td>70</td>
<td>65</td>
<td>78,5</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>45 – 30</td>
<td>70</td>
<td>63</td>
<td>70</td>
<td>10</td>
<td>4,5</td>
</tr>
<tr>
<td>30 – 20</td>
<td>80</td>
<td>65</td>
<td>49</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>20 – 11</td>
<td>80</td>
<td>56</td>
<td>31,5</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

- Drying process programme recommended by Hilderbrand for thicknesses over 60 mm:

<table>
<thead>
<tr>
<th>Wood moisture</th>
<th>Dry temperature °C</th>
<th>Moistured temperature °C</th>
<th>Relative moisture %</th>
<th>Hygroscopic balance moisture %</th>
<th>Drying process gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 60</td>
<td>65</td>
<td>62,5</td>
<td>88,5</td>
<td>16</td>
<td>-</td>
</tr>
<tr>
<td>60 – 45</td>
<td>65</td>
<td>60,5</td>
<td>80,5</td>
<td>13</td>
<td>4,6</td>
</tr>
<tr>
<td>45 – 30</td>
<td>65</td>
<td>56</td>
<td>63</td>
<td>9</td>
<td>5</td>
</tr>
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<td>65</td>
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<td>20 – 11</td>
<td>80</td>
<td>56</td>
<td>31,5</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
**General considerations over maritime pine drying process**

- Maritime pine is a species relatively easy to dry; its drying cycles with standard drying systems are quite short even in the case of large thicknesses.
- The duration of its drying cycles grows steadily with the thickness increase of products.
- Increasing the drying process temperature helps to reduce the drying cycles, but in practical terms, the use of temperatures higher than 100 °C requires the availability of highly efficient and specific techniques.
- To remove the resin from the wood to avoid later problems in the wood application, a 80 °C temperature is enough.

**Energy consumption related to the maritime pine drying process**

In the artificial wood drying process, two different kinds of energy consumption should be considered:

**Calorific energy of the drying process**

Electric energy for the ventilation and air extraction operations.

Although in every case the ventilation and air interchangeable system is powered by electric energy, in the caloric energy case there are distinct possibilities.

In heat pump dryers, heating is achieved by air passing through the condenserator, and as such its operation is fully electrical. In acclimatised hot air dryers, the caloric energy used comes from the combustion of the plant wastes or other fuels, such as gas.

As a reference, the following table comprises the caloric energy consumptions (expressed in Kwh by kg of water extracted) obtained in several different studies carried out by CTBA in cooperation with other organisations.

<table>
<thead>
<tr>
<th>Wood species</th>
<th>Wood thickness (mm)</th>
<th>Moisture content</th>
<th>Energy needs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial (%)</td>
<td>Final (%)</td>
<td>Medium temperature 80° C</td>
</tr>
<tr>
<td><strong>Pinus pinaster</strong></td>
<td>27</td>
<td>80-90</td>
<td>10-12</td>
</tr>
<tr>
<td>Scots pine</td>
<td>27</td>
<td>90</td>
<td>15</td>
</tr>
<tr>
<td>Oak</td>
<td>27</td>
<td>64</td>
<td>12</td>
</tr>
<tr>
<td>Black poplar</td>
<td>27</td>
<td>170</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<td>Black poplar</td>
<td>27</td>
<td>170</td>
<td>10</td>
</tr>
</tbody>
</table>

**Electric energy consumption**

The ventilation power to be installed depends on the stacks geometry (mainly width) and on the air circulation speed. Normally, for standard dryers with a 30 to 80 m³ capacity, the required power is about 0.3 Kw/m³ of useful capacity. This value is slightly higher in high temperature drying processes.

Electric consumption of the ventilation system for maritime pine drying process with acclimatised hot air at a medium temperature:

- 20 Kwh/m³ or 0,06 Kwh/kg of extracted water (27 mm thickness and 80% to 10% moistures).
- 40 Kwh/m³ or 0,13 Kwh/kg of extracted water (54 mm thickness and 80% to 15% moistures).

The aforesaid data establishes the large quantity of energy needed for wood drying purposes (around 450 Kwh/m³, what is approximately equivalent to 10 times the energy used in sawing). For this reason, the knowledge and management of energy consumption associated with the drying process is a determinant factor in controlling the production costs of the process.
GLUEING
Although wood glueing procedures have been performed for centuries, some operation defects and/or insufficient characteristics of the existing glues contributed to build the idea that glue joining did not guarantee mechanical resistance, let alone long-term durability. Doubts on the reliability of this procedure led to the use of resourceful mechanical fittings, on the one hand to increase the gluing area, and on the other to guarantee the overall stability in case of adhesive failure. This solution is expensive and often results in over-dimensioned fittings.

Lately, there have been big developments within the scope of glue properties. Today, there are standardised procedures that help to achieve an accurate evaluation of the potential fields for glue usage (structural and non-structural, indoor and outdoor, and so on), and of the qualitative characteristics of a glued joining.

From the glued joining potentiality perspective, we can refer the following as the most relevant ones:

- Achievement of shapes and dimensions hard to obtain from one single piece of solid wood without defects.
- Behaviour improvement in dimensional stability and warping.
- Better use of small-sized pieces.
- Local elimination of defects.
- Local quick and easy preparation of components.
- Increase of mechanical resistance and tension regular distribution.
- Possibility of performing mechanisation operations with rebuilt elements.

Limitations and poor performances attributed to glueing procedures are due to deficient executions and/or unfamiliarity with the actual limits of this technique. As such, it is necessary to take into account the process conditions, as well as the adhesive and the wood species characteristics. General information on the glueing technology, including a series of specifications applicable to glueing procedures on maritime pine wood will follow.
Adherence general characteristics

Adherence mechanisms

The adherence mechanism has been explained under different forms for different materials. In the case of wood, there are some theories that explain adherence as a combination of purely mechanical phenomena, which are accompanied by chemical-related bondings.

Chemical bonding

Every substance/material is constituted by atoms that bond together, forming molecules and other stable aggregates. The bonding forces between atoms, named interatomic bonding forces, have an electronic nature and possess high bonding energies that range between 10 and more than 100 kcal/mol. These forces determine the molecule structure and have less to do with the adherence phenomena that lead to the glueing process.

In turn, bonding between molecules, named as intermolecular bonding forces, are fundamentally of electrostatic nature and possess much lower bonding energies than the first ones (from 2 to 4 kcal/mol), therefore, they are not sufficiently strong for molecules to associate with each other and form new chemical substances.

As such, they are responsible for the resistance to sliding between molecules, what explains the solid and liquid behaviour of the various materials. These intermolecular forces (Van der Walls forces and hydrogen links) only become active when molecules are sufficiently close to each other (distances lower than $3 \times 10^{-8}$ cm) what is closely related to adhesion/adherence that conditions glueing phenomena. The adherence of glues to wood through intermolecular attraction forces is the most contributing mechanism to total resistance, according to experts on this process.

Mechanical bonding

The mechanical bonding tries to explain the wood glueing phenomenon through the action carried out to adapt the glue to surface irregularities and to penetrate in the porous structure of the wood. As such, after the polymerisation or the glue drying process, the glue is firmly fixed onto the wood by mechanical joining.

Resistance to joining

The glueing process consists of the overlapping of two surfaces, flat or curve, that are fit to each other by a very thin adhesive layer. Glueing is fundamentally subject to two types of efforts:

- The relative movement induced between two surfaces (“cut”), as a consequence of the application of tension/strain, what can be produced in any direction (including the rotation over an axis).
- Traction tensions perpendicular to the surface (“tearing”), inducing some forces on wood that tend to separate the bonding.

In the Pinus pinaster case, like in other species with good acceptance to glueing procedures, the resistance to superficial cutting tensions at the joining area is higher than the resistance of the wood itself. Also the perpendicular traction resistance limits are superior to the cross cohesion of the wood itself. Exceptions to this behaviour can only be explained as a consequence of an inadequate adhesive selection or by failures in the glueing operation. The presence of resin high content areas or other contaminant substances either fat or impervious may harm the joining quality, affecting mostly the resistance to perpendicular traction.

Tensions in the joining surfaces can arise from service calculation tensions due to external loads. Other “hidden” requests arise at conexion areas as a result of movements between the two joining components. These mechanical tensions come up
as a consequence of variations in environmental conditions (air temperature and relative moisture). Since retraction and swelling are different in axial, tangential and radial directions, it must be expected that wood inadequately bond causes relevant tensions at the connexion areas. This kind of tensions are one of the main causes for ageing by fatigue of the glueing connexion, and ultimately, can even be the reason for the joining collapse.

**Substrate characterisation**

In wood, due to its singular characteristics (such as: anisotropy in its physical and mechanical properties and structure), the pieces surfaces are quite irregular. This irregularity can be aggravated by failures in the machines or by a deficient design or maintenance of the cutting tools. Through an adequate detailed observation (microscopic ampliation or with a 40x binocular magnifier), it can be checked that wood surfaces are very rough, with fibres pulled out, wholes and cracks. Other kind of imperfections can be seen at a higher scale, since there are local flatness differences all over the piece width.

Although from the glueing process viewpoint, mechanical adherence/adhesion can benefit from primary roughness, chemical adherence/adhesion is quite negatively affected by defects in shape and secondary roughness. For most adhesives, thickness discontinuity of the layer is a disturbing factor for the connexion good performance. The exception are the epoxide glues, as they do not suffer retraction during the glueing phase, the joining efficiency is not negatively affected.

**Process characterisation**

In the glueing process, there are specific time ranges defined for each operation phase. As such, "open time" corresponds to the interval between the adhesive application and the surfaces positioning, "close time" corresponds to the interval between the pieces positioning and the beginning of the pressing process, and finally "pressing time" corresponds to the period of time the pieces should be under pressure.

Manufacturers are particularly careful in indicating these time periods, which are strongly dependent on the operation conditions and the wood species. Pinus pinaster shows a high water permeability at the sapwood, if the maximum open and close times are not fully accomplished, at the pressing time the glue might already be too "dry" to allow an effective bond.

The control of the adhesive viscosity is fundamental to guarantee an adequate product dosing. It must be taken into account that too high or too low viscosities can hinder the layer extensibility and the penetration in the substrate, respectively.

Temperature is relevant, even when the adhesive is still in a liquid state, stored, waiting for the application moment. A characteristic of vinyl adhesives is that under certain temperatures their components decompose irreversibly. This critical temperature is called white point. Depending on formulations, white point temperatures can range between 12ºC (for poor quality glues) and 3ºC. In climates with winter temperatures occasionally below these values and considering that most workshops are not heated, a special attention should be given to this characteristic.

A too high temperature can also be harmful for the glue conservation, since it helps losing the solvent and the polymerisation process starts too early. The most convenient storage temperatures lie between 15 and 25 ºC.
Temperature control during the glueing process operation is also relevant to balance the moisture content and above all to be adapted to the own requirements of certain adhesives that need heat to start or carry on the cross-linking or healing phenomena.

Another important aspect to consider has to do with the thermoplastic glues group. In this case, mechanical resistance properties are lost when temperature rises above certain values, indicated by manufacturers in each specific formulation. In general, this temperature lies above 60ºC.

The most convenient pressure values vary according to the adhesive type and the surfaces characteristics. In any case, warping should be avoided, an uneven force distribution should be avoided, since it may originate a discontinuity at the glueing joint. This fact can also be caused by a deficient quality in the surfaces finishes.

Stabilisation or glue healing time is the range between the final pressing operation and the beginning of the service mechanical request. It represents the minimum time before which the connexion/junction should not be placed at maximum load. Although the pressing minimum time is established to allow removing the pieces from the pressing equipments, the resistance increase is still slow and continuous during almost the 8 following days.

In practice, for the most current glues, the connexion/junction starts its normal service earlier, considering that, for safety reasons, junctions/conexions are projected for service tensions much lower than rupture tensions.

Extremity glueing process

The wood high resistance to traction efforts paralleled-driven to fibres accentuates the difference between the resistance of solid wood and of the extremity joining. The simple extremity glueing (flat surface perpendicular to the fibres direction) does not allow resistences higher than 10% of solid wood. Therefore, it is necessary to use auxiliary solutions based on the increase of the contacting surfaces (triangular multiple grooves, bevel joint, etc), to help a better transmission of axes efforts.
**Edge glueing process**

Edge glueing joinings are those performed through lengthwise surfaces. They can be divided into two variants, depending on the fibres position: perpendicular fibres (right angle joinings) or parallel fibres (for instance to form large pieces). From the joinings mechanical behaviour viewpoint, rupture tensions to cross traction are very similar in both cases. Total cohesion is more dependent on the limits of the wood itself than on the glueing process efficiency. With regard to the resistance to cutting efforts, it should be taken into account that the perpendicular-driven joining may give rise to differentiated retractions that may bring additional tensions.

**Adhesive types**

In general, all adhesives used in woods show good results in Pinus pinaster wood joinings, provided that the appropriate procedures are followed, generally with higher values than the cohesion of the wood itself (excepting at axes joinings).

Adhesive selection is closely related to the manufacturing conditions, price and use demands and with environmental characteristics. It should also be taken into account that some adhesives may cause (especially during some process phases) undesirable air emissions or even forbidden (above the limits) ones.

Wood adhesives can be classified according to several criteria, the most common and of practical interest is the one related to the usage conditions, in other words, indoor and outdoors adhesives. Within the scope of this classification, the European standard EN 204:2001 - Classification of thermoplastic wood adhesives for non-structural applications” establishes 4 categories (D1, D2, D3, D4), according to the criteria presented in the following table:
With regard to the wood adhesives classification for structural applications in different usage conditions, the following categories are defined: Type I and Type II, according to the European Standard EN 301:1992, whose applications are summarised in the following table:

<table>
<thead>
<tr>
<th>Durability classes</th>
<th>Examples of climate conditions and application fields</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Indoor and moisture balance conditions not above 15 %, indoors.</td>
</tr>
<tr>
<td>D2</td>
<td>Indoor, occasionally or for short periods of time, the wood is subject to water contact or high moisture levels and moisture balance conditions are not over 18 %.</td>
</tr>
<tr>
<td>D3</td>
<td>Indoor with frequent contacts with liquid water or prolonged exposure to high moisture levels. Covered outdoor premises.</td>
</tr>
<tr>
<td>D4</td>
<td>Indoor with prolonged exposure to condensated or running water. Non-covered outdoor premises with an adequate surface protection covering.</td>
</tr>
</tbody>
</table>

Quite often they are classified according to their source, in this case, adhesives are divided into two large groups: natural adhesives and synthetic/plastic adhesives. Natural adhesives are divided into two subgroups: animal adhesives and vegetable adhesives. In turn, plastic/synthetic adhesives are divided into three subgroups: thermosetting, thermoplastic and elastomer.

The following table shows the classification of adhesives that may be used in *Pinus pinaster* gluing process. Next to the abbreviated international terminology for the various standard formulations, an indication of the usage fields according to the final product and exposure conditions is also included.

<table>
<thead>
<tr>
<th>Designation</th>
<th>Thermosetting</th>
<th>Elastomer</th>
<th>Thermoplastic</th>
</tr>
</thead>
<tbody>
<tr>
<td>UF</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>MUF</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>PF</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>RF</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>TPF</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>MDF boards</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Boats</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mouldings</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Interior doors</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Furniture</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Veneer</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Particle boards</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Plywood</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

**Polyvinyl acetate**

This is an adhesive polymerised in small particles, which are kept in dispersion of a solid in a liquid environment, water acts as a solvent. The adhesive hardening is a pure physical process caused by evaporation or water absorption by the wood. The glueing joining is colourless or slightly white.

The advantages of these adhesives are their low price, easy use (already supplied ready to use), they are not abrasive to cutting tools, they are easy to be applied and clean, they do not need a strong pressing during the gluing process and dry well in cold conditions. The adhesive layer is elastic and the mechanical resistance is very high in dry environments. The less positive aspects are: they suffer a certain creep under the action of high tensions for an extended period of time, there are...
Urea formaldehyde

Urea is an amino compound obtained from carbon dioxide and ammonium. These compounds react with formaldehyde, and afterwards the solvent is extracted to obtain a kind of white powder (the commercial presentation of this product). This is a relatively low priced resin. The adhesive layer is very resistant in dry environments, but degrades and loses its characteristics in prolonged water immersions and worsens in alternate cycles of water immersion and drying processes.

The disadvantages of urea resins can be reduced through the addition of melamine, but this procedure rises the price.

Melamine formaldehyde

Melamine adhesives are also offered as a crystalline white powder or as a liquid obtained by condensation. The glueing joining is colourless, with a very high mechanical resistance, elastic and water resistant. They are glues with a chemical composition similar to the urea formaldehyde adhesives, the difference is that one part of the urea is replaced by melamine, with the purpose of increasing water resistance.

This adhesive is particularly indicated to perform high frequency glueing processes. Its main application field is structural laminated wood. It has been replacing resorcin for aesthetical reasons (colourless glue layer). It enables the inclusion in class D4 established under EN 204 standard.

Resorcin

Resorcin adhesives are obtained through the resorcinol reaction with formaldehyde. This process is performed with a formaldehyde deficit and the process is concluded when this reactive disappears. Resin is stored as a liquid and has a long lifetime if left in a closed reservation container (years). To be used the adhesive preparation is made by adding a hardener that contains formaldehyde and burdens/loads. After preparation, the product has only a few hours maximum lifetime.

The cure is performed at the environment temperature (10 - 20°C) or by a hot procedure. It is necessary to apply high pressure. The wood joining is extremely strong and durable, cold and hot water resistant, even in saline environments. It has the advantage of not delaminating even in fire exposure cases. From an aesthetical perspective, it may have the inconvenient of showing a dark joining layer. This adhesive complies fully with demands from class D4 of the EN 204 standard, tested under moisture conditions.

Epoxides

These resins are supplied in two components, one is epoxide and the other is bifunctional amine. None of the components contains solvents. In the mixture, both react to form a very hard and resistant compound/composite that does not decrease in volume during the cure phase. This property is quite useful to fill in thick joints or for repair works. Pine wood joinings with epoxide resins are extremely resistant and durable, and can be placed among the resorcin and the melamine adhesives. Due to their characteristics, these products are most adequate for vessels construction, for degraded components repairs and for wood joinings with other materials (metallic and so on).
Thermofusibles

These adhesives are substances that melt, in a reversible way, at temperatures ranging between 130ºC and 160ºC, without producing any other chemical alteration or interference with the material to be glued, besides a superficial mechanical adherence. They may show a quick high resistance during the first hours after the application, but there are no guarantees of a good long-term joining if they are subject to permanent mechanical tensions. They are adhesives especially adequate for edges gluing processes, frames or coatings. Versatility and fitness to high-speed production processes are among its advantages.

Defects and anomalies

It is known that in Pinus pinaster wood there are cultural, genetic and climate conditions that promote the development of certain characteristics. Generally speaking, trees with upstraight branches and faster growths will produce less thick and also less nervous wood. For example in Portugal, experience shows that coastal Northern wood, due to the combination of several favourable soil and climate conditions, presents characteristics close to those required for carpentry applications and above all for furniture.

