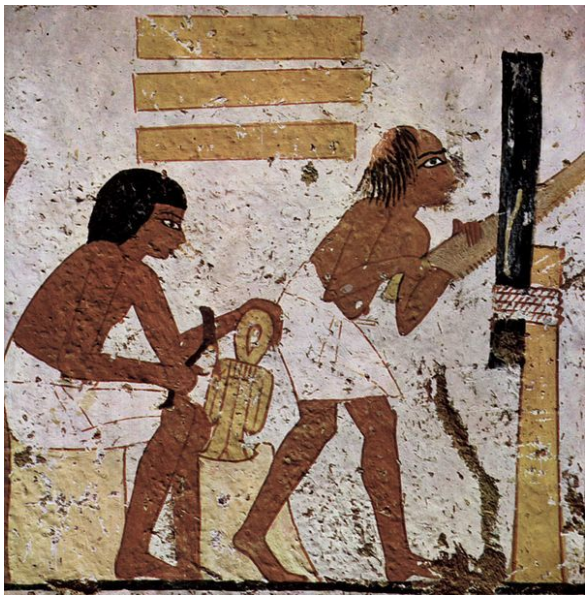
Wood Craft

Contents

Chapter 1

Woodworking

Artists can use woodworking to create delicate sculptures.



Ancient Egyptian woodworking

Woodworking is the activity or skill of making items from wood, and includes wood carving, joinery, and carpentry.

1.1 History

Along with stone, mud and animal parts, wood was one of the first materials worked by early humans. Microwear analysis of the Mousterian stone tools used by the Neanderthals show that many were used to work wood. The development of civilization was closely tied to the development of increasingly greater degrees of skill in working these materials.

Among early finds of wooden tools are the worked sticks from Kalambo Falls, Clacton-on-Sea and Lehringen. The spears from Schöningen (Germany) provide some of the first examples of wooden hunting gear. Flint tools were used for carving. Since Neolithic times, carved wooden vessels are known, for example, from the Linear Pottery culture wells at Kückhofen and Eythra.

Examples of Bronze Age wood-carving include tree trunks worked into coffins from northern Germany and Denmark and wooden folding-chairs. The site of Fellbach-Schmieden in Germany has provided fine examples of wooden animal statues from the Iron Age Wooden idols from the La Tène period are known from a sanctuary at the source of the Seine in France.

The ancient civilization that first used woodworking was the Egyptians. Woodworking is depicted in many ancient Egyptian drawings, and a considerable amount of ancient Egyptian furniture (such as stools, chairs, tables, beds, chests) has been preserved in tombs. As well, the inner coffins found in the tombs were also made of wood. The metal used by the Egyptians for woodworking tools was originally copper and eventually, after 2000 BC bronze as ironworking was unknown until much later.[1]

Woodworking shop in Germany in 1568, the worker in front is using a bow saw, the one in the background is planing.

Commonly used woodworking tools included axes, adzes, chisels, pull saws, and bow drills. Mortise and tenon joints are attested from the earliest Predynastic period. These joints were strengthened using pegs, dowels and leather or cord lashings. Animal glue came to be used only in the New Kingdom period.[2] Ancient Egyptians invented the art of veneering and used varnishes for finishing, though the composition of these varnishes is unknown. Although different native acacias were used, as was the wood from the local sycamore and tamarisk trees, deforestation in the Nile valley resulted in the need for the importation of wood, notably cedar, but also Aleppo pine, boxwood and oak, starting from the Second Dynasty.[3]

The progenitors of Chinese woodworking are considered to be Lu Ban (□□) and his wife Lady Yun, from the Spring and Autumn Period. Lu Ban is said to have introduced the plane, chalk-line, and other tools to China. His teachings were supposedly left behind in the book *Lu Ban Jing* (□□□, "Manuscript of Lu Ban"). Despite this, it is believed that the text was written some 1500 years after his death. This book is filled largely with descriptions of dimensions for use in building various items such as flower pots, tables, altars, etc., and also contains extensive instructions concerning Feng Shui. It mentions almost nothing of the intricate glue-less and nail-less joinery for which Chinese furniture was so famous.

Damascene woodworkers carving wood for hookahs, 19th century.