Considering the aforesaid, the glueing appropriateness can be affected by defects, such as knots, pronounced deviations in fibre direction, resin pockets/bags and biological stresses. Internal cracks are relevant defects produced as a consequence of an inappropriate drying process. These cracks appear after the drying process and are almost invisible. Ruptures in areas next to glueing plans, that occur in situations under the predictable ones, can be a consequence of this phenomenon.

Treated wood or presence of oils and resins

Wood surfaces should be clean from dust, sawdust and fat, such as natural resins from the wood. To remove oils and resins, adequate solvents should be used or a superficial planning should be performed. It is also recommended to increase the joining pressure (abiding by the wood resistance limits), and to use highly alkaline adhesives, as is the case of the phenolic ones, which are easier to spread on the substrate.

It must also be considered that products for wood protection treatments, depending on their formulation, can affect the glueing final outcome. Generally speaking, oil products affect negatively the glueing process. On the contrary, metallic salts do not show a remarkable incidence whenever wood is dry at the recommended levels for the natural wood glueing process. Evidence of this can be found in the records of manufacturing
tests carried out to Pinus pinaster glued laminates from wood treated with hydrosoluble salts CCA type, whose results were excellent, including at the exposure under moisture environments after the glueing process.

Moisture content

Wood moisture affects significantly the glued joinings behaviour, due to its close connection to dimensional changes that can affect the material, and also due to the influence both over the cure speed and the joinings final resistance.

The relevance of knowing the moisture content value has to do with the connection of this property to the adhesive viscosity evolution, the assembling time, the adhesive cure time, the creation of tensions at the glued plan and to the possible rise of non-glued areas due to water steam formation.

To control wood movements by swelling or shrinkage, it is most convenient to fit the wood moisture content to the hygroscopic balance conditions that correspond to the location and final use of the product.

Density

In general terms, wood density is influential in two ways. On the one hand, density growth brings mechanical resistance growth, what favours the joining resistance by reducing the possibility of wood rupture. On the other, high density woods (approx. higher than 700 kg/m³) can originate problems, due to the poor mechanical anchoring produced as a consequence of the small quantity of existing cavities/hollows. In the Pinus pinaster case, considering the density range that corresponds to the wood of this species, density is a factor positively correlating to the joining resistance.

Growth rate and texture

Growth rate is defined according to the annual growth rings. There are two ways of quantifying the growth rate. One of them consists of counting the number of annual rings located at a radial distance of 1 cm. According to this criterion, for Pinus pinaster (in Portugal), it is considered that 5 or more annual growth rings per centimetre is a reduced growth rate, whereas less than 2 rings per centimetre corresponds to a high growth rate. There is a good reverse correlation between the growth rate and the wood density.

Texture expressed as the percentage of summer wood is also a useful information to characterise the higher or lower appropriateness to glueing procedures. A lower texture percentual value corresponds to less thick woods, as such this is also a determinant factor in the mechanical and technological characteristics, including the glueing appropriateness, as previously stated.

Quality control

Glueing tests are divided into two large groups: compatibility checking of the adhesive with the wood and manufacturing control of the glued joinings. This last point is especially relevant in the case of structural elements. In this case, tests consist mainly of performing cutting efforts and/or delamination tests. Glue characterisation tests and wood appropriateness analysis to the glueing process are carried out by measuring the joining resistance (to traction) in small test tubes previously submitted to a short or prolonged water immersion or to a boiling water immersion.
Pinus pinaster increases all adhesives applications of class D4 (according to EN 204), since it meets the minimum resistance limits required by the standardised cold and hot water treatments.

In recent tests on the Pinus pinaster gluing process with epoxide glues the best expectations were fulfilled. The conexions/joinings resisted perfectly to the tests after treatments with boiling water. This kind of adhesive shows interesting potentialities in performing joinings between wood (in angle), structural fittings and also conexions between metal and wood.
PRESERVATIVE TREATMENTS
The wood behaviour before eroding agents depends on the chemical composition of the material and, mainly, on its extracts content (terpene, polyphenol, fat acids, etc.). Most part of these components are at the heartwood, producing a characteristic dark colour and, generally, conferring a larger durability. This explains the remarkable differences that can be frequently seen between the conservation state of the sapwood and the heartwood at construction elements, such as structural beams.

The nature of these components varies from one species to the others. In pines, there are substances, such as pinene and limonene at the sapwood and pinosilvine at the heartwood. Other coniferous species, such as cypresses present substances, such as tropolene that increase durability. Substances like tannins, due to its protein precipitation capacity, are also durability factors for woods. In this case, however, the high solubility in water and relatively low toxicity decrease its protective relevance. It should also be considered the influence of certain organic components, such as sugars (glucose, fructose, etc.) and carbon hydrates (starch, etc) present in living cells of the timber rays and other parenchyma cells that promote the development of some biodegraders, such as sapwood xylophagous insects.

On the other hand, it should be taken into account that there are anatomical indiosyncrasies/features that can influence the structure of the main internal vessels/ducts of the wood. For instance, the formation of thyllos (common in some hardwood, such as Castanea sativa or Quercus spp.) can produce obstructions in the vessels lumen and hinder liquid penetration. In the coniferous case and mainly in Pinus pinaster, the configuration of the resin ducts have a strong influence on the natural durability, as well as on the predisposition to receive protection treatments by impregnation.

However and despite these variability factors, the available knowledge on the natural durability characteristics, impregnation suitability and treatment products characteristics helps to carefully chose the wood (either treated or not), securing an adequate procedure that guarantees the required useful life. For that, there are standards establishing criteria to be applied to each case.
Deterioration forms

Abiotic deterioration
- Thermal deterioration
- Chemical deterioration (hydrolysis and oxidation).
- Superficial erosion produced by swelling and shrinkage phenomena produced, photodeterioration (ultraviolet rays) and/or other causes (oxidation, aeolian erosion, etc).

Biotic deterioration
- Perforation and superficial abrasion by marine xylophagous animals.
- Perforations and galleries by xylophagous insects in their larval cycle or termites.
- Chromogen and putrid fungi.

The consequences from wood deterioration phenomena are from different natures. The most striking ones are: weight loss, mechanical properties reduction and changes in permeability and hygroscopicity characteristics.

Treatment conception and prescription procedure

Characteristics of the Pinus pinaster wood

Pinus pinaster is a species with good capacity to receive in-depth impregnation treatments applied to the sapwood (heartwood cannot be impregnated). This wood attracts termite and larval insects, for this reason it is characterised as having low or medium duration capacity against putrid fungi.

Hardwood examples of natural durability and impregnability

<table>
<thead>
<tr>
<th>Species</th>
<th>Natural durability</th>
<th>Impregnability</th>
<th>Sapwood thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fungus</td>
<td>Hesperophanes</td>
<td>Anobium</td>
</tr>
<tr>
<td>Castanea sativa (Chesnut)</td>
<td>2</td>
<td>S (Hesp)</td>
<td>S</td>
</tr>
<tr>
<td>Entandophragma cylindricus (Sapelli)</td>
<td>3</td>
<td>-</td>
<td>n/d</td>
</tr>
<tr>
<td>Fagus silvatica (Beech)</td>
<td>5</td>
<td>S (Hesp)</td>
<td>S</td>
</tr>
<tr>
<td>Juglans regia (Walnut)</td>
<td>3</td>
<td>S (Hesp)</td>
<td>S</td>
</tr>
<tr>
<td>Clorophora excelsa (Iroko)</td>
<td>1-2</td>
<td>S (Hesp)</td>
<td>n/d</td>
</tr>
<tr>
<td>Quercus rubra (American Oak)</td>
<td>4</td>
<td>S (Hesp)</td>
<td>n/d</td>
</tr>
</tbody>
</table>

Durability against rot fungus: 1-Very durable, 2-Durable, 3-Moderately durable, 4-Little durable, 5-Not durable.
Durability against xilophage insects (larval cycle): D-Durable, SH-Heartwood also sensitive, S-Sensitive.
Durability against termites and marine xilophages: D-Durable, M-Moderately durable, S-Sensitive.
Impregnability: 1-Impregnable, 2-Moderately impregnable, 3-Little impregnable, 4-Not impregnable.

Softwood examples of natural durability and impregnability

<table>
<thead>
<tr>
<th>Species</th>
<th>Natural durability</th>
<th>Impregnability</th>
<th>Sapwood thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fungus</td>
<td>Hylotrupes</td>
<td>Anobium</td>
</tr>
<tr>
<td>Abies alba (Fir)</td>
<td>4</td>
<td>SH</td>
<td>SH</td>
</tr>
<tr>
<td>Picea Abies (Spruce)</td>
<td>4</td>
<td>SH</td>
<td>SH</td>
</tr>
<tr>
<td>Pinus pinaster</td>
<td>3-4</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Pinus sylvestris (Scots pine)</td>
<td>3-4</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Pinus radiata</td>
<td>4-5</td>
<td>S</td>
<td>SH</td>
</tr>
<tr>
<td>Pseudotsuga douglasii (Douglas fir)</td>
<td>3-4</td>
<td>S</td>
<td>S</td>
</tr>
</tbody>
</table>

Important remark: Durability against rot fungi is only related to heartwood, since sapwood of all species is considered sensitive. On the contrary, against insects attacks only the sapwood is considered, since the heartwood of all species is found resistant.
Risks classes

Risk classes evaluate the risk of attack according to the conditions of the storage place.

**Risk class 1**
Wood is under a deck, fully protected from bad weather conditions and it is not exposed to moisture. Moisture contents are always lower than 18%.

**Risk class 2**
Wood is under a deck, protected from bad weather conditions, but occasionally with a high environmental moisture that may lead to a superficial, non-persistent moistening. The average moisture of wood is lower than 18%.

**Risk class 3**
Wood is uncovered, but not in direct contact with the ground. The exposure to bad weather conditions produces a frequent humidification with wood achieving a moisture content higher than 20%, with fast alternations between moistening and dryness periods.

**Risk class 4**
Wood lies in direct contact with the ground or with fresh water; it is exposed to a permanent humidification, with moisture values above 20% (in the whole or in part of the volume) for long periods of time.

**Risk class 5**
Wood is permanently in contact with salt water.

Apart from the aforesaid, it is IMPORTANT to consider the following questions/issues:

- There is no systematic relationship between a risk class and a work application: it will all depend on the configuration and exposure conditions in each case. The analysis and the identification of the “sensitive area” should be enough to determine the specific risk class.
- Biological risks are associated with the actual working (operation) of the components. Risk of xylophagous insects attack may be present in all classes. On the contrary, risk of putrid fungi attack increases systematically and most significantly with the risk class.

General characteristics of preservative products

Chemical products for wood preservation should have the following characteristics:

- Preventive or lethal action against wood deteriorating agents.
- High penetrability through wood tissues.
- Long-term fixing capacity.
- Non-corrosive.
- Do not affect physical or mechanical properties required from wood.
- Safe handling.

Basic components are those chemical products that act directly against xylophagous animals (insecticides or fungicides), auxiliary materials that strengthen the protective action, improving the product characteristics and solvents that act as a vehicle to penetrate into the wood (evaporating after the application).

The protection offered depends on the product quality, the penetration grade and the quantity introduced in the wood. This retention is regulated by EN 351 standard that establishes a critical value for each risk class. Besides, with regard to the penetrating depth of the preservative product, there are several protection grades, depending on the penetration achieved.
EN 351-1 Standard establishes the following classification:

<table>
<thead>
<tr>
<th>Penetration class</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>None.</td>
</tr>
<tr>
<td>P2</td>
<td>At least 3 mm in sapwood lateral faces and 40 mm in axial.</td>
</tr>
<tr>
<td>P3</td>
<td>At least 4 mm in sapwood lateral faces.</td>
</tr>
<tr>
<td>P4</td>
<td>At least 6 mm in sapwood lateral faces.</td>
</tr>
<tr>
<td>P5</td>
<td>At least 6 mm in sapwood lateral faces and 50 mm in axial.</td>
</tr>
<tr>
<td>P6</td>
<td>At least 12 mm in sapwood lateral faces.</td>
</tr>
<tr>
<td>P7</td>
<td>At least 20 mm in sapwood lateral faces.</td>
</tr>
<tr>
<td>P8</td>
<td>Sapwood full penetration.</td>
</tr>
<tr>
<td>P9</td>
<td>Sapwood full penetration and 6 mm in heartwood.</td>
</tr>
</tbody>
</table>

The regulation on biocides commercialisation, which includes wood preservative products, is established on the European Directive 98/8/CE. This Directive is concerned with the commercialisation and authorisation of the use of biocides within the Member-States, the mutual recognition of authorisations within the European Union and the preparation of a EU broad list with the active substances that can be used in biocides.

**Products types**

<table>
<thead>
<tr>
<th>Definition</th>
<th>Hydrosoluble products</th>
<th>Natural organic products</th>
<th>Products in organic solvents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types</td>
<td>(1)</td>
<td>(1)</td>
<td>(1)</td>
</tr>
<tr>
<td>Application methods</td>
<td>(2)</td>
<td>(2)</td>
<td>(2)</td>
</tr>
<tr>
<td>Usages</td>
<td>(3)</td>
<td>(3)</td>
<td>(3)</td>
</tr>
</tbody>
</table>

**Hydrosoluble preservatives**

1. Mineral salts mixtures with biocide characteristics in aqueous solution.
2. Copper salts (fungicide), boron salts, fluorine, arsenic (insecticide) and chromium (fixation).
3. Prolonged immersion or autoclave (Bethell system).
4. Construction wood (laminate wood, fillets, etc.) or in direct contact with soil or water (fences, pickets/posts, etc.).

**Natural organic preservatives**

1. Obtained from coal tar distillation or oil pyrolysis.
2. Creosotes.
3. In autoclave.
4. Professional and industrial usages (e.g. railways) adapted to limitations established on Directive 2001/90/CE.

**Preservatives in organic solvents**

1. Preservative products in which the active principles are dissolved in an organic solvent.
2. Curative or preventive. In the preventive case, a distinction should be made between in-depth or primer treatments (generally, they do not change the wood natural aspect) and decorative treatments (incorporating pigments to protect against photodeterioration).
3. Through double vacuum processes (application in autoclave) or through superficial treatments of short immersion, painting or pulverisation/spraying.
4. Applications in construction, carpentry and furniture.
Treatment processes in autoclave

Treatment processes in autoclave are fundamentally based on Bethel, Ruping and Lowry processes. The differences lie on the pressure conditions and treatment time used each phase. The final result is mainly affected by the retention of the preservative product.

The Bethel method (or filled cell) is employed when the utmost retention of the preservative product is required, filling in all cellular hollows and impregnating the cellular wall. As such, this system is indicated for treatments with hydrosoluble preservatives for risk classes 4 and 5, as well as for treatments with organic solvent preservatives of hardly impregnable woods. Here wood is required to be fully debarked and to hold a moisture content lower than 28%.

The Lowry method (or empty cell, intermediate). In this case, the introduction of the preservative product is performed by atmospheric pressure. The purpose is to obtain a high penetration level of the product with a relatively low retention. It is employed in treatments of posts/pickets and fences with creosote.

The Ruping process (or empty cells) is used when there is a retention excess in the sapwood of easily impregnable woods. In this case, the product introduction is carried out in conditions of "positive" pressure. This process requires the use of special accessory equipments (pressure chamber and dosing pump).
Anti-blue stain treatments

Blue stain is a frequent chromatic alteration in the sapwood of coniferous wood. It is produced as a consequence of the mycelium of certain chromogen fungi that eat the reserve substances accumulated in the sapwood. Contrary to the so-called putrid fungi, in this case the main components of the wood structure (lignin and cellulose) are not affected by this attack.

However, the occurrence of blue stains may cause significant economic losses, due to the wood depreciation, mainly for decorative applications.

Blue stain prevention means

When the tree is alive, there are protection elements available that avoid the wood attack from the blue fungus. When the tree is weakened or dead, or there are open wounds, an infection may occur, as well as the blue stain development in the standing tree.

After the tree felling, the timber can be contaminated by spore, and the attack can occur if the weather conditions allow its development. Therefore and mainly in the high risk period, it is recommended to avoid that more than 1-2 weeks go by after the felling until the sawing.

Likewise, the more effective prevention system to avoid the blue stain consists of drying wood in a chamber to quickly reduce the moisture content to a value lower than 18-20%. Like this it is possible to drastically reduce the risk, by decreasing the exposure period to favourable conditions of fungi development.
Treatment systems

Although there is the possibility of treating roundwood with bark with an anti-blue stain product, there are a series of technical and organisational difficulties that normally hinder the use of this practice. As such, for the conservation of standing wood, the most recommendable system is to optimise the logistic organisation, so that the shortest period of time occurs between the tree felling and the sawing.

After the sawing process, wood is more susceptible to blue stain fungi attacks, due to its moisture content and to the large surface in contact with the air. Considering the normal moisture and temperature conditions in Galicia, this risk can last for several months if the drying process is carried out in the open air.

To protect sawn timber during the period of time until reaching a moisture content below 18-20%, it is necessary to apply a specific superficial chemical treatment. Normally, the chemical products used are solutions or emulsions for immersion treatments, and the wood is submerged in the preservative product during a couple of minutes.

It is important to highlight that with this kind of treatments, there is only a superficial protection. Therefore, if the wood is infected inside, despite this treatment, the development of blue stains at the central area of the pieces may occur.

The most commonly used treatment systems are:

- **Board by board immersion devices.** This system consists of a small-sized container with the product solution, through a mechanical system the boards, one by one, pass through this solution. The wood immersion time is controlled by the feeding system speed.

- **Bundles immersion devices.** This system consists of a large-sized deposit where the immersion of one or several wood bundles is performed. The advantages of this process are the avoidance of manual handling of the recently treated wood and the bundles joint processment.

Practical recommendations

The most part of biocides used in blue stain preservative treatments are dissolved in water at different concentrations, according to the product and the required wood protection level. Therefore, the first recommendation to get an effective treatment is to carry out the right product dosing in the treatment container. The most practical system is to use dosing pumps. In other cases, equipments, such as flowmetres and measured containers, should be used, to perform a correct product dosing.

Normally, these preservatives are manufactured as emulsifiable concentrates or soluble concentrates. While in the bath, they show the following characteristics:
- **Disolution.** In this case an homogeneous mixture is achieved. Any part of the mixture (even the smallest drop) keeps the same concentration. Besides, there is no sedimentation of the product.

- **Emulsion.** This is a stable and homogeneous mixture of two liquids that normally cannot mix, but through the use of an emulsifying agent, it disintegrates and forms microscopic drops in suspension. An emulsion can be undone (separated into two liquids) through mechanical handling or chemical effects.

- **Suspension.** The product is either a powder or made of small particles that disperse in water; whenever the suspension is left resting, the particles will deposit.

Once the right bath dosing is performed, several factors that may jeopardise it must be taken into account:

1. **Rain water.** It must be avoided that rain water goes into the bath, since it may affect the concentration.
2. **Water quality improvement.** Water should be controlled, to guarantee that it is clean, without a high harshness degree or high metal content or any other substance that may affect the bath concentration.
3. **Control the filth that goes into the bath.** It must be avoided that land or other elements go into the bath. Besides, the sawdust quantity stuck to the wood should be controlled, since it may cause a slight concentration decrease. With regard to this point, emulsions are more sensitive.
4. **Control possible effects from sudden temperature changes (freezings) that may jeopardise the emulsion.**
5. **Control the container state.** With some products, mainly acid products dissolutions, the occurrence of severe corrosion attacks to the container may affect the dosing.
6. **Container agitation.** Suspensions require the bath agitation.

There is another phenomenon that cannot be avoided: the progressive impoverishment of the active substance in the container; since by treating the wood, this absorbs more quantity of product than of water. This fact is influenced by several reasons, for instance the active substance type and the wood species. (strongly present in quaternary ammonium cases and, in some wood species, with TCMTB-based formulations).

In any case, it is recommended to follow the manufacturer’s specific instructions.

**Blue stain consequences on the wood characteristics**

As a consequence of the great storm in 1999 in Aquitaine that destroyed the maritime pine production equivalent to more than 3 years, and despite all efforts to rapidly select and use the utmost quantities possible, a significant amount of wood was affected by blue stain. This led the business community to request a study to CTBA to analyse the appropriateness of blue stained wood both to the glueing process and to the application of decorative treatments.

The finishes types (paintings and integrated surfacing coatings) were selected, using pigmented products to mask the dark shade produced by the blue stain. The outcome of the accelerated artificial ageing (6 weeks) tests and the natural ageing tests (1 year) were satisfactory both in the blue stained and in the non-blue stained wood. Adherence tests, as well, did not present any significant change. Besides, in observations carried out with a fluorescence microscope, it could be proved that the paintings impregnation were slightly higher in the blue stained wood. It can definitely be concluded that blue stained wood is perfectly fit for adhesives and finishes application.

With regard to adhesives (non-structural bicomponent vinyl type and structural formaldehyde urea melamine type), the study performed tests of delamination and shearing by traction (in the wood initial state and after being submitted to several
pre-treatments). In the delamination tests, it could be proved that there is no significant effect. With regard to shearing tests, the results obtained prove that there is a better mechanical anchoring in blue stained wood (as a consequence of its better porosity) and a higher hygroscopicity of the blue stain wood (that induces a larger dimensional instability). Anyway, an overall analysis to the results obtained brings to the conclusion that blue stained wood is appropriate to be used in joinings with adhesives.

Methods to assess adherence of paintings on stained wood

<table>
<thead>
<tr>
<th>Stage</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>7 days in normal weather (20 °C/65 % HR)</td>
</tr>
<tr>
<td>C3</td>
<td>7 days in normal weather (20 °C/65 % HR), 4 days in cold water at 20 °C</td>
</tr>
<tr>
<td>C5</td>
<td>7 days in normal weather (20 °C/65 % HR), 6 hours in boiling water, 2 hours in cold water at 20 °C</td>
</tr>
<tr>
<td>C6</td>
<td>7 days in normal weather (20 °C/65 % HR), 6 hours in boiling water, 2 hours in cold water at 20 °C, 7 days in normal weather</td>
</tr>
</tbody>
</table>
Phytosanitary compliance of wood packages for export purposes

Despite the strong competition from plastic and metal materials, wood is still one of the most used material in the packaging business. More than 90% of pallets manufactured in Europe are made of wood, mainly from coniferous, and above all from maritime pine.

The International Standard on Phytosanitary Measures (Norma Internacional sobre Medidas Fitosanitarias - NIMF no. 15), regarding the guidelines to regulate the wood package used in international trade, was adopted aimed at describing phytosanitary measures to be used, in order to reduce the risk of plagues introduction and dissemination that could, otherwise, use wood packages as a means to convey and propagate themselves.

The purpose of standard FAO NIMP 15/ISPM dated 23 August 2003 is:

- Standardize measures to be adopted to avoid dissemination of noxious organisms that could use wood packages as a conveyor and propagation mean.

- Specify the responsibilities and control procedures to be implemented by national bodies from export countries with responsibilities in this field.

As from 2004, numerous countries (North America, European Union, Southeast Asia) demand the application of the phytosanitary measures stated on NIMP 15 for those packages that enter in their countries. The presence of a specific marking attests the conformity of packages.

The European Union has incorporated NIMF 15 phytosanitary treatments to the EU legislation, through changes introduced to the Directive 2000/29/EC, that came into force on 1 March 2005. This Directive does not demand any kind of treatment to containers, packages and wood pallets used in intracommuni-
PRESERVATIVE TREATMENTS
rated from the others. In general terms, this procedure consists of a control to the containers components, since the sawmill treatment, the container plant until its use by an export company.

There are two kinds of phytosanitary treatments:

- Thermal treatment of the wood at 56 °C during 30 minutes performed at the heart of the wood.
- Fumigation with methyl bromide.

Besides, the wood employed in the manufacture of packages is demanded to be debarked and exempt of hollows larger than 3 mm diameter.

**Thermal treatment**

To abide by the phytosanitary demands of the thermal treatment, the heart of the wood should reach a 56 °C temperature during 30 minutes.

The adequate conditions of the treatment chambers (dryers) are the following:

- If the treatment is at 60 °C, the premises should have available an automatic temperature recording system, besides an air moisture recording system.
- Temperature sensors should be installed next to the air exit stack and distributed along it. They should be separated from each other at a maximum distance dependent on the length (approx. 3 m) and according to the available height, they should be placed alternatively at a 1/3 distance from the upper extremity and 1/3 from the lower extremity.
- For measuring the air moisture, a sensor installed next to the air exit stack will be enough.
- Sensors should be contrasted at least every six months.
- Temperatures will be recorded, according to the conformity programme demands.
- There will be a technician responsible for performing these operations.

All operations will be recorded in a Registry Book that will be kept for 5 years and will contain the following data:

- Data on the treatment operations.
- Drying process times.
- Drying temperatures (dry and moistured or dry and relative moistured).
- Treated products.
- Dysfuncions, failures or any work repairs on the heating structure.

The minimum permanence time of the wood will be decided, according to the wood characteristics (moisture, thickness and species, in the pallets case) and to the chamber temperature parametres, to gurarantee the accomplishment of the requirements. This is the treatment table developed by CTBA:
Fumigation with methyl bromide

This kind of treatment should abide by the legislation in force, and in subcommissioning cases, these companies should have the mechanisms to prove they conform to the phytosanitary programme.

There should be a Registry Book recording all operations performed in the last 5 years, including the following data:

- Data on the treatment operations.
- Concentrations (g/m³).
- Treatment temperatures.
- Treated products.

The performing conditions will consider the following points:

- Temperature >10 ºC.
- Exposure time ≥ 16 hours.

Concentration readings should be performed at 30 minutes, 2 hours, 4 hours and 16 hours, achieving the minimum concentrations shown in the following table:

### Sawnwood

<table>
<thead>
<tr>
<th>Temperature (ºC)</th>
<th>Thickness</th>
<th>22mm</th>
<th>45mm</th>
<th>80mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_initial = 20ºC / Any moisture / Any species</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>1h 40</td>
<td>2h 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>1h 10</td>
<td>2h 30</td>
<td>3h 10</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>1h</td>
<td>2h</td>
<td>2h 50</td>
<td></td>
</tr>
<tr>
<td>T_initial = 10ºC / Any moisture / Any species</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>1h 50</td>
<td>3h 50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>1h 20</td>
<td>2h 50</td>
<td>3h 40</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>1h 10</td>
<td>2h 20</td>
<td>3h 20</td>
<td></td>
</tr>
<tr>
<td>T_initial = 0ºC / Any moisture / Any species</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>2h</td>
<td>4h 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>1h 30</td>
<td>3h 15</td>
<td>4h 10</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>1h 20</td>
<td>2h 45</td>
<td>3h 50</td>
<td></td>
</tr>
</tbody>
</table>

### PALETS

<table>
<thead>
<tr>
<th>Temp. (ºC)</th>
<th>Wood moisture</th>
<th>Species</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_initial = 20ºC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>&gt; 25%</td>
<td>Conifers</td>
<td>9h 30</td>
</tr>
<tr>
<td>60</td>
<td>&gt; 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>7h 40</td>
</tr>
<tr>
<td>60</td>
<td>≤ 25%</td>
<td>Fœuillus</td>
<td>5h</td>
</tr>
<tr>
<td>70</td>
<td>&gt; 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>3h 30</td>
</tr>
<tr>
<td>70</td>
<td>&gt; 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>3h</td>
</tr>
<tr>
<td>70</td>
<td>≤ 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>3h</td>
</tr>
<tr>
<td>80</td>
<td>&gt; 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>2h 40</td>
</tr>
<tr>
<td>80</td>
<td>&gt; 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>2h</td>
</tr>
<tr>
<td>80</td>
<td>&lt; 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>2h</td>
</tr>
<tr>
<td>T_initial = 10ºC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>&gt; 25%</td>
<td>Conifers</td>
<td>10h 10</td>
</tr>
<tr>
<td>60</td>
<td>&gt; 25%</td>
<td>Fœuillus</td>
<td>8h 15</td>
</tr>
<tr>
<td>60</td>
<td>≤ 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>5h 30</td>
</tr>
<tr>
<td>70</td>
<td>&gt; 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>4h</td>
</tr>
<tr>
<td>70</td>
<td>&gt; 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>3h 20</td>
</tr>
<tr>
<td>70</td>
<td>≤ 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>3h</td>
</tr>
<tr>
<td>80</td>
<td>&gt; 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>3h</td>
</tr>
<tr>
<td>80</td>
<td>&gt; 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>3h</td>
</tr>
<tr>
<td>80</td>
<td>≤ 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>2h 15</td>
</tr>
<tr>
<td>T_initial = 0ºC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>&gt; 25%</td>
<td>Conifers</td>
<td>10h 40</td>
</tr>
<tr>
<td>60</td>
<td>&gt; 25%</td>
<td>Fœuillus</td>
<td>8h 50</td>
</tr>
<tr>
<td>60</td>
<td>≤ 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>5h 45</td>
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<td>70</td>
<td>&gt; 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>4h 20</td>
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<td>70</td>
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<td>3h</td>
</tr>
<tr>
<td>80</td>
<td>&gt; 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>3h 20</td>
</tr>
<tr>
<td>80</td>
<td>&gt; 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>3h</td>
</tr>
<tr>
<td>80</td>
<td>≤ 25%</td>
<td>Conifers &amp; hardwoods</td>
<td>2h 30</td>
</tr>
</tbody>
</table>

Note: For treatment at 60 ºC the wet temperature must be ≤ 55 ºC.

Marking usage

The marking use endorses that the wooden package was submitted to phytosanitary measures. This marking will be legible, indelible, non-transferrable and visible at least in two opposite sides of the package, and should allow an identification without ambiguities to the users.
The final marking will be stamped by the wood package manufacturer or by the package recycling company. The subcommissioned companies will issue a treatment certificate, with the marking stamped and the parameters employed in the treatment (in case of packaged material, they will use a label with the marking, otherwise each unit will be marked).

The marking consists of a rectangle divided into 2 parts:

- At the left part, the logotype is placed, a wheat ear with the IPPC sigla/acronym vertically set.
- At the right part, at least the following information should be stated: The ISO code of the country and region and the company registration number assigned by the country competent authority. The initials of the phytosanitary treatment used (HT for thermal treatment and MB for fumigation), as well as the initials DB to certify the debarking, whenever that is requested.

Adherent companies to the phytosanitary conformity programme can add to the reference numbers any other identification data, provided that no confusions, ambiguities or possible interpretation misleads occur.

The marking should be legible, indelible and non-transferrable. To carry this out, several marking techniques can be used, such as: pyrography, inking or paint spraying.

There are no colours forbidden to perform the conformity marking. However, red and orange use is dissuaded, to avoid confusions with hazardous substances labelling.

There are no minimum sizes, although the marking should be legible, visible and fit to the element dimension.

Only companies with a registration number are authorised to use the marking in wooden packages. To avoid the multiplicity of marks, the definitive marking should be fixed on the wooden package by the manufacturer or by the package repairer. It is preferable to fix the mark on the two opposite faces of the treated product.

While purchasing packages, it should be checked if each element has the enforced marking and if the goods are accompanied by the supplier invoice stating the registration number indicated on the product.
ACCREDITED OFFICIAL BODIES

SPAIN
Ministerio de Agricultura, Pesca y Alimentacion.
Subdirección General de Sanidad Vegetal.
Avenida Ciudad de Barcelona, 6 - 2a Planta - 28007 MADRID.
Fax: + 34 91 347 82 48
e-mail: Inspfito@mapya.es

FRANCE
Ministère de l’Agriculture et de la Pêche
Sous Direction de la Protection des Végétaux
251, rue de Vaugirard - 75732 PARIS CEDEX 15.
Fax: + 33 1 49 55 59 49
e-mail: Sdqpv.dgal@agriculture.gouv.fr
Bsv.sdqpv.dgal@agriculture.gouv.fr

PORTUGAL
Direcção-Geral de Protecção das Culturas
Quinta do Marquês - 2780-155 OEIRAS
Tel: +351 214 464 055
Fax: + 351 21 442 06 16
e-mail: Dsgaat@dgpc.min-agricultura.pt

INFORMATION REGARDING PHYTOSANITARY TREATMENT:

INTERNATIONAL PLANT PROTECTION CONVENTION (IPPC)
IPPC Secretariat
Plant Protection Service
Food and Agriculture Organisation of the United Nations (FAO)
Viale delle Terme di Caracalla - 00100 Rome, Italy.
E-mail: ippc@fao.org
Website: http://www.ippc.int
NEW TECHNOLOGIES
Greenwood glueing process

The Greenwood glueing process consists of glueing wood with a moisture content above the saturation degree of the fibre. Today, there is worldwide an interest in developing this technique, since it brings clear advantages against the traditional glueing methods applied on wood with a much lower moisture content than the fibre’s saturation degree (30% in general terms). Naturally in this last case, the wood drying process should be carried out before the defects elimination, necessary to perform the glueing process. The Greenwood glueing process allows splicing the moistered wood to dry afterwards when the material is already sanitised. Any movement produced during the drying process can be corrected by planing the surface of the obtained boards.

Some years ago, some formulations were developed to glue wood with high moisture content. The most renown adhesive is a modified resorcin glue (Greenweld®) developed by the Forest Research Institute in New Zealand. The practical use of this adhesive was limited, due to contamination and toxicity problems from the ammoniacal component. Also in the United States and Japan, some promising results were achieved with adhesives based on the combination of synthetical resins with soya-derivated components (“Soybond” and “Sumitak”).

In Europe, particularly in France, works were driven towards the formulation of a polyurethane type adhesive. The working principle consisted basically in obtaining chemical covalent bonds between the wood and the glue, that could guarantee the glueing process in any circumstance. For that, highly reactive compounds were used (terminal isocyanate groups), whose cure is promoted by the presence of moisture.

In 2004, several experiments were carried out with maritime pine to obtain wood for pallet construction (section: 20 mm x 100 mm). The results obtained show that, as a consequence of the shrinkages related to the wood drying process, a strengthening of the resistance is achieved, whose characteristic values are higher by 20% than the ones of the joinings carried out with dry wood and resorcin adhesives. The same goes for
the rupture, in the greenwood glueing process, rupture is mostly produced outside the joining area.

A detailed analysis to the density evolution at the joining area proves that the existing discontinuity in the end of the splicing area (glueing process in dry) disappears while performing the greenwood glueing process. Likewise, the creation of a continuous wood-glue interface can be observed at the oblique joining areas. All this corroborates and explains the experiment data obtained at the flexion tests.

As such, the chamber drying process can be optimised to avoid the processing of a significant residual wood quantity (30-50%) with idiosyncrasies or defects. Additionally, by obtaining a better quality in the drying process, it is possible to reduce wastes from deformations or cracks that occur at the final drying stage, as a consequence of the wood dimensional variations. Finally, the optimisation of the raw material use (in quantity and quality) and the benefits from the standardisation (by reducing significantly the number of lengths handled) settle the potential advantages that this process may bring.

The reasons that hinder the industrial development of this technique come from the adhesives prices, the complexity of the application of toxicological precautions and relatively complex specific equipments and mainly to the need of adaptation and homologation by the ruling standard concerning the use of laminate wood in structural applications. This recognition is underway.

The previously stated data was obtained from the framework of a research project developed by a syndicate constituted by 3 research institutes located in Aquitaine (Laboratoire de Rhéologie du Bois de Bordeaux, Institut du Pin and CTBA), an
adhesive manufacturer and 4 companies from the woodworking sector with operations in sawing systems and packages manufacture. The project was co-financed by the Ministry of Economics, Finance and Industry.

Heat-treated wood

As from the 90’s, restrictions imposed to the use of biocides traditionally employed in wood preservation (creosotes, CCA salts, etc.) arose the interest in developing techniques to improve the wood durability without the use of biocide chemical products.

These methods consist basically of changing the chemical structure of the wood to improve some or several of its properties (mainly durability, but also other qualities, such as dimensional stability, aesthetic aspect or thermal conductivity). This can be achieved, by applying a treatment, using heat, an enzyme or a chemical agent of various nature (among numerous processes under investigation and experiment phases, the most known one is acetylation).

The heat treatment consists basically in applying temperatures near or above 200°C, during several hours, in an atmosphere with low oxygen content. This “inert” atmosphere (necessary to adequately control the process) can be held by using a liquid as a heat transmission mean (vegetable oils) or by reducing the presence of air, by introducing water steam or a gas (nitrogen, for instance).

According to the means employed and the operation conditions, several processes were developed in countries, such as: France, Germany, Finland or the Netherlands. Basically, there are two work lines: air/gaseous treatment chambers or oil-bath processes.

The main changes produced to the wood characteristics are:

- Colour change to more dark tones, in variable grades, depending on the treatment applied. This colour change is not stable against the effect of ultraviolet raditions.

- Characteristic odour that can last for months, although quickly decreasing its intensity.

- Reduction in the balance moisture of the wood (around 50%), as a consequence of the decrease of hydroxyl groups. This fact conditions water absorption, granting a larger dimensional stability to wood.

- The mechanical properties are negatively affected, mainly in the resistance to dynamic flexion and rupture module to flexion (MOR). This decrease in resistance varies, according to the conditions applied to the process (mainly temperature), and can even reach values above 50%. The negative effects in the elasticity module (material rigidity) are not so significant.

- The elimination of resin and of other volatile components indi-
cates a loss of weight that may range between 5 and 15 %. The thermal conductivity is reduced to 10-30 %.

- As a consequence of the deterioration of some wood components, the natural durability is significantly improved, mainly in what concerns putrid fungi attacks. This promotes the use of wood in risk classes 1, 2 and 3. Some studies indicate that heat-treated wood does not show a significant resistance to termite attacks.

![Graph showing weight loss (%)](image)

**Results after 16 weeks**
(miniblock biotest - Brabery 1979)

The characteristics of heat-treated wood demand some special precautions:

- Wood holds different hygroscopic characteristics, what affects the use of water-based adhesives, and makes it necessary to extend the pressing and cure times.

- Wood holds a more friable structure, as such the cutting tools should be carefully adjusted. In joinings, it is recommended to carry out a previous drilling and use appropriate screws/bolts (larger screws and larger head).

- The use of classic finishes processes shows no special difficulties. Studies carried out on Pinus pinaster in France prove that there is no negative influence either in the adherence/adhesion, or in the ageing tests. These tests that could prove the effects of the better dimensional stability achieved, were performed during 3 weeks by using a treatment cycle with exposure to ultraviolet 300 W lamps (24 minutes), drying process at environmental conditions (27 minutes), water immersion (12 minutes) and drying process at environmental conditions (27 minutes).

**Oléothermie treatment**

This innovative system developed by CIRAD Fôret (*Centre International de Recherche en Agronomie pour le Développement*) consists of submerging successively the pieces in two oil baths. The first bath keeps a temperature of 100 to 210 °C to treat wood (green or dry), reducing its moisture content. This phase duration can range between a few seconds and several hours, it depends on the volume. Afterwards and very quickly to favour the product penetration, the wood is introduced in natural linseed or rape oil at a temperature between 10 and 90 °C. The treatment principle consists of creating in the core of the wood an internal depression that is used to facilitate the penetration of the treatment liquid.
Another process has been developed industrially that consists of replacing directly, and without the aerial phase, the hot oil of the first bath by cold oil, what allows to carry out the first bath at a less high temperature of 110 to 140°C. The purpose of this operation is to eliminate the remaining water of the wood successively by vaporisation (in the hot oil) and condensation (in the cold oil), with a definitive fixation of tannins through the oil impregnation.

Among the advantages of this system, there are:

- Easy installation and adaptness to the technological levels of potential users.
- Reduced operating and installation costs.
- Promotion of residual oils recovery from agroalimentary industries.
- Allows the use of treatment products with a low environmental impact.
- Can be used with green wood.
- Preserves the original aspect of the wood.
- Tannins fixation.

The dimensional stability permitted by the combined effect of the heat treatment and the presence of hydrophobic substances, reduces the effect of the swelling and shrinking phenomena, that originate warplings, as well as the occurrence of cracks, that facilitate the penetration of xylophagous deteriorating agents. Likewise, pathogenic agents are eliminated by sterilisation and durability is improved, as a consequence of the changes induced to the wood components (for instance, starch is destroyed, a relevant attractive element for some insects, such as powderpost beetles - Lyctus bruneus).

This process opens up new markets for woods needing to improve its natural durability or those difficult to impregnate (fir, for instance).

Today, investigations developed are fundamentally aimed at defining appropriate operation conditions for different wood types and sizes, as well as to check the maintenance of the protection efficiency in time.

Wood plastic composites

The wood plastic composites growth is remarkable, mainly in North America during the last decade. Departing from an almost nonexistent production 15 years ago, currently it has reached more than 700,000 t/year. In Europe, except for the automobile industry where wood and other natural fibres are commonly used, there is a reduced production of this new material type (although there are already plants in France, Austria, Germany, Sweden, Italy,…).

Wood plastic composites (hereinafter WPC) consist of a mixture of small-sized wood particles dispersed on a matrix formed by a thermoplastic material with a fusion temperature lower than the wood deterioration temperature (220-230°C). This type of materials (polypropylene, polyethylene, polystyrene, …), according to the used temperature, have the characteristic of alternatively harden or lose cohesion/coherence and become fluid. This property helps the mixing with wood, and makes it is possible to obtain a vast easily recyclable products range.
In Europe, the most used thermoplastic is polypropylene (not from recycling), in the United States predominates polyethylene obtained through diverse material recycling (plastic bags, milk bottles, other containers, etc.). Products produced from polystyrene show an excellent appearance, but have disadvantages related to their reaction against fire. The percentage of wood-plastic used ranges normally between 55:45 - 80:20. In the United States, the wood average percentage is lower 55:45 – 50:50 what favours the resistance against moisture.

The manufacturing process includes basically two phases. In the first one, the components are prepared and mixed to obtain an homogeneous compound material. This operation can be performed separately, obtaining in this case pellets that can be stored for ulterior use. The forming of the final product can be performed using different techniques of injection or extrusion. The following figure represents a production line.

The main advantages of WPC are their excellent dimensional stability and durability against fungi and insects attacks. Both aspects extend their useful life with reduced maintenance needs.

Likewise, the environment-related characteristics of the product (life cycle, appropriateness for recycling, etc.) were determined by the relevant development of these kind of products in the last years. Here it is important to refer that WPC generally include thermoplastic polymers free from chlorinated compounds. For this reason, they can easily be processed as fuel at the end of their life cycle.

Characteristics, such as: hardness, resistance to abrasion, compression, cutting effort and screw/bolt pulling are comparable to those of the wood. On the contrary, the elasticity module and the resistance to flexion and impact are generally lower. Density is significantly higher than in wood (1.0-1.1 g/cm³ against 0.35-0.65 g/cm³).

The wood used comes normally from the grinding of subproducts/by-products (scraps, chips and sawdust) that can be used to obtain wood particles, thinly divided that show a flower-like consistence. Wood fibre can also be used (virgin or recycled). Although with some processment difficulties, this last possibility obtains a final product with better mechanical characteristics. Likewise, the use of additives helps to improve some properties, such as colour, surface appearance or stability against light.

Physical and mechanical properties, such as: hardness, rigidity, resistance to impact, density and colour condition the various applications. For instance, applications in the car industry benefit from the reduction achieved in the density compared to thermoplastics full of inorganic material. Consumption products (such as: tool handles) use the aesthetics to obtain a product that has a certain similarity to wood and can be processed as a plastic. There are advantages in non structural construction applications, such as outdoor floorings, tiles, windows frames, due to this material insulation capacity and dimensional stability.

Recently developed technologies promote the use of a high percentage of wood. In this case, wood acts not only as a filling material, but also as a reinforcement material that contributes with specific qualities depending on the final requirements. Besides other technical advantages, it is possible to replace synthetical oil-based polymers by a product whose supply is guaranteed at relatively stable prices. Likewise, aimed at fully replacing the use of synthetical products, an European company has developed and patented a process that enables the manufacture of WPC through extrusion, using a starch-based product and other natural resins as binders.

Currently, the applications of this material type are mainly concentrated in construction materials, which account for 75% of the production. The main products are outdoor floorings, and in lower quantities, products for industrial use (20%) and for consumption (5%) are also manufactured.
### Product Development status

<table>
<thead>
<tr>
<th>Product</th>
<th>Development status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor pavements (deckings)</td>
<td>Well established</td>
</tr>
<tr>
<td>Enclosure materials, balustrade, handrails</td>
<td>Under commercialisation</td>
</tr>
<tr>
<td>Pedestrian passages, stairs, doors</td>
<td>Small development</td>
</tr>
<tr>
<td>Windows threshold</td>
<td>Under commercialisation</td>
</tr>
<tr>
<td>Surfaces/Coatings</td>
<td>Under commercialisation</td>
</tr>
<tr>
<td>Children games equipment</td>
<td>Not developed in Europe</td>
</tr>
<tr>
<td>Tiles, insulating panels</td>
<td>Under development</td>
</tr>
<tr>
<td>Equipment parts for paper manufacturing</td>
<td>Under commercialisation</td>
</tr>
<tr>
<td>Counters, kitchen and lab components</td>
<td>Potential application</td>
</tr>
<tr>
<td>Sound barriers in highways</td>
<td>Under commercialisation</td>
</tr>
<tr>
<td>Concrete wooden surfaces</td>
<td>Under commercialisation</td>
</tr>
<tr>
<td>Indoor floorings, book cases, cables conveyors</td>
<td>Potential / Under development</td>
</tr>
<tr>
<td>Portable houses, sport harbours, balustrade</td>
<td>Small commercial development</td>
</tr>
</tbody>
</table>

PRODUCTS
Wooden containers

Apart from conforming with technical conservation and protection requirements demanded for handling and transport purposes, wooden containers show aesthetical and environmental qualities that grant relevant advantages from the commercial attractiveness viewpoint. The natural and renewable character of Pinus pinaster wood combined with its attractive idiosyncratic texture makes from this application one of the most appropriate.

All this led to an increasing use of Pinus pinaster wooden cases, especially in the agroalimentary sector. The undoubtful association of wooden containers as quality products represents a very interesting and growing recovery possibility.

Among the various containers types, there are:

- **Wine cases.** In Galicia, Portugal and Aquitaine, there are numerous companies engaged in manufacture of wine cases. To reduce transport costs, normally the assembly is performed next to the packaging areas (Porto, Bordeaux, Rioja, Ribera del Duero, etc.)

- **Fruit cases.** Although the use of Pinus pinaster wood has been replaced by rapid growth species, such as poplar, there is still some consumption in citrus and other fruit producing areas. In Spain, this consumption is mainly centralised in Valencia, Murcia and Andalusia.

- **Fish and seafood cases.** This is one of the traditional uses with a relevant activity still today. The consumption is mainly for deep water fleets engaged in dark fish capture (sardine, horse mackerel, freckel, anchovy, etc). There is also a significant consumption for seafood containers (crab, mussel and oysters).

Apart from the aforesaid, there is an increasing use in the manufacture of special containers for high quality food products, such as: olive oils, cheeses and similar products.
Technical specifications

Wood employed in the manufacture of bottles containers admits sound knots with a diameter until 25 mm. It must be exempt of resin pockets/bags and blue stains. Excepting the inside elements, wood must be planed both at the surfaces and edges.

Although configurations may significantly vary, as a reference, a description of the elements used in the three common types of wine cases is shown below:

<table>
<thead>
<tr>
<th>Type</th>
<th>Piece</th>
<th>Pieces per case</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 bottles</td>
<td>Working face</td>
<td>2</td>
<td>245</td>
<td>105</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Sides</td>
<td>2</td>
<td>317</td>
<td>105</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Cover/Bottom</td>
<td>2</td>
<td>317</td>
<td>267</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Inner part</td>
<td>6</td>
<td>253</td>
<td>78-44</td>
<td>7</td>
</tr>
<tr>
<td>6 bottles</td>
<td>Working face</td>
<td>2</td>
<td>245</td>
<td>171</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>Sides</td>
<td>2</td>
<td>340</td>
<td>171</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>Cover/Bottom</td>
<td>2</td>
<td>332</td>
<td>267</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Inner part</td>
<td>6</td>
<td>253</td>
<td>78-44</td>
<td>7</td>
</tr>
<tr>
<td>12 bottles</td>
<td>Working face</td>
<td>2</td>
<td>320</td>
<td>171</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>Sides</td>
<td>2</td>
<td>497</td>
<td>171</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>Cover/Bottom</td>
<td>2</td>
<td>497</td>
<td>332</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Inner part</td>
<td>6</td>
<td>483</td>
<td>78-44</td>
<td>7</td>
</tr>
</tbody>
</table>

In fish cases, a difference with the aforesaid is that greenwood and wood with non-breakable knots can be used.

<table>
<thead>
<tr>
<th>Type</th>
<th>Piece</th>
<th>Pieces per case</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 kg cases</td>
<td>Working faces</td>
<td>2</td>
<td>400</td>
<td>80</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Sides</td>
<td>2</td>
<td>600</td>
<td>80</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Bottoms</td>
<td>1</td>
<td>600</td>
<td>420</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Sleepers</td>
<td>2</td>
<td>420</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>20 kg cases</td>
<td>Working faces</td>
<td>2</td>
<td>475</td>
<td>100</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Sides</td>
<td>2</td>
<td>770</td>
<td>100</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Bottoms</td>
<td>1</td>
<td>770</td>
<td>490</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Sleepers</td>
<td>1</td>
<td>500</td>
<td>50</td>
<td>10</td>
</tr>
</tbody>
</table>

Packages

*Pinus pinaster* wood is fit for packages manufacture. This wood offers solutions with an excellent quality-price relationship that can perfectly be adapted to a vast range of products.

In the 30’s, pallets production started, as a consequence of the use of lifting pushcarts and wheelbarrows. Wood pallets emerged as a response to the need of facilitating and improving goods handling, by grouping them in load platforms. These platforms help to achieve a rational use of space, without harming the goods safe handling and the package protection.

After World War II, the development of trade relationships led to an excessive proliferation of pallets models (in 1958, there were more than 700 types). As such, the ISO 800 x 1.200 mm and 1.000 x 1.200 mm were established as load handling units in pallets. Currently, more than 90% of the goods are handled in wooden pallets, since it is a simple, economic and efficient mean.

Pallets can be divided into two types; it depends whether they can be reused or not. In some cases, when recovery is not an option, due to high costs in the return transport, the pallet construction should be reduced to its essentials, both in dimensions and wood qualities. Reusable pallets should have a stronger resistance in the characteristics of the materials and in the joinings.

Although there is a trend towards international standardisation, there are still several commonly used sizes:
- **1000 x 1200 mm.** Used throughout Europe and Anglo-Saxon countries.
- **800 x 1200 mm.** Known as “European pallet”, mainly used in continental Europe.
- **1140 x 1140 mm.** Designed to be used in ISO containers, it is widely used in Japan, Southeastern countries and Australia.
- **1016 x 1219 mm.** Widely used in the United States and Canada.

Apart from the aforesaid sizes, another problem to be dealt with is their vertical size and the distance between the entries. The International Standard Organization (ISO) recommends the following rules:

- The vertical size should not be lower than 98 mm, and 95 mm can be accepted for free entry pallets.
- The vertical size of the entries should not be higher than 45 mm.
- For 4-way pallets, total height should not be higher than 127 mm.
- The pallets inner vertical size based on the whole perimeter should not exceed 156 mm.

In turn, the recommended sizes for the horizontal entries are:

<table>
<thead>
<tr>
<th>Pallet size: length or width (mm)</th>
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<td>Maximum central block (mm)</td>
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Pallets design should be adapted to the goods to be handled, according to the required resistance characteristics and the supporting surface needs. In this sense, there are three loading types:

- Medium rigid cases (e.g. food and beverages).
- Uniform loads distribution (e.g. fertilizer sacks).
- Uneven load distribution or unevenly concentrated (e.g. steel moulds).

The resistance of the upper board is determined by the wood thickness and quality, and by the boards width and spacing. The purpose of the lower deckboard is to grant rigidity to the whole system. In this case, the resistance requirements are higher than in the boards of the upper deckboard, since they are less in number and with a limited thickness (to 28 mm.) to facilitate the entrance of the stacking device.

With regard to sleepers or central blocks, the main characteristics demanded are a high density and a good capacity in receiving and retaining the fixing elements. In what fixing elements are concerned, very dense woods or excessively dry can show problems hard to sort out. For all these reasons, the *Pinus pinaster* wood is one of the most suitable for this kind of applications.

*Pinus pinaster* wood with a density of approx. 530 - 600 kg/m$^3$ (at 12 % moisture) is perfectly fit for the manufacture of all pallet elements, including those submitted to more mechanical requirements, such as cross beams/traverses and blocks. Lighter woods with less than 400 - 450 kg/m$^3$, for instance poplar or cryptomeria, only exceptionally should be accepted. Plate boards can only be produced from medium/low mechanical resistance woods. A module of rupture (MOR) of 35 N/mm$^2$ in Greenwood (357 Kgf/cm$^2$) is considered as a minimum demand.
**Raw material sizes**

Sections commonly used in the manufacture of nonreturnable pallets (blank spaces left for irrelevant combinations).

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<th>Thickness (mm)</th>
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*LF: Less frequent. VF: Very much frequent. MF: Much frequent.*

Sections commonly used in the manufacture of recyclable pallets (blank spaces left for irrelevant combinations).

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<th>Thickness (mm)</th>
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*LF: Less frequent. VF: Very much frequent. MF: Much frequent.*
Synthesis of the most commonly used sections in the manufacture of pallets (blank spaces left for irrelevant combinations).

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
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LF: Less frequent. VF: Very much frequent. MF: Much frequent.

Sections of the most commonly used blocks in nonreturnable pallets (blank spaces left for irrelevant combinations).

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<tr>
<th>Thickness (mm)</th>
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Sections of the most commonly used blocks in reusable pallets (blank spaces left for irrelevant combinations).

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<th>Thickness (mm)</th>
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Assembly of pallets and packages

Metal fixing elements are extremely important to guarantee the pallets consistency and durability.

Nails are classified according to their shanks (smooth, ring, helical or square) and to the shape of their point (diamond or beveled).

2-3 Smooth: The most common type. Shank is round and smooth and the point can be either diamond or beveled. 4 Ring: Shank is made of convex rings. Very resistant to detachment. 5 Helical: Shank is square and twisted. Very resistant to detachment. 6 Square: Tooth-like shank. Very resistant.
To achieve a suitable assembly, the following rules should be followed:

1. Generally speaking, nailing should start by the thinnest element.

2. When the element is to be nailed through its larger part to another set edgewise, nails should penetrate in the second piece, at least in two third parts lengthwise.

3. While nailing two elements to each other through their larger part, the nails length should be slightly higher than the thicknesses sum, and the points should be adequately bent or finished.

4. While using nails higher than 100 mm length to join wood pieces that can split or crack, some drillings should previously carried out with a diametre slightly lower than the nails shank.

5. Whenever the thickness of the joining elements allows it, it should be left a separation of approx. 1/5 of the nail length between the nails and the edges of the elements.

6. To achieve a stronger adhesion/adherence, nails should always penetrate perpendicularly to the wood fibre (the adhesion capacity is reduced to the half when they penetrate in the same direction of the fibre).

7. Preferably, nails should penetrate perpendicularly to the wood surface. It allows a large adherence/adhesion.

Apart from the aforesaid, the wood moisture degree is very important here, since it influences the material weight and resistance, as well as the nailing adherence/adhesion and the preservation of the materials to be packed. Woods whose moisture content is higher than 20% are inadequate for packing metal articles sensitive to corrosion.

In the pallets cases, normally rivets are used. This technique consists of deforming/twisting the nail point to grant a stronger resistance to detachment.

Riveting is performed through a metal sheet, plain or corrugated, that forces nails to bend in J-shape or L-shape. In some cases, this procedure can be replaced by the use spikes or ring nails.
**Wood pallets and ecobalance**

Generally, wood grants environmental advantages due to the CO₂ absorption and carbon fixation achieved at its forming and growing stage. As a reference, it should be stated that 1 cubic metre of wood (with a density of 625 kg/m³, representative of the average of all planet’s species) is equivalent to 1 tonne of absorbed CO₂. Compared to alternative materials, wood to be processed requires a reduced energy quantity.

With regard to packages, in France, CTBA and the ECOBILAN company carried out a study on reusable pallets commonly used by all subsectors (800 x 1,200 mm) that sets forth some data regarding the wood use in this kind of applications. These studies were financed by the Environment Agency, the Energy Agency and the French Ministry of Agriculture.

As can be observed in the following charts when considering energy consumption and CO₂ emissions, the wooden pallets life cycle shows remarkable advantages. In the energy consumption chart, the negative sign corresponds to the obtained revenues due to energy recovery.

By the end of their life cycle, containers can be recovered through composting, board manufacture and energy production. Currently, there is a growing trend towards increasing wood recycling. Next, a schematically outline of the containers and wooden packages life cycle.
This data was based on a most unfavourable situation where wastes were processed through combustion (the energy recovery corresponded to just 50% of the material). In case of wood recovered for board manufacture, the balance is even more positive.

Flooring and surfaces

Floorings and surfacings (friezes and boardings) are often manufactured from the same sawed product, using similar manufacturing means and techniques. For this reason they are jointly considered in this item, despite their different specifications. In floorings, there are determined mechanical and aesthetic criteria to be accomplished, whereas surfaces require other kind of decorative and insulating qualities.

Likewise, in the case of boards, the classification criteria of the sawn timber are conditioned to the surface characteristics, the one with less defects, that will become the visible parameter after its settlement. On the contrary, in frieze production, normally the pieces are manufactured, so that each wood piece generates two surfacing pieces that correspond to the two faces of the board.

The current trend points to the development of finished products in the plant with decorative treatments (paints, finishes, oils, etc) adapted to new decoration styles. In line with this, products are increasingly being supplied with accessories and techniques that make the installation and maintenance easier, improving its performance and durability. Considering this, several innovations have been performed to improve the wood position against other competitive materials. Within this context, maritime pine is ranked in a proeminent place in France. Currently, wooden floorings compete with other materials (textiles, ceramics, plastics and similar products), achieving a market share of 5% within Europe.

France

In the last 10 years, wooden floorings usage grew by 20%. In 2001, it represented a little more than 14 million m², of which approx. a third was produced from maritime pine. This species stands in the first place of the French market without a little more than half of solid wood sales. The production of 4.7 million m² of maritime pine floorings requires 110.000 m³ of finished product. This amount corresponds to a roundwood consumption of 400.000 - 450.000 m³.
In the last 25 years, the wooden surfaces market (panelling) underwent a solid development, although in the last decade, there has been a stagnation. To a great extent, this trend was a consequence of the development of finished products at the plant ready for their final use. In 2002, 30 million m² of friezes or panellings and similar products were traded. From this figure, 18 million m² corresponded to solid wood (84% maritime pine). The production of 15 million m² of Pinus pinaster solid surface represents a volume of 150,000 m² of finished product. Their production represents 600,000 - 650,000 m³ of roundwood consumption.

In short, in Aquitaine the production of floorings and surfaces altogether represents a consumption of at least 1 million m³ of roundwood.

Spain

According to the data of Asociación Nacional de Fabricantes de Parquet (ANFP - National Association of Parquet Manufacturers), in 2003, the domestic production achieved 7.6 million m². Consumption for the same period was 14.4 million m².

The most requested wood species are oak (57%), tropical woods (27%), and other boreal hardwood (16%).

Traditionally in Galicia there has been an important use of pine floorings (mainly Tongue and Groove boards) for home uses. In general, its manufacture is related to the sawmills activity that also supply the local market. Currently, competition with alternative products has decreased the use of pine boards for home purposes, and has limited it to industrial or secondary applications.

Portugal

Alike in Galicia, the application of Pinus pinaster wood in floorings, traditionally used, has been decreasing in the last times.

By historical reasons (commercial relationship with Brazil and other countries from Africa and Asia) in Portugal there is an outstanding preference for the use of exotic woods. As a consequence, the manufacture of floorings and surfaces is performed by companies bound to the trade of this kind of woods.

Almost 70% of the production is consumed within the country. The balance of trade is favourable to Portugal. Wooden floorings export represented a turnover by 38,4 million euros in 2004.
Floorings

The mechanical characteristics of the maritime pine parquets make it fit for home usages. For commercial usages, they can also be employed in hardly used areas (private offices, hotel rooms,...).

The parquet selection should be decided according to the expected use, hardness characteristics and resistance to efforts and impact on the wood. Hardness is measured according to EN 1534 Standard (Wooden floorings and parquet. Determination of the resistance against Brinell footprint. Test method). Classification is performed according to EN 685 standard that distinguishes 4 classes (A minimum - D maximum). Pinus pinaster is included in class B.

Manufacturing types according to Parquet Guide (SEDIBOIS-CTBA).

Solid wood floorings with grooves and tongues (EN 13226)

The pieces are normally manufactured with a 23 mm thickness for nailing installation, and with 14 mm thickness for glueing installation.

Size characteristics:

<table>
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<tr>
<th>Thickness (mm)</th>
<th>Solid wood floorings</th>
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<tbody>
<tr>
<td>≥ 14</td>
<td>Solid wood floorings</td>
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<tr>
<td>Width (mm)</td>
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<tr>
<td>Length (mm)</td>
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Moisture contents between 7 and 11% for all species, excepting maritime pine and sweet chestnut (in this case, the range is 7-13%).

Solid wood floorings with interlocking system (EN 13228)

These are similar products to the previous ones, but with different geometry and assembly system. Their installation is always performed by glueing.

Size characteristics (mm):

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>English block</th>
<th>Surfacing parquet</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 13</td>
<td>8 ± e 14</td>
<td></td>
</tr>
<tr>
<td>Width (mm)</td>
<td>40 - 80</td>
<td>40 - 100</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>200 - 400</td>
<td>200 - 2000</td>
</tr>
</tbody>
</table>

The edges may be beveled.

The counterface may have a slot (or slots) with a depth not higher than 1/5 of the overall thickness of the element.

The system called “English block” should have a minimum space of 0.25 mm in all spots between the tongue and groove profiles of the interlocking system.

A bevel or a groove should be lengthwise mechanised in both sides. The pitch of the facing to the counterfacing should be ranging between 0.5 and 1.5 mm.

Moisture content from 7 to 11% for all species, excepting sweet chestnut and maritime pine, which is from 7 to 13%.
3. Solid lamparquet products (EN 13227)

Among tongue and groove parquets and according to their size characteristics, there are: "lamparquets" (a well disseminated product, normally with 10 mm thickness), "maxilamparquets" and "wide lamparquets". These last ones are however less disseminated in France.

Size characteristics:

<table>
<thead>
<tr>
<th>Nominal sizes (mm)</th>
<th>Thickness</th>
<th>Length</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamparquet element</td>
<td>9 a 11</td>
<td>120 a 400</td>
<td>35 a 75</td>
</tr>
<tr>
<td>Wide lamparquet element</td>
<td>6 a 10</td>
<td>400</td>
<td>60 a 180</td>
</tr>
<tr>
<td>Maxilamparquet element</td>
<td>13 a 14</td>
<td>350 a 600</td>
<td>60 a 80</td>
</tr>
</tbody>
</table>

Tolerances: ± 0.2 mm.

Visual grading

For each type of parquet defined by the European standards, there is a visual grading available for the most commonly used species. There are three quality classes defined by the following symbols ⊗, □, △. Five grading parameters, such as the maximum knot diameter differ according to the parquet type and the used wood species.

Class ⊗ is the one that accepts the least quantity of features. Either knots and cracks are small-sized or they are not allowed.

Class □ is the one that accepts the largest quantity of features (Larger-sized knots and in some cases without limitation).

Class △ is an intermediate class.

Apart from these accurately defined classes (⊗, □, △) there is still the possibility of the manufacturer to propose own classes, as is the case of multilayered parquet.

The manufacturer can designate these classes and define its own specifications, whenever the necessary criteria for this grading are correctly identified, indicating limit values for each feature admitted in the appendix of the product standard.

The preservation treatment is optional, and can be demanded in some countries. When that happens, the durability class should be indicated according to EN 460 standard or the preservation treatment according to EN 351-1 standard.
Recommendations for parquets installation

The installation surface should be clean, plane and dry. A special attention should be given to the sill moisture (a moisture lower than 2.5% is recommended), to the cohesion and hardness of the supporting framework (it should be hard enough to support the fillets installation), as well as the flatness and horizontality of the surface (what can be proved with a ruler and a level).

Fillets have normally rectangular or trapezoidal sections. To ease the setting and avoid warpings, it is recommendable to perform cross cuts at the lengthwise direction, every 50-100 cm, incising until 1/2 or 1/3 of their thickness. In case the fixing system of the fillets is made through mortar (an advantageous system while using boards with uneven lengths), nails should be set every 40 or 50 cms to improve the grip.

The following table shows the relationship between the main parameters that affect the installation of the supporting system:

<table>
<thead>
<tr>
<th>Board thickness (mm)</th>
<th>Maximum separation between fillets (cm)</th>
<th>Recommended minimum sections (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17-22 mm</td>
<td>25-35</td>
<td>40x30</td>
</tr>
<tr>
<td>&gt;23 mm</td>
<td>35-40</td>
<td>60x40</td>
</tr>
</tbody>
</table>

The fillets installation can start by leaving a separation perimeter from the wall of approx. 10 cm. This configuration will grant a sufficient supporting surface for the short-sized pieces to perform the finishes.
The nailing should be performed until a minimum 20 mm penetration in the fillet, while maintaining a vertical 45º angle. If the angle is to tight, the lower part of the tongue and groove can break. On the contrary, if the nailing is performed much horizontally, the resistance to traction is reduced, what may cause lifting.

Nails sizes are normally 1.3 x 35 mm or 1.4 x 40 mm. Each element should be fixed at least in two spots. This demands to leave aside pieces with a length lower than the double of the fillets separation (except in perimeter). Likewise, to avoid warppings due to the wood hygroscopic movement, it is convenient to leave a clearance of 10 mm between the board and the wall.

In case the framework is straight and with an adequate surface finish, a glueing fixing system should be employed, by setting 6 mm glue portions every 10 cm interval.

To improve insulation, when the space between fillets is empty, it should be filled with sheets of polystyrene fibreglass or rock wool. An acoustic insulation based on reticular polyethylene foam of 2 to 3 mm thickness can also be placed between the board and fillet.

**Decorative surfaces**

Decorative surfacing consists of a series of sheets assembled to each other and set over a surface. Unlike the floorings, this product does not need to conform with specific mechanical characteristics.

This surfacing also known as frieze or boarding is manufactures with different profiles. The main types are:

*With jonquil.* Shows a small lengthwise rounded framework with a 3 mm ray.

*With bevel or V-profile.* The bevel is oblique and is formed by a depressed face. Shows a 2.5 mm depth.
**With depression (or hollow joint).** The depressed area is a rectangular slot located at the pieces joint. The slot width has normally an equivalent size to 10 times the sheet thickness.

**Special panelling.** Besides the 3 traditional boarding profiles, previously described, special profiles are also produced to meet specific requirements.

**Size characteristics.**

In France, sizes and characteristics of tongue and groove should conform with NF B 54090 standard. Reference characteristics consider a moisture content of 12%.

**Thickness**
- The boarding is manufactured with a 10 mm thickness (tolerance +0.2 mm and -0.5 mm).
- Upper face thickness: 3.5 mm.
- Tongue and groove thickness: 3 mm

**Length**
Length tolerance is ± 2 mm. The boards can be produced from a single piece or by serrated lengthwise joinings.

**Width**
In general, the boards are manufactures from 6 to 14 cm widths (with 1 piece until 8 cm and with 2 pieces for larger widths). Tolerance is ± 1%.

Bevel boards or with depression are performed with widths ranging between 6 and 8 cm, seldom with double profile.

**Moisture**
Upon delivery, boards should have a moisture content between 8 and 15 % and should be stabilised.
General rules for appearance/visual grading (NF B 54 090, article 6.1.1)

The element should be sound, without traces of fungi attacks, rottenness, and insects attack. No visible manufacturing defects are allowed at the facing. The board should not have more idiosyncrasies than the ones accepted in each class.

The following idiosyncrasies are not considered:

- Knots with a diameter until 2 mm, if they are not grouped.
- Resin pockets/bags or pith traces until 10 mm
- Poorly visible cracks and slots
- Defects that cannot be seen after the boards joining (for instance, small loose knots over the tongue/groove or lack of localised width).

- Natural colour differences in the wood.

The measurement is performed taking as a reference the larger size of the knots at the facing of the visible faces of the board. When the knot centre is not on the facing (virtual centre), it is considered as an edge knot.

**Quality “without knots” SN symbol**
Prestige, red label (AFNOR 54 090; 54 091)
Wood that does not tolerate on the facing any idiosyncrasy/feature included in the standard.

**Quality “small knots” PN symbol**
Selection, blue label (AFNOR 54 090; 54 091)
The following features can be admitted on the facing:

- Sound and adherent knots, including small-sized cracks, with a diameter lower than 35 mm, not grouped.
- Knots, excluding the concealed ones, or failures of material in the facing until 15 mm diameter.
- Closed resin pockets/bags and traces of pith with a length until 70 mm.
- Not much widely opened cracks or slots.

**Quality “knotty”, NO symbol**
Tradition, yellow label (AFNOR 54 090; 54 091)
The following features are admitted to the facing:

- Knots with unlimited diameters, excepting the non-adherent ones.
- Non-cross resin pockets/bags and traces of pith without length limits.
- Not much widely opened cracks

**Quality “declassified”**
It is applied to all boards that cannot be included in any of the previous classes (article 6.1.3 of NF B 54 090).
This product sets off maritime pine’s graining by the association of finishing techniques: planing and lasur. The objective is to go beyond the visual aspect adding a tactile dimension. Maritime pine is particularly suitable to the implementation of these kind of techniques aiming to increase in value its outstanding aesthetic qualities.
In this case, the finishing is aiming to associate the features of wood and paintings. The result is an original mixture between a wooden material and a whitewashed surface. The visual and tactile aspects are closely linked.
Recomendations for surfaces installation

It is not convenient to perform the installation whereas the place is not back into its normal environmental utilisation and protected from anomalous humidity. Plasters and cements used in the works should be finished, clean and dry (normally, the drying period found necessary is of 20 days in a ventilated atmosphere). As reference values, it should be considered that concrete and mansonry are dry when they achieve a moisture content lower than 2.5%. The concrete limit lies on 5%. Furthermore, products finished on plant should be installed after finalising all painting works.

Before setting the surfaces, it is necessary to fix the fillets to the wall. The most current sections are from:

- Solid wood (20 x 30 mm - 30 x 40 mm).
- Plywood (10 x 20 mm - 15 x 30 mm).
- Chipboard (10 x 20 mm).

If the fillets are to be supported on a moisture wall, it is necessary to use a fungicide treatment. This can be performed by several means (immersion during some minutes, autoclave, etc.), using preservative products in an organic solvent.

The separation of the supports (placed on the wall through screwing or nailing) should not exceed 40 cm. Likewise, on walls that may transmit moisture, the fillets height should be at least of 10 mm, in order to create an air chamber of 1 cm minimum. The air circulation in this space should not be hindered by the fillets placement. For that, it is convenient to alternate with hollows. It is also recommended to create and opening of about 50 cm² by linear metre of wall, through the use of an appropriate construction solution (double fillet, a lifted socket, ventilation gratings, etc.).

The surfacing installation should begin by the upper part. The placement of the fixing element should be oblique to the tongue and groove or slot. The nail length should be at least equal to 3.5 times the thickness of the lower flange of the piece (in case the fillet has a thickness lower than 10 mm, it is inadvisable to fix the surfacing through nailing). There is also the possibility of using staples with a minimum length of 14 mm or fixing systems through clips.

In case the installation is to be performed in environments where occasionally there might be high moisture conditions for a period longer than 2 weeks (e.g. a dry place but not heated in autumn or spring), the use of small clearances between the pieces should be considered. Steam barriers should also be provided.
Carpentry and furniture

From the value-added generation perspective, carpentry and furniture applications consist of one of the most attractive destinations for Pinus pinaster wood. The technical characteristics of wood (moderately hard and easy to work) and its natural characteristic appearance (veined) offer advantages that associated with the use of the most adequate design and appropriate finishes technologies allow a wide range of first quality products to be obtained.

The successful experience of some companies with a long tradition in Pinus pinaster wood consumption (for instance, the furniture sector, mainly present in Portugal) proves that it is possible to guarantee optimal results in the product quality.

The aesthetical value added to Pinus pinaster wood offers many possibilities, by acting on the colour tonalities and brightness graduations (since matt to glossy) of the finishes, including the possibility of obtaining special finishes through superficial abrasion treatments. The finishing treatment is relevant for the wood decorative recovery and its technical characteristics (surface hardness, size stability, resistance against the action of deteriorating agents, etc.).

In the Pinus pinaster case, the use of finishes can be negatively affected by the presence of resin compounds mainly concentrated at the heartwood. The most reasonable solution consists of using a drying process at a temperature higher than 65 ºC to release the most harmful volatile components. Alternative solutions may consist of acting over the wood selection or applying pre-treatment techniques to the finishing process.

On the other hand, it must be taken into account that the oxidation of the wood chemical components occurs in time, mainly due to the ultra-violet radiation and can cause a change in the wood tonality, darkening the natural aspect of pine wood. This may change the wood tone from a relatively light to a darker tone (brown- reddish). Considering this, it may be convenient to use radiation filters or pigments to stabilise the material against the light effect. This preservative effect may be achieved through the use of glazes (metal oxides and anilines).

In spring wood penetration in the axial direction is 1 or 2 mm, however, crosswise it only reaches a few tenth of a milimetre (in autumn wood, there is only penetration). This fact accentuates the wood texture when glazes or other pigmented products are used.

The recent legal demands regarding safety and the environment preservation require the use of finishing systems that reduce the emissions of volatile composites and do not show toxicity. Therefore, the finishing techniques are constantly under innovation to develop new products and processes.

New products in aqueous dispersion allow an easier washing of the installation systems and the product reuse (after the necessary filterings), thus reducing to the minimum the emissions of liquid and gaseous compounds.
Prototypes

Next page displays a selection of the prototypes developed in the frame of the “Atlanwood” project with the aim of showing furniture applications.

In the creation phase, it was specially considered the raw material characteristics.

Design proposals resorted to solutions seemingly simple, allowing to show off wood’s decorative possibilities and, particularly, its marked graining.

Also, wood’s natural colour and its suitability to receive all sort of decorative products, makes possible to have a wide range of finishing possibilities (examples in pages 158-161).
CONSTRUCTION APPLICATIONS
Apartments in Arès

In June 1999, in the centre of Arès (Arcachon basin) the architect Bernard Bühler created 38 apartments within four buildings.

In this work, the wood is not used as a structural component but as the prominent material of a double façade, what makes it into the most characteristic element in the construction.

The façade, which is located at 1.5 m from the building wall, helps to create an intermediate space between public and private areas. Acting as a filter, this chamber enables a glimpse from the outside into the inner common areas, and from these into the public square. In both cases, this is a veiled observation, more suggestive than revealing and preserving the completeness of each area.

The façade unifies the common and private areas of the apartments, providing terraces and corridors. At the same time, sunbeams penetrate through the wood sheets, creating a variable habitat throughout the day.

The solution also helps to integrate the building in its surrounding area, by adapting the axis of the façade to the curve of the square located opposite to the building. At the same time, it stands out the dormers of the four buildings.

The main structure of the building was built in concrete. As it can be seen from the images, part of the secondary structure (vertical elements) is metallic. The wooden pieces are fixed individually onto this metallic structure, acquiring a slight curvature.

The wood of marine pine is a perfect solution, due to its aesthetical qualities and durability, as well as to its flexibility in finding an architectonic solution aimed at creating unique areas.

10 years after its construction, this set of villas is already and integrant part of the centre of the Arès town.
industrial applications of Pinus pinaster
CAFSA headquarters in Bordeaux

The erection of this building was the solution found for enlarging the premises of CAFSA (Cooperativa Agrícola y Forestal Sur-Atlántico) to receive the new information technology branch (S. DIGIT) and provide own rooms to impart formation.

The new CAFSA building in Pierroton (Bordeaux) comprises a 457 m² useful surface distributed by two floors. This area resettles the new information technology installations, the geographic information services, the forest management consultancy offices and the shared services that include a meeting room and training rooms.

Designed by the architect Emmanuel de la Ville, this building is inspired in the shape of Landes’s traditional barns, integrating the forest tradition of the region with the modern technology required by CAFSA to develop their work.

The outcome, that gathers an adequate technology to a traditional image, can be easily repeated and confirms the wood economic competitiveness against solutions with other materials, such as concrete. Its total budget amounted to 511,000 euros and execution time was 8 months (1 month for foundations and sill, 3 months for structural components and 4 months for indoor finishes).

At the same time, the building is a gallery of possibilities offered by maritime pine (Pinus pinaster) wood-based products, and of combination possibilities of wood with other materials.

During the work development, several solutions and construction details were studied. For instance, the façade combines pine wood preserved for a risk class 4 with aluminium carpentry. The design (the roofing structure, the gutter, etc) was planned to avoid water retention, and as such improve wood preservation.

Inside the building, there are multiple solutions carried out with pine wood. The wall panelling shows solid wood friezes, 18 mm thickness OSB and grooved 15 mm thickness plywood.

The staircase combines solid pine steps and handrails with a steel bearing structure. Frames, bookcases, parquet are from solid wood. The flooring was treated with finishing oil. Other carpentry and furniture elements used MDF and chipboard.

Glued laminated timber T-double joists with OSB core and LVL sides were mainly used in the structure. Solid wooden beams of 120 x 90 mm were also used.
industrial applications of Pinus pinaster
In his works, the architect François Gassan (who is quite used to work with wood in general and maritime pine in particular) is used to build in assymetrical lands, using piles to sustain its houses over dunes, preserving natural volumes and promoting their integration. “A house the lesser we can see it, the more beautiful it is”, assures the architect.

Several different materials are combined (wood, steel, concrete,...) and wood species (maritime pine, tropical hardwood,...). His constructions reflect life styles required by his customers. One of his main objectives is a planning based on the behaviour guarantees in time. Notwithstanding, this ethical limit does not hinder the audacity of his proposals.

The assemblies are performed, taking into consideration the placement of each element in the construction and the conditions it will be subject to. The joinings are performed, so that possible movements of the material in the future are not restrained.

The wood of the outer coatings is from tinted maritime pine and was not planed to keep the natural appearance and the contrast of texture and light. The parquet was made of guayacan. Two dominating colours favour the construction integration: the dark brown tone of the tree bark and the blackish green.

“Wooden houses should be the outcome of a chain of professions: sawyer, carpenter and architect, each one concerned in adequately meeting the needs of the following” states Gassan.
Villa at St. Girons

The house is located in front of the ocean, on the summit of a dune, it is exposed to the light and all other elements. The architect H. Blanchot conceived it perfectly adapted to this natural environment.

The villa has been entirely built with marine pine. The wood has been treated in autoclave for risk class IV and has not received any additional decorative surfacing. The treatment has provided to the wood a homogeneous appearance, which is still kept five years later. Despite its exposure to the strong storm occurred in 1999, there were neither remarkable structural damages nor changes.

There is a double reason for the architect to select marine pine; on the one hand, pine wood satisfies all aesthetic requirements of the work and, on the other, it meets all technical needs. Besides, the origin of the selected raw material is local. The obtained result consolidates its selection, since the villa is fully integrated in its surroundings and all technical solutions were solved satisfactorily, thanks to the carpenter technical knowledge and experience.

The exposure coincides with the villa rear façade, the number of hollows were reduced here, mainly to favour air circulation during the summer. On the contrary, the house opens up on the western and southern sides. These façades consist of wide galleries protected by the covering eaves and the placement of grids that filter the direct incidence of the sunlight.

The vertical one-pieced bearing elements were decided to be placed at a high section. They delimit both the outer and the inner spaces of the house, considering the orientation of the building. As a sample, the enclosed table shows that the sizes of the used elements oscillates between 150 x 80 mm and 240 x 120 mm. The wall panelings are 96 x 36 cm.

With the exclusive use of maritime pine wood, this solution provided a balanced construction both in quality of life to the residents and in the respectful integration within its surrounding area. It gathers sand, western Atlantic space, wind and sun.
The Graoux Centre

The Graoux Center is located in the heart of the natural regional Park of Landes in Gascogne, one of the largest woodlands in Europe, in the intersection of Camino de Santiago de Compostela (Way of St. James) with the river Leyre.

The Center is part of the natural park; its purpose is to promote the nature tourism and the discovery of the environment to a vast range of people: visitors, organised school groups, etc. It is open every day of the year and provides a wide offer of sport and recreational activities to their visitors.

Created in 1990 by the architecture firm BCCR REOL of Bordeaux, this project proposes a set of buildings where wood is combined harmoniously with other materials (metal, glass, etc).

The two-levelled reception building is located on the side of a hill close to the watercourse. A stairway bridges this building with the multi-use room. The set is complemented by nine wooden villas that altogether can receive 60 people in double and triple rooms. The meals are served in an organised space around a large chimney.

The wooden structural sections are designed with double elements of 5 x 10 cm and 4.5 x 15 cm in the higher spaces. The distance between elements is of 50 or 60 cm. The pannelling incorporates a plaster and a moisture insulating sheet.

To guarantee their durability, all claddings were made by marine pine wood treated in autoclave for a risk class IV.

To accomplish the resistance to fire standards, the roofs and the false roofs of the administrative building were performed with a fire-proofed chipboard, surfaced with a pine veined melamine. The cover structure is made of glued wooden laminates.

From an aesthetics and functionality viewpoint, the buildings accomplish their purpose and the set is fully adapted to this natural environment, enabling a complete integration of the resident with the surrounding area.

15 years after their construction, the buildings still perform their functions and the wooden elements that were left rough went through the ageing process, getting a natural patina and without requiring later maintenance. The strong storm occurred in 1999 did not produce any structural damage.

The aforesaid is also the outcome of a careful design in the creation of wooden construction solutions. Auxiliary elements that do not interfere with the solutions proposed from the architectural point-of-view, such as: the use of façades with big eaves, constitute good examples of the passive protection of wood.
CONSTRUCTION APPLICATIONS
Duplantier house

With this accomplishment, the architect Laurent Duplantier confirms the possibility of integrating an architectural project in a natural setting without changing it, even when the project location is an exceptional habitat. For that, heavy equipment to prepare the land was avoided (bulldozers or similar).

The outcome confirms the success of the integration of both the house within the nature and the variety of the materials employed; concrete, steel, glass and other wooden species were selected by aesthetic and technical reasons.

The house is located on a dune that is still intact. The foundations and the concrete masonry are supported on a pile system, which is driven into a sandy soil, and allows the house to be set up over the soil level. This solution enables air circulation and avoids direct contact with the soil of any wooden element. In turn, with the purpose of preserving the bond with the nature, the architect favoured the presence of hollow crystal surfaces.

The vertical bearing structure under the villa is made of concrete. In height the pillars were made of galvanised steel to give lightness to the shole setting (with a diameter of 12 cm). The wooden structure forms a framework of 3.5 x 3.5 m. The beams have sections of 30 x 10 cm and the joints of 20 x 8 cm (both are standardised sizes of marine pine structural wood).

The flooring, walls and the roofs are made of wood and combine several coniferous species. A marine pine framework surfaced with a 10 mm thickness plywood board contrasts with the flooring in orange tonalities made of Oregon pine. Canadian cedar wood was used for the external coating.
UCPA
Soustons’s holiday and leisure sport centre

The Center is located at the far Southern Landes coast between Hossegor and Biarritz, opposite to the Pyrenees and the Spanish coast. This centre consists of several elements set out homogeneously by the architect M. Mogan. This complex is set within a lovely natural area between a lake and a beach surrounded by a pine forest. It includes a reception venture, commercial areas, common use areas and private villas.

Here the combination of wood with other materials produced a variety of construction solutions. Both wood and galvanised steel were left raw, to enable their natural evolution and ageing in time. The external carpentry works are made of anthracite grey aluminium to match with the other materials.

Pine is mainly used in interior coatings, as well as in some structural elements and in the external coating of the villas. In the common areas, structural elements and handrails are made of galvanised steel.

Decks are made of steel (initially, they were projected in zinc, but this possibility was discarded for economic reasons). Villas are developed around a central concrete core over which the wood framework is set.

Wood sections are adapted according to their usage. Considering the small size of the buildings, it was decided to opt for a classic structural solution with a primary framework, a secondary framework, OSB, and external sheet and a moisture isolator. The size of the selected sections is 18 x 6 cm.

The walls inside the villas have an insulating plafond ("Placostyl"). The façades structure/configuration are made of traditional panels.

The structure of some common areas (restaurant, kitchens, social club, etc.) were made of glued laminated timber lasur surfaced for aesthetical reasons.

According to the architect, the whole architectural solution was based on “simple” materials without relevant technical achievements needed.
CONSTRUCTION APPLICATIONS
Maison Rozes

This building opposite to the sea is set on a sand dune. With an overall surface of approx. 300 m², more than a house, this is a residential complex.

The construction general principle is based on a post-beam framework, with the walls acting as a filling element, what leaves great freedom to the carpentry design and to the indoor separating elements. The wood construction was made over a previous concrete construction. The new pillars go through the old part and become fixed to the ground to support alone the upper part of the construction. The wood is never in direct contact with the ground.

The house is exclusively made of maritime pine and was rigorously projected. The owner has personally selected all trees that were cut in the winter. Wood was left to dry under a covering for several months. A year went by between the timber felling and cutting, 60 m³ of wood were used to accomplish this work.

Wood was processed as if it were greenwood, the framework was made using the traditional method of tongue and groove, through acacia plugs. Only resin pines were selected, due to their high content of resin that grants natural durability and a strong aesthetical quality (the wood was not treated).

With the exception of tiles, which were manually recovered, all other elements are made of wood. The walls are made of 40 and 27 mm elements set at the outer part of the structure. An air chamber provides thermal insulation both in winter and summer.

Terraces were constructed with a 45 mm thickness boarding, oil impregnated to preserve from fungi and xylophagous insects. The wood, despite horizontally settled and exposed to rain and sun, has only changed its appearance.

The external coating is simple and consists of boards and fishplates. The sawn boards were only superficially sanded to avoid xylophagous insects settlements.

Traditional sections were selected due to their role and to the mechanical resistance demands. During the handmade assembly of the structural framework, the carpenter was called to improve an aesthetical parameter, displacing a post to attune the visual perception of the area or changing the beams section for the same reasons.

The villa stands for a framework carpentry house where the raw material – maritime pine – was turned into “life space” by the carpenter Franck Strumia, a heir and transmitter of an ancient construction tradition. As of an ancient tradition, the outcome was a modern and attractive house, designed to coexist in perfect harmony with the nature in the middle of the 21st century.
St. Paul les Dax Gymnasium

The gymnasium was designed by the architect Dumon, a supporter of the wood usage, particularly maritime pine. This architect has created numerous sporting equipment works (about fifty) and also social construction and independent villas.

This gymnasium was erected in 1998, has an area of 44 x 24 m, and can host 300 people in its premises.

The structure perimeter was performed at a brick factory. The curved decking is supported on some pillars and its framework consists of glued laminated timber beams of maritime pine. The external coating next to the front part of the building was built in maritime pine wood with a pigmented decorative finishing.

The decking structure consists of 5 laminated timber beams with a 28 m span and a section of 15x50 cm. Part of the beams edges (30 cm) is hidden by a false ceiling. Beams are braced by a triangulation made of 20x5 cm maritime pine sections tightened by cables.

The decking/covering was made of a very light metal incorporating an insulating element. The flooring is made of a concrete sill with a resin coating.

The architectonic principles of this building are simple; the space created is comfortable and pleasant, besides meeting perfectly the promoters and the sport people needs.

Since 1998, this building is a perfect example of the integration of several materials and maritime pine wood. From a technical viewpoint, the laminated timber beams grant character and lightness to the structure. In turn, the presence of wood grants warmth to the whole set.

The selection of maritime pine is both related to the previous experience of the architect, and also to his will of employing and valuating a local raw material – a wood from his country - is his works.
The Bartherotte cabins

The brothers Hadrien and Martin Bartherotte called “cabins” to their undertakings, like the cabins used by oysters growers and resin collectors. The current “cabins” are entirely made of maritime pine (Pinus pinaster) and occupy different areas 70, 160 and even 300 m².

The whole work performed is inspired and done according to the wood construction tradition, including the individual marking of each element according to the carpenters code, so that the house can be disassembled and rebuilt if that is the case.

All indoor and outdoor wood was not planed to keep its natural appearance. Furniture was also made of maritime pine, from beds until kitchen and bathroom elements. To accomplish this, each cabin constitutes an investigation work on the possibilities of combining wood according to its colour and veins, in order to improve the beauty and functionality of the space. As such, the most reddish wood with a higher resin content was used in the bathrooms, to reduce possible effects from high moisture contents.

Although this work is a true exhibition of the possible maritime pine usages, the outcome is not excessive and helps to keep distinct environments full of seduction.

The framework is a perfect example of a pole and beam system, where poles act as bearing elements whereas horizontal beams complete the structure. The resulting structure is similar to a boat’s with a predominant horizontal framework. The wood was treated as a risk class II.

The assembly is made through acacia plugs that help to reinforce the structure stability, in case there are wood retractions. Like this, the framework is assembled, so that when the wood dries it reinforces the assemblies.

There is no sill (ventilation is guaranteed by the created hollow). Wood is never in direct contact with the ground.

The external boarding was performed with 40 to 50 cm width and 4 cm thickness maritime pine boards, selected to grant an homogeneous appearance. Normally, the boards come from the lower part of the tree trunk to obtain the required widths.

The cabins construction was perfectly integrated in the surrounding area, according to a project that considered the preservation of the existing trees and the integration within a forest environment. In turn, the maritime pine wood can show its richness and diversity. It is a bright wood that in time will acquire a bronze patina that will grant warmth to the cabins.

With an useful surface of 160 m² including the terrace, the whole work was performed in about 4 months with a 6-person team.
School premises in Teich

This project is the first phase of an educational campus that will comprise 13 classrooms. After a first phase where the first 7 classrooms were built, it is foreseen to complete the educational area and enlarge the existing schoolyard to create a restaurant.

For this project, the architect M. Gorce proposes a global concept based on the joint use of wood and concrete, combined with solar radiation. This strategy consists of profiting from the materials complementarity to achieve an optimal solution in the structuring of the buildings and to select its geographic orientation. Wood is used in external coatings, structure and protected interior walls. In turn, concrete provides the thermal inertia of the building, based on the uptake of solar radiation.

The project achieves a full integration in the environment that abuts with a forest. Access is direct and comfortable through a large pedestrian way, where bicycles can circulate. Moreover, the preservation of the existing bushy vegetation, the placement of wooden sleepers on the sand that are full of pine needles and the vegetation covering of the decking reinforce the integration of this work in the surrounding nature.

The bearing structure framework (beams and pillars), as well as the façades coatings are made of wood. The main structural elements in glued laminated timber; the secondary structure and the walls framework of maritime pine and spruce, and the façades were also made of maritime pine. The covering was made of green slate. Durability and sanitary quality determined the selection of the interior materials, to be placed over the cellulosic and hemp insulating basis. The interior walls were made of plaster sheets reinforced with cellulosic fibre. The total cost of this complex amounts to 1.5 million euros. Wood carpentry represents almost 20% of the total cost.

The whole buildings are grouped in E-shape to protect the complex from the predominant winds. The main building develops curved shapes. In turn, the classrooms adopt structural and regular forms fit for their purpose. The large eaves and the schoolyard covered areas offer protection from rain and help to keep shadow areas.

This complex is a reference on the possibilities provided by wooden constructions combined with other materials to provide functional areas warm and comfortable. The aim here is to build a school campus integrating several buildings with different purposes in the surrounding environment. Above all, the underlying idea was to create a space where children live and learn in an architectonic complex that respects the surrounding area and promotes the quality of the “work” conditions.
industrial applications of pinus pinaster
Outdoor works and urban furniture

The capacity of fitting wood constructions to irregular grounds, while respecting the surrounding natural configuration makes from this material an adequate choice for the construction of small auxiliary works, such as gateways, pedestrian accesses and footbridges. The following images prove the numerous integration possibilities offered by pine wood in urban and recreational areas.

As can be seen, the combination possibilities with other materials (steel, concrete, etc.) or with woods from various geometries and types (roundwood, sawn timber, treated in autoclave, with protective and/or decorative surfacings, etc.) contribute to the development of new applications. Imagination is the only limit to the creation of functional and attractive areas perfectly fit to the surroundings. All this can be achieved by using a local raw material at a relatively reduced cost.

By following some elementary rules concerned with the construction design (protect extremities/heads/headings, round edges, keep a distance from moisture accumulation areas, etc.) combined with an appropriate wood treatment for the corresponding risk class helps to obtain excellent durability results.
industrial applications of Pinus pinaster
APPENDIX 1

APPEARANCE/VISUAL grading CRITERIA (NON-STRUCTURAL USAGES)
For a long period of time there were no standards concerned with the visual grading of Pinus pinaster wood for non-structural purposes. This situation led the manufacturers to develop non-standardised grading rules.

Currently, there are European standards that standardise the visual grading of sawn timber for non-structural usages, UNE-EN 1611-1:2000 “Sawn timber: Visual grading of softwoods. Part 1: European spruces, firs, pines, Douglas firs and European larches”. Currently, the application of these standards is still reduced due to the lack of knowledge from the producers and consumers side, together with the well disseminated traditional classification systems.

The following table contains the various standards or decorative appearance/visual grading rules available for maritime pine sawn timber by region.

<table>
<thead>
<tr>
<th></th>
<th>Aquitaine</th>
<th>Galicia</th>
<th>Portugal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial rules</td>
<td>Commercial rules for</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(non standardized)</td>
<td>the classification of</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>maritime pine sawnwood</td>
<td></td>
</tr>
<tr>
<td>National standard</td>
<td>NF B 53520</td>
<td></td>
<td></td>
</tr>
<tr>
<td>European standard</td>
<td>EN 12246</td>
<td>EN 12246</td>
<td>EN 12246</td>
</tr>
<tr>
<td></td>
<td>EN 1611</td>
<td>EN 1611</td>
<td>EN 1611</td>
</tr>
</tbody>
</table>

A new visual grading standard for the Galician pine for carpentry purposes is currently under study in Galicia. The purpose is to achieve a new classification (by quality and size) that promotes the trade of this wood for some applications.

EN 1611-1:2000 Standard


These standards, transferred from the European Standard EN 1611-1, develop the visual grading criteria of sawn timber, dry or green, from several European softwoods (European spruces, firs, pines and Douglas firs).

The pieces are classified according to defects (gems, resin ducts, fibre deviation, fungi attacks, etc.) on the faces and edges of sawn timber:

Two procedures are established for the grading:

- G2. Grading according to knots presence (in two faces) and other features.
- G4. Grading according to knots presence (in two faces and two edges) and other features.

If there is no coincidence in the quality of the two faces, the standard establishes that the piece quality will be considered at the immediately above level of the one corresponding to the worst quality face. As such, while applying the G4 criterion, the piece quality will be the one corresponding to the worst quality edge.

Once the grading procedure is decided, the sawn timber will be divided by category into stacks, each piece will be individually classified after checking visually the accomplishment of the grading criteria.

The standard establishes five categories:

Quality 0: Special
Quality 1: First
Quality 2: Second
Quality 3: Third
Quality 4: Fourth
The following tables present the classification according to knots and other features, both for grading according to criterion G2 and G4.

### Defects and Criteria

<table>
<thead>
<tr>
<th>Note</th>
<th>Defect</th>
<th>Maximum values for G2 and G4 criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Quality 0</td>
</tr>
<tr>
<td>(A)</td>
<td>Knot size (round or oval) at the classification/grading face</td>
<td>Sound and adherent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dead or partially adherent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>With phloem</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Putrid or loose</td>
</tr>
<tr>
<td>(D)</td>
<td>Knot size (round or oval) at the classification/grading edge</td>
<td>Sound and adherent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dead or partially adherent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>With phloem</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Putrid or loose</td>
</tr>
<tr>
<td>(C)</td>
<td>Number of knots at the worst quality metre of each face</td>
<td>Number of total knots</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Putrid, loose or phloem</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ear or eared face</td>
</tr>
</tbody>
</table>

(*) Only applicable to phloem knots.

### Qualities

<table>
<thead>
<tr>
<th>Quality</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
</table>

### Maximum ø in % de thickness of the piece

<table>
<thead>
<tr>
<th>Quality</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
</table>

### Edge knots

(Annex 1) Knot sizes equal or lower than 10 mm are not considered, except those putrid or loose. (B) For European spruces, firs and Douglas firs whose width is 225 mm or higher, the maximum size of knots should be increased 10 mm. Likewise, in pine for a piece width equal or higher than 180 mm, it is possible to increase the knot size in 10 mm. (C) For a width larger than 225 mm, the total number of knots should be increased by 50 %. (D) Edge knots can be admitted in pieces with qualities G4-2, G4-3 and G4-4.
### Other features

<table>
<thead>
<tr>
<th>Note</th>
<th>Defects</th>
<th>Maximum values for G2 and G4 criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Quality 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cutting idiosyncrasies/features</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gem</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Face width from one edge to the other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Width on the edge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moelle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cracks on the classification/grading face</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Head thickness &lt;60 mm (% of width)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Head thickness &gt;60 mm (% of width)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passed %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Defects (in 2 m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Face deflection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thickness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Edge deflection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Warping (%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Curl (1%)</td>
</tr>
</tbody>
</table>

### Biological changes

<table>
<thead>
<tr>
<th>(F)</th>
<th>Rottenness</th>
<th>Excluded</th>
<th>Excluded</th>
<th>Excluded</th>
<th>Excluded</th>
<th>Some traces</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chromogen fungi and coldness</td>
<td>10 %</td>
<td>50 %</td>
<td>Without restraints</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface</td>
<td>Excluded</td>
<td>Excluded</td>
<td>20 %</td>
<td>100 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Insects attacks (in any face)</td>
<td>Excluded</td>
<td>Excluded</td>
<td>Excluded</td>
<td>Non active and black peckings &lt;2 mm in 15% of the surface</td>
<td>Non active and black peckings &lt;2 mm</td>
</tr>
</tbody>
</table>

(E) The abnormal fibre deviation includes interfaced fibre (F) Determined according to standard EN 1311. If there are several affected areas, they should be summed up.

### EN 12246:2000 standard

#### "Wood quality classes for pallets and packages"

This standard considers two classes (P1 and P2) of wood for the manufacturing of industrial packages and reusable pallets.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>P1 Class</th>
<th>P2 Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knots</td>
<td>Knots should be measured on the two faces as per 4.1.2 of the EN 1310:1997 standard. Those at the edges should not be considered. Knots lower than 10 mm should not be considered. Grouped knots should be considered as individual knots.</td>
<td>Knots should be measured as per EN 1310 standard.</td>
</tr>
<tr>
<td>Adherent knot</td>
<td>≤ 33% of the piece width</td>
<td>≤ 60% of the piece width</td>
</tr>
<tr>
<td>Loose knot</td>
<td>≤ 20 mm</td>
<td>≤ 30 mm</td>
</tr>
<tr>
<td>Hidden knot</td>
<td>≤ 30 mm</td>
<td>≤ 30 mm</td>
</tr>
<tr>
<td>Visible phloem</td>
<td>Admissible on one face</td>
<td>Admissible on one face</td>
</tr>
<tr>
<td>Hidden phloem</td>
<td>Admissible</td>
<td>Admissible</td>
</tr>
<tr>
<td>Cracks</td>
<td>Cracks at extremeties, faces and edges will be considered. They should be measured as per EN 1310 standard.</td>
<td></td>
</tr>
<tr>
<td>Face cracks</td>
<td>Admissible*</td>
<td>Admissible*</td>
</tr>
<tr>
<td>Passing crack</td>
<td>1 crack per board ≤ once the board length</td>
<td>1 crack per board ≤ twice the board length</td>
</tr>
<tr>
<td>Resin pocket/bag</td>
<td>Only admissible on one face</td>
<td>Only admissible on one face</td>
</tr>
<tr>
<td>Gem</td>
<td>Not admissible</td>
<td>Not admissible</td>
</tr>
<tr>
<td>Blue stain</td>
<td>Vide **</td>
<td>Vide **</td>
</tr>
<tr>
<td>Biological alteration excepting blue stain</td>
<td>Not admissible</td>
<td>Not admissible</td>
</tr>
<tr>
<td>Active pecking</td>
<td>Not admissible</td>
<td>Not admissible</td>
</tr>
<tr>
<td>Black pecking</td>
<td>Only until 5 hollows of ≤ 3 mm diameter are admissible</td>
<td>Only until 5 hollows of ≤ 3 mm diameter are admissible</td>
</tr>
<tr>
<td>Gem (without bark)***</td>
<td>Gem should be measured as per 4.8 of EN 1310:1997 standard. It is admissible until 25% of the piece width, until 33% of the thickness and it is admissible on both sides of the face if it is ≤ 10 mm for each side.</td>
<td>It is admissible until 30% of the piece width, until 50% of the thickness and it is admissible on both sides of the face if it is ≤ 20 mm for each side.</td>
</tr>
</tbody>
</table>

(*) Except at the nailing surrounding area (refer to the corresponding product standards).

(**) The blue stain does not affect mechanical properties. The blue stain can be avoided through a chamber drying process and other methods.

(***) If the gem is excluded, the product standards or the contracts should define it.
Rule for the commercial grading of Galician pine sawn timber
(common designation of Pinus pinaster from Galicia)

This rule is used for the grading of board and plank for construction and carpentry.

The quality grading is divided into 4 main types:

**Clean timber**
- Free from defects, such as knots and resin pockets/bags.
- Without gem on the edges and without blue stains on any of the pieces.

**Special timber, semiclean, or carpentry**
- Until 2 knots or other small defects of lower size than 25 mm per piece.
- Blue stains not admissible.

**Current timber (most common quality)**
- Non loose knots and other defects without limits are admissible, unless they affect the mechanical stability of the piece (example: "moustache-shaped" knots). In some strict situations and in some pieces, gems on the edges and blue stained areas are admissible.

Note: In some areas (for instance: Pontevedra), there is another quality division known by “tarima”. This type corresponds to the best quality wood selection of the "current" timber.

**Wooden surfacing board**
- Defects without limitations are admissible.
- It also admits lateral gems and coloration by chromogen organisms.
- The most common thickness for this quality is 25 mm.

The boards classified under "clean" and "special" qualities are also called “semiclean” or “carpentry” are intended for carpentry and furniture. This type of wood has normally a 2.5 m length and no grading by width ("straight widths"). Just like with pallets, currently the package industry also tends to use 2.5 m timber with a predetermined width. For this reason in the last years, some sawmills have introduced the grading system by fixed widths and offers timber packages with a single width size.

The most common board thicknesses are 15, 20, 25, 30 and 40 mm. Planks have thicknesses from 50 to 55 mm and the board from 70 to 76 mm.

With regard to widths, the most common grading is the following:
- 10 to 16 cm (in "straight widths").
- 17 to 24 cm (in "straight widths").
- Higher than 25 cm.

Companies that carry out the timber drying process at the open air, normally deliver timber with a moisture percentage of approx. 20%. Companies that have drying chambers deliver timber with a 10 - 12% moisture content.
Classification of maritime pine timber

For the grading of maritime pine roundwood, there are only some national rules adopted by the professional sector in France. Although this document has been proposed for a standard, it has still not been formally recognised.

Sizes

<table>
<thead>
<tr>
<th>Class</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short wood</td>
<td>&lt; 3 m</td>
</tr>
<tr>
<td>Medium length</td>
<td>3 - 5 m</td>
</tr>
<tr>
<td>Long wood</td>
<td>&gt; 5 m</td>
</tr>
</tbody>
</table>

The minimum oversize is 3 cms. The tolerance admitted is 1 centimeter per meter of length.

The length is measured using intervals (10 - 10 or 25 - 25 cms).

Indicatively, the volume is given with a 3% tolerance.

<table>
<thead>
<tr>
<th>Diametric classes</th>
<th>Thinner section</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>6 - 19 cm</td>
</tr>
<tr>
<td>D2a</td>
<td>20 - 24 cm</td>
</tr>
<tr>
<td>D2b</td>
<td>25 - 29 cm</td>
</tr>
<tr>
<td>D3</td>
<td>30 - 38 cm</td>
</tr>
<tr>
<td>D4</td>
<td>40 - 49 cm</td>
</tr>
<tr>
<td>D5</td>
<td>50 cm and more</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quality class</th>
<th>Sawn &amp; veneer production</th>
<th>Trituration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conical shape</td>
<td>A  B  C  D  PT  T</td>
<td></td>
</tr>
<tr>
<td>- Average ≤ 5% del Ø</td>
<td>o  o  o  o  o  o</td>
<td></td>
</tr>
<tr>
<td>- Strong &gt; 5% del Ø</td>
<td>o  x  o  o  o  o</td>
<td></td>
</tr>
<tr>
<td>Cracks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Section</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Heartwood</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Round cracks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Felling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Side cracks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alterations related with fungus activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Stained wood (excepting bluing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Rot wood (initial state)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Soft-rot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Blueing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insects attacks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Small hole</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Big hole</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Burned surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Scared wounds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Strange bodies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Dried trees</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

x - Not admissible                       | (4) 1 superficial wound (less than 1 cm from cambium layer) | (5) 2 superficial wounds. |
○ - Admissible                           | (6) 3 superficial wounds | (7) More than 3 superficial wounds. |
Specifications of the purchase conditions

The purchase specifications is a commercial document performed individually by a company to collect its raw material needs and specific demands. Normally, this document is supported on grading rules recognised by the sector.

Example: Wood production for pallets manufacturing with a production line with chipper carter and twin saws

Length
- Nominal length: 2.40 m
  Requested length: 2.50 m ± 20 mm
- Nominal length: 2.00 m
  Requested length: 2.10 m ± 20 mm

Diameter of the thinner point
- For a width of 2.50 m
  Minimum: 160 mm / Maximum: 300 mm
- For a width of 2.10 m
  Minimum: 200 mm / Maximum: 300 mm

Conformity demands
- Deflection: 5 cm over length
- Conicity: lower than 40 mm/m

Admissible idiosyncrasies
  Knot crowns (upright):
- 4 as a maximum over 2.5 m
- 3 as a maximum over 2.10 m

Excluded features
- Trunks with blue stains or rottennesses
- Trunks with cracks or slots

Allowed tolerance
- Until 10 non-conformed trunks by truck that should be replaced by conformed pieces by the supplier.
APPENDIX 2

grading CRITERIA FOR STRUCTURAL USAGES
Wood is a renewable material, with various properties according to its species, genetics and growth conditions. This properties variety is also present within the same tree, where we can find relevant variations both widthwise and lengthwise. Furthermore, the sawing orientation has a remarkable impact on the product properties.

As this variability affects the timber mechanical properties, it is necessary to perform a grading that attributes to each piece reference values of resistance according to its characteristics.

In this way, it is possible to have a standardised material available, in terms of resistance, size (width, thickness and length), physical characteristics (moisture content, density) and aesthetical attributes (De esta forma, es posible disponer de un material normalizado en términos de resistencia, dimensión (anchura, espesor y longitud), características físicas (contenido de humedad, densidad) y atributos estéticos (nodosity, gems, biological changes). Besides, these products should be assigned with the CE marking.

There are two systems for the grading of sawn timber for structural usages:

- Appearance/Visual grading.
- Machine/Mechanical grading.

In the Appearance/Visual grading, the following procedure is used to assign qualities and resistance classes:

**Structural visual classification procedure and class of resistance assignment**

<table>
<thead>
<tr>
<th>Structural timber provenience</th>
<th>Aquitaine</th>
<th>Galicia</th>
<th>Portugal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood specie</td>
<td>Pinus pinaster</td>
<td>Pinus pinaster</td>
<td>Pinus pinaster</td>
</tr>
<tr>
<td>Standard for visual classification of structural timber</td>
<td>NF B 52-001</td>
<td>UNE 56544</td>
<td>NP 4365</td>
</tr>
<tr>
<td>Class of quality assignment to timber</td>
<td>ST-I, ST-II, ST-III</td>
<td>ME-1, ME-2</td>
<td>E</td>
</tr>
<tr>
<td>Class of resistance assignment</td>
<td>ST-II ↔ C24, ST-III ↔ C18</td>
<td>ME-1 ↔ C24, ME-2 ↔ C18</td>
<td>E ↔ C18</td>
</tr>
</tbody>
</table>

The UNE 56544:2003 standard “Appearance/Visual grading of sawn timber for structural usage” establishes a measurement methodology and a defect evaluation, classifying wood into two qualities (ME-1 and ME-2).

This standard classifies greenwood and dry wood, according to the following criteria:

- **Moistured wood**: when the average moisture is higher than 20% (25% for pieces with a section larger than 200 cm²). Wood is labelled as “WET GRADED”.
- **Dry wood**: when the average moisture is lower than or equal to 20% (25% for pieces with a section larger than 200 cm²), provided that no individual measurement exceeds 24% (29% for pieces with a section larger than 200 cm²). Wood is labelled as “DRY GRADED”.

The reasons for an accurate assessment of wood moisture are:

- Wood classified as Wet Graded can gradually develop (after the grading) cracks, warpings and size changes during the drying process. It should be taken into account that this wood has neither incorporated specifications for crackings nor maximum warping demands. On the contrary, for wood classified as Dry Graded cracks, warpings and density assessments are performed.

- Since specifications by crack size are related to a 20% maximum moisture content, wood with lower moisture content can show cracks of a slightly higher size than the specified one, however they should not be considered as lower quality.
- To avoid extensive losses due to an excess of warpings for the purchaser of moistured wood, the standard establishes an indirect form to limit them on the first quality (ME-1). For that, there are specifications for the maximum size of the growth ring, what limits the quantity of juvenile wood among the pieces, which is the main reason for most warpings produced during the drying process.

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Quality</th>
<th>ME-1</th>
<th>ME-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knots specifications</td>
<td>Knots on the face</td>
<td>d ≤ 1/5 de h</td>
<td>d ≤ 1/2 de h</td>
</tr>
<tr>
<td></td>
<td>Knots on the edge</td>
<td>d ≤ 1/2 de b y d ≤ 30 mm</td>
<td>d ≤ 2/3 de b</td>
</tr>
<tr>
<td></td>
<td>* For sections whose relationship is h/b ≤ 1.5, the four surfaces will be considered as faces. Knots with a lower or equal diameter to 10 mm can be depreciated, except those parasites knots.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specifications for the maximum ring width</td>
<td>Maximum ring width (only for greenwood)</td>
<td>≤ 8 mm</td>
<td>without limitation</td>
</tr>
<tr>
<td>Cracks specifications</td>
<td>Drying process cracks (depth)</td>
<td>≤ 2/5 de b</td>
<td>≤ 3/5 de b</td>
</tr>
<tr>
<td></td>
<td>Freezing, ray and acaboaiduras cracks</td>
<td>Not admissible</td>
<td>Not admissible</td>
</tr>
<tr>
<td></td>
<td>* * For sections whose relationship is h/b ≤ 1.5, the four surfaces will be considered as faces.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gems specifications</td>
<td>Gems</td>
<td>Length ≤ 1/4 de L</td>
<td>Length ≤ 1/3 de L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length G ≤ 1/4</td>
<td>Length G ≤ 1/3</td>
</tr>
<tr>
<td>Fiber deviation specifications</td>
<td>Fiber deviation</td>
<td>1:10</td>
<td>1:6</td>
</tr>
<tr>
<td>Other idiosyncacies specifications</td>
<td>Resin pockets/bags and phloem</td>
<td>Admissible if with a lower than 80 mm length.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Compression wood</td>
<td>Admissible in 1/5 of the section or of the piece surface.</td>
<td>Admissible in 1/5 of the section or of the piece surface.</td>
</tr>
<tr>
<td></td>
<td>Pith</td>
<td>Admissible in dry classification/grading</td>
<td>Not admissible in moisture classification/grading</td>
</tr>
<tr>
<td></td>
<td>Mistletoe (See Album)</td>
<td>Not admissible</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blue stain</td>
<td>Admissible</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rottenness</td>
<td>Not admissible</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Galleries of xylophagous insects</td>
<td>Not admissible</td>
<td></td>
</tr>
<tr>
<td>Sizes and tolerances</td>
<td>According to the specifications of UNE-EN 336 standard.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum warpings (not considered while trading moistured wood and referred to by 20% of moisture content)</td>
<td>Face curvature</td>
<td>10 mm (for a 2 m length)</td>
<td>20 mm (for a 2 m length)</td>
</tr>
<tr>
<td></td>
<td>Edge curvature</td>
<td>8 mm (for a 2 m length)</td>
<td>12 mm (for a 2 m length)</td>
</tr>
<tr>
<td></td>
<td>Warping</td>
<td>1 mm (for each 25 mm of h)</td>
<td>2 mm (for each 25 mm of h)</td>
</tr>
<tr>
<td></td>
<td>Transverse warping or curled</td>
<td>1/25 de h</td>
<td>1/25 de h</td>
</tr>
</tbody>
</table>

* For sections whose relationship is h/b ≤ 1.5, the four surfaces are considered as faces.
Appearance/Visual grading of *Pinus pinaster* structural timber in France

The NF B 52001 standard for visual grading of sawn timber for structural usage establishes three wood qualities (ST I, ST II and ST III). The NF B 52001 standard includes the main softwood and hardwood species used in structures, maritime pine is among them. These are the parameters and features used to assign visual qualities to maritime pine.

<table>
<thead>
<tr>
<th>Measurement system for the rings width.</th>
<th>Measurement system for knots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Criterion</th>
<th>ST I</th>
<th>ST II</th>
<th>ST III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width of growth rings (mm)</td>
<td>≤ 6</td>
<td>≤ 8</td>
<td>≤ 10</td>
</tr>
<tr>
<td>Knots diameter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knots on the face</td>
<td>ø ≤ (1/10) of (l)</td>
<td>ø ≤ (1/3) of (l)</td>
<td>ø ≤ (2/3) of (l)</td>
</tr>
<tr>
<td></td>
<td>ø ≤ 15 mm</td>
<td>ø ≤ 50 mm</td>
<td>ø ≤ 100 mm</td>
</tr>
<tr>
<td>Knots on the edge</td>
<td>ø ≤ (1/3) of (e)</td>
<td>ø ≤ (1/2) of (e)</td>
<td>ø ≤ (1/2) of (e)</td>
</tr>
<tr>
<td></td>
<td>ø ≤ 15 mm</td>
<td>ø ≤ 30 mm</td>
<td>ø ≤ 30 mm</td>
</tr>
<tr>
<td>Cracks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crossing</td>
<td>Length ≤ twice the piece width</td>
<td>Length ≤ 600 mm</td>
<td></td>
</tr>
<tr>
<td>Not crossing</td>
<td>Length ≤ half the piece width</td>
<td>Without limitation</td>
<td></td>
</tr>
<tr>
<td>Resin pockets/bags thickness</td>
<td>Not admissible</td>
<td>Admissible if &lt; 80 mm</td>
<td></td>
</tr>
<tr>
<td>Phloem</td>
<td>Not admissible</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiber deviation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local</td>
<td>1:10</td>
<td></td>
<td>1:4</td>
</tr>
<tr>
<td>General</td>
<td>1:14</td>
<td></td>
<td>1:6</td>
</tr>
<tr>
<td>Gems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>Not admissible</td>
<td>≤ (1/3) of the piece length and &lt; 100 cm</td>
<td></td>
</tr>
<tr>
<td>Width</td>
<td>≤ (1/3) of the piece length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biological changes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue stain and mistletoe marks</td>
<td>Admissible</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black peckings</td>
<td>Admissible if they only appear on one face</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rottenness</td>
<td>Not admissible</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum warping in mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(for a 2 m length)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face deflection (mm)</td>
<td>&lt; 10</td>
<td></td>
<td>&lt; 20</td>
</tr>
<tr>
<td>Edge deflection (mm)</td>
<td>&lt; 8</td>
<td></td>
<td>&lt; 12</td>
</tr>
<tr>
<td>Warping</td>
<td>1 mm / 25 mm width</td>
<td>2 mm / 25 mm width</td>
<td></td>
</tr>
<tr>
<td>Curled</td>
<td>Without restrictions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(I = \) piece width
\(e = \) piece thickness

Cracks length is influenced by moisture and as a consequence these limit values for the board are only applicable at the grading time.
Appearance/Visual grading of Pinus pinaster structural timber in Portugal

The Portuguese NP 4305:1995 standard “Maritime pine sawn timber for structures. Appearance/Visual grading” establishes two quality classes: “E” (Structures) and “EE” (Special for structures).

grading criteria:

The standard establishes that pieces with rotten/putrid fungi or insect attacks should be left aside. The presence of chromogen fungi is always accepted, provided that they are within limits that do not compromise the usage.

<table>
<thead>
<tr>
<th>Wood characteristics and defects</th>
<th>Quality class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Class EE</td>
</tr>
<tr>
<td>Knots</td>
<td>Marginal KAR</td>
</tr>
<tr>
<td></td>
<td>Total KAR</td>
</tr>
<tr>
<td>Fibre orientation</td>
<td>&lt; 1/10</td>
</tr>
<tr>
<td>Growth rate</td>
<td>&lt; 6 mm</td>
</tr>
<tr>
<td>Cracks</td>
<td>Not pasantes</td>
</tr>
<tr>
<td></td>
<td>Marginal KAR</td>
</tr>
<tr>
<td></td>
<td>Total KAR</td>
</tr>
<tr>
<td>Cracks</td>
<td>Pasantes</td>
</tr>
<tr>
<td></td>
<td>Marginal KAR</td>
</tr>
<tr>
<td></td>
<td>Total KAR</td>
</tr>
<tr>
<td>Gems</td>
<td>&lt; 1/3a; (</td>
</tr>
<tr>
<td>Curvatures</td>
<td>Face (in 2m)</td>
</tr>
<tr>
<td></td>
<td>(interpolate for intermediate thickness values)</td>
</tr>
<tr>
<td></td>
<td>Edge (in 2m)</td>
</tr>
<tr>
<td>Warping (in 2m)</td>
<td>Z (</td>
</tr>
<tr>
<td>Transverse warping</td>
<td>Xt (</td>
</tr>
<tr>
<td>Resin pockets/bags or phloem</td>
<td>Not pasantes</td>
</tr>
<tr>
<td></td>
<td>Pasantes</td>
</tr>
<tr>
<td>Pith</td>
<td>Not admissible</td>
</tr>
</tbody>
</table>

**Measurement method of knots.** Difference between marginal KAR (thicker striped area) and total KAR (fully striped area).
Assignment of resistance classes according to the appearance/visual quality. EN 338 standard

The resistance classes system adopted by EN 338 standard “Structural wood. Resistance classes” discriminates the following classes:

Coniferous and poplar. Here there are twelve resistance classes named C14, C16, C18, C20, C22, C24, C27, C30, C35, C40, C45 and C50.

Hardwood. Here there are six resistance classes D30, D35, D40, D50, D60 and D70.

The number next to the letters “C” (coniferous and poplar) and “D” (hardwood) corresponds to the flexion resistance expressed in N/mm². Furthermore, rigidity properties (elasticity modules) and density values are also assigned (see Table 1).

To assign a resistance/strength class according to the species and quality, it is necessary to use EN 1912 standard “Structural wood. Resistance classes. Assignment of visual/appearance and species qualities”.

<table>
<thead>
<tr>
<th>Strength class</th>
<th>Visual/Appearance classification/grading standard</th>
<th>Quality</th>
<th>Trademark</th>
<th>Origin</th>
<th>Scientific classification/grading</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>C24</td>
<td>France NF B 52001:96</td>
<td>ST-11</td>
<td>Maritime pine</td>
<td>France</td>
<td>Pinus pinaster</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spain UNE 56544</td>
<td>ME-1</td>
<td>Maritime pine</td>
<td>Spain</td>
<td>Pinus pinaster</td>
<td>Limited to a 50 mm thicknesses</td>
</tr>
<tr>
<td>C18</td>
<td>France NF B 52001:96</td>
<td>ST-111</td>
<td>Maritime pine</td>
<td>France</td>
<td>Pinus pinaster</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spain UNE 56544</td>
<td>ME-2</td>
<td>Maritime pine</td>
<td>Spain</td>
<td>Pinus pinaster</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Portugal NP 4305</td>
<td>E</td>
<td>Maritime pine</td>
<td>Portugal</td>
<td>Pinus pinaster</td>
<td></td>
</tr>
</tbody>
</table>


**Knots**

Knots diameters are measured perpendicularly to the longitudinal axis of the piece (see figure below).
Knots with a lower or equal to 10 mm diameter can be depreciated, excepting pasantes knots, which are those that appear at least in two opposite surfaces.

Superficial knots on the inner face are depreciated. By inner face it is understood the one closest to the pith (see figure), either contains it or is quite near it. If they appear at the face or edge, they will be measured and evaluated as face or edge knots, respectively.

The bark surrounding the knot will be measured together with it. If the fiber irregularities around the knot cannot be separated from it, the measurement of the knot size should include it. Hollows left by loose knots should be measured as if they were knots.

Knots should be measured in all surfaces where they appear. They should be evaluated according to the relationship between diameter and the size of the surface where they appear, “d/h” for face knots and “d/b” for edge knots. There are two exceptions, margin knots and spike knots.

Margin knots are those face knots located at a “s” edge distance lower than its diameter “d” (see figure). These knots will be measured on the face, but will be evaluated as if they were edge knots: with a ratio between the knot diameter and the piece thickness “d/b”, and will be graded according to the edge knot demands.

Edge knots are those that appear on two contiguous surfaces, face and edge. They are measured on the surface that allows the most perpendicular cut (see figure): if it is the face, they are handled as margin knots, if it is the edge, they are handled as edge knots. In both cases, the evaluation will be “d/b”. In case of doubt, the higher value will be considered (“d1” and “d2” maximum values).
Grouped knots/Cluster knots on the face or edge are those whose distance between cores (see figure), measured according to the longitudinal axis of the piece, is lower than 150 mm; when the piece width is larger than 150 mm or larger than the piece width or when this is lower or equal to 150 mm.

Cluster knots will be measured through the sum of its diameters when they do not overlap to the perpendicular direction towards the longitudinal axis of the piece. When cluster knots overlap to the perpendicular direction towards the longitudinal axis of the piece, they will be globally measured.

Measurement criterion of cluster knots.
Left: knot diameter $d = d_1 + d_2$. Right: knot diameter: $d$.

Definition criterion for cluster knots
If $L_1$ and $L_2 < 150$ mm for $h > 150$ mm and if $L_1$ and $L_2 < h$ for $h \leq 150$ mm.

Resin pockets/bags and pholem
These will be measured lengthwise (in mm), parallel to the piece axis.

Cracks/fissures
Crossed cracks are those that comprise two opposite surfaces. According to their locations, they can be face, edge or head cracks.

As an evaluation criterion, the projection of the cracks depth over the section edge will be determined. The cracks depth will be measured at the deepest spot using a 0.2 mm thick gauge. Those cracks with a lower length than the lower size of the two following cracks will not be considered: $\frac{1}{2}$ of the piece length and 1 metre. Cracks whose width does not exceed 1 mm can be depreciated.
**Fibre deviation**

The standard is concerned with the general deviation, which is measured at the most unfavourable area.

**Growth ring width**

The maximum width of the ring will be determined at the widest straight segment that can be traced perpendicularly to the growth rings and that crosses transversely the piece. The measurement will start at the extremity closest to the pith, and the average width value of the first five growth rings will be determined.

**Gems**

Gem will be evaluated lengthwise, expressed as a fraction of the piece total length; and by its width, measured at the edge or face, as a relative difference between nominal and actual values of the edge or of the face width at the maximum difference spot. If the gem is shown in more than one area of the same face, all lengths will be summed up.

**Knots**

For isolated knots, the evaluation is made by total KAR and by the largest marginal KAR. In case of knot clusters, the total and marginal KAR is calculated for the whole knot cluster.
Knot clusters correspond to those cases when knots are placed in such a way that fibers located among them are inclined (see figure).

*Fiber distribution in knots cluster (left) and isolated knots (right).*

The standard established no distinction with regard to KAR evaluation, between alive and dead knots; hollows left by loosen knots are also considered as knots.

*Fiber deviation*

The fiber inclination is measured against the longitudinal axis of the piece, using a tracer (see figure). The measurement should take place at a reasonable length, so that the general inclination can be determined despite local deformations.

*Measurement of the fiber deviation (x/y).*

**Growth rate**

The growth rate evaluation is carried out by measuring the growth rings average width in milimeters. Its measurement is performed as illustrated in the following figure.

*Measurement of the growth rate (R in mm/no. of growth rings included).*

**Cracks**

Cracks size always corresponds to the distance between its two delimiting lines, and is always measured in paralell to the faces.

**Gems**

The evaluation of this defect is expressed by the quotient between the projection of the gem on the face (edge) and the total width of that face (edge).
Resin bags/pockets and cracks

These are measured like the cracks.

Compression wood

It is acceptable, when it represents a small percentage.

CE Marking

The Council Directive on Construction Products, 89/106/CEE from 21 December 1988 and its transfer to Spain (Real Decreto 1630/1992), France (nº 9 2-467 from 8 July 1992) and Portugal (Decreto-Lei 113/93, from 10 April 1993), demands the compulsory CE marking incorporation on all products covered by this Directive. The Directive establishes as construction products any product, which is produced for incorporation in a permanent manner in construction works, and as such, is affected by the following main requirements:

- Mechanical resistance and stability.
- Safety in case of fire.
- Hygiene, health and environment.
- Use safety.
- Protection against noise.
- Energy saving and thermal insulation.

The conformity in case of products with special demands is defined by national standards transferred from the European standards (harmonised standards) and DITE guides approved by EOTA (European Organization of Technical Approvals). These documents collect the technical specifications necessary for the CE Marking.

With regard to sawn timber for structural use, there is a project of harmonised standard, prEN 14081. As of the definitive implantation of EN 14081 standard, there will be a voluntary period of one year to incorporate the marking and afterwards another one year period for the compulsory marking. After the last period, structural sawn timber products will no longer be traded without the CE Marking. The responsibility for the marking is from the producer, who at least will have to include the following information:

- Structural visual class (ST-1, ST-11, ST-111, ME-1, ME-2, E) or resistance class obtained according to the chosen grading system (visual or mechanical).
- Wood species or wood species group.
- Trademark or the producer identification number.
- Reference standard used for the structural classification.
- Possible wood usages according to its resistance class.
Mechanical classification

The visual grading disadvantage is its very low profitability. As a consequence most pieces are graded/classified into resistance qualities below their actual ones.

For instance, a study carried out with the use of the French visual grading standard NF B 52 001 proved that there is a great difference between results achieved by manual classification and the actual resistance measurement obtained by using destructive tests on all pieces.

This fact led to the development of a wide variety of mechanical grading systems to improve the results of the visual system. The operation of these equipments is based on the measurement of a parameter, an easy to measure indicator, which is related to the mechanical properties of the wood. Among other systems, there are measurements of the elasticity module (by performing a bending resistance test), vibration methods, micro-waves and ultrasounds are also used. There is also the possibility of combining physical and anatomical parameters (density and knots).

With the purpose of improving the correlation between the indicator property and the wood resistance, the grading machines tend to incorporate a large number of mechanical, physical and anatomical parameters. However, the increasing number of measured parameters does not seem to improve significantly the grading profitability, as shown in the following figure:

The results obtained for the Scotch pine grading through several different types of machines are shown below:
Machines for the wood structural grading

As an example, some classification systems are presented here, whose efficiency is already proved.

Cook-Bolinder (TECMACH) e Eurogrecomat 704

These equipments calculate the elasticity module of each piece through the measurement of the load necessary to achieve a certain deflection. Each piece goes through the machine twice, or through two machines to offset the natural deflection of each sawn piece.

**Operating principle of the Cook-Bolinder equipment (TECMACH).**

<table>
<thead>
<tr>
<th>Cook-Bolinder</th>
<th>Measurements</th>
<th>Feeding speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating principle</td>
<td>Load</td>
<td>Deflection</td>
</tr>
<tr>
<td>Measurement of the load necessary to achieve a certain deflection: Distance between rollers: 900 mm</td>
<td>Load of 10 to 20 KN precision &lt; 1%</td>
<td>NO</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eurogrecomat 704</th>
<th>Measurements</th>
<th>Feeding speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating principle</td>
<td>Load</td>
<td>Deflection</td>
</tr>
<tr>
<td>Measurement of the load necessary to achieve a certain deflection: Distance between rollers: 700 mm</td>
<td>2 loads of 0 to 10 KN precision ±0.1%</td>
<td>±5 ±15 mm precision 0.25%</td>
</tr>
</tbody>
</table>
Computermatic and Micromatic

These equipments are bending machines that operate by using a constant load. To estimate the elasticity module, the deformation deflection is measured.

<table>
<thead>
<tr>
<th>Micromatic</th>
<th>Measurements</th>
<th>Feeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating principle</td>
<td>Load</td>
<td>Deflection</td>
</tr>
<tr>
<td>Measurement of the deflection developed by a constant load of 13.3 MPa</td>
<td>NO</td>
<td>0-24 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Computermatic</th>
<th>Measurements</th>
<th>Feeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating principle</td>
<td>Load</td>
<td>Deflection</td>
</tr>
<tr>
<td>Measurement of the deflection developed by a constant load of 13.3 MPa</td>
<td>NO</td>
<td>0-24 mm</td>
</tr>
</tbody>
</table>
**Ersson**

This equipment is based on the measurement of the load to achieve a determined deflection.

Operating principle of the Ersson machine combined with a measurement system with cameras.

<table>
<thead>
<tr>
<th>Ersson</th>
<th>Measurements</th>
<th>Feeding speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating principle</td>
<td>Load</td>
<td>Deflection</td>
</tr>
<tr>
<td>Measurement of the necessary load to develop a certain deflection. Distance between rollers: 900 mm</td>
<td>Load of 0 to 10 KN precision ±1%</td>
<td>NO</td>
</tr>
</tbody>
</table>
**Dynagrade**

This equipment is based on the estimate of the elasticity module through the analysis to the wood vibration spectrum subject to a mechanical shock. The longitudinal elasticity module is estimated according to the mechanical models of Bernoulli and Timoshenko.

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**Upper view of the Dynagrade equipment.**

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**Details of the shock system produced on the wood.**

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<table>
<thead>
<tr>
<th>Dynagrade</th>
<th>Measurements</th>
<th>Feeding speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating principle</td>
<td>Vibratory analysis to wood subject to an impact performed by a mechanical impulse.</td>
<td>20-100 pieces/min</td>
</tr>
<tr>
<td>Vibration analysis</td>
<td>Deflection</td>
<td>Wood sizes</td>
</tr>
<tr>
<td></td>
<td>Length through laser</td>
<td>Density</td>
</tr>
<tr>
<td>2 microphones within the range 20-20,000 Hz</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>
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