Micronesian of Tobi, Palau, making a paddle for his wa with an adze.

1.2 Materials

Historically, woodworkers relied upon the woods native to their region, until transportation and trade innovations made more exotic woods available to the craftsman. Woods are

typically sorted into three basic types: hardwoods typified by tight grain and derived from broadleaf trees, softwoods from coniferous trees, and man-made materials such as plywood and MDF.

Typically furniture such as tables and chairs is made using solid stock, and cabinet/fixture makers employ the use of plywood and other man made panel products.

1.3 Notable woodworkers

See also: List of furniture designers

- Alvar Aalto
- Norm Abram
- John Boson
- Henning Engelsen
- Wharton Esherick
- Tage Frid
- Greta Hopkinson
- James Krenov
- Mark Lindquist
- Sal Maccarone
- Thomas J. MacDonald
- John Makepeace
- Sam Maloof
- David J. Marks
- George Nakashima
- Nick Offerman
- Jere Osgood
- Alan Peters
- Matthias Pliessnig
- André Jacob Roubo
- Paul Sellers
- Evert Sodergren
- Henry O. Studley
- Roy Underhill
- Alexander Grabovetskiy

1.4 See also

- Boat building
- Cabinet making
- Carpentry
- Ébéniste
- Fire hardening
- Glossary of woodworking terms
- History of construction
- History of wood carving
- Intarsia
- Japanese carpentry
- Lath art
- Luthier
- millwork
- Marionette
- Marquetry
- Saw pit
- Segmented turning
- Sloyd, a system of handicraft-based education
- Stave church
- Studio Furniture
- Tack cloth
- Timber framing
- Turning
- Wood as a medium
- Wood carving
- Wood glue
- Wood Inlay
- Woodturning
- Woodworking workbench

1.5 Notes

[1] Leospo, Enrichetta (2001), "Woodworking in Ancient Egypt", *The Art of Woodworking*, Turin: Museo Egizio, p.20

[2] Leospo, pp.20-21

[3] Leospo, pp. 17-19

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- Joyce, Edward; revised and expanded by Alan Peters (1987). *Encyclopedia of Furniture Making*. New York: Sterling Publishing Co. ISBN 0-8069-6440-5.
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1.6.1 Further reading

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1.7 External links

- Video about the Zafimaniry peoples in Madagascar.

Chapter 2

Carpentry

"Carpenter" and "Carpenters" redirect here. For other uses, see Carpenter (disambiguation) and Carpenters (disambiguation).

Carpentry is a skilled trade in which the primary work performed is the cutting, shaping and installation of building materials during the construction of buildings, ships, timber bridges, concrete formwork, etc. Carpenters traditionally worked with natural wood and did the rougher work such as framing, but today many other materials are also used[1] and sometimes the finer trades of cabinetmaking and furniture building are considered carpentry. Carpentry in the United States is almost always done by men. With 98.5% of carpenters being male, it was the fourth most male-dominated occupation in the country in 1999,[2] and there were about 1.5 million positions in 2006.[3] Carpenters are usually the first tradesmen on a job and the last to leave.[4] Carpenters normally framed post-and-beam buildings until the end of the 19th century; now this old fashioned carpentry is called timber framing. Carpenters learn this trade by being employed through an apprenticeship training—normally 4 years—and qualify by successfully completing that country's department of labour competency test in places such as the UK, USA and South Africa. It is also common that the skill can be learnt by gaining work experience other than a formal training pro-

Two German carpenters working (1975)

Traditional carpenter's tools
Ethnographic Museum of Western Liguria, Cervo, Italy

Carpenters in an Indian village

Khati or Tarkhan, carpenter caste of the Panjab, India. Man sawing a plank.(1825)

gram, which may be the case in many places.

2.1 Etymology

The word “carpenter” is the English rendering of the Old French word *carpentier* (later, *charpentier*) which is derived from the Latin *carpentrius [artifex]*, "(maker) of a carriage.[5] The Middle English and Scots word (in the sense of “builder”) was *wright* (from the Old English *wryhta*, cognate with *work*), which could be used in compound forms such as *wheelwright* or *boatwright*.[6]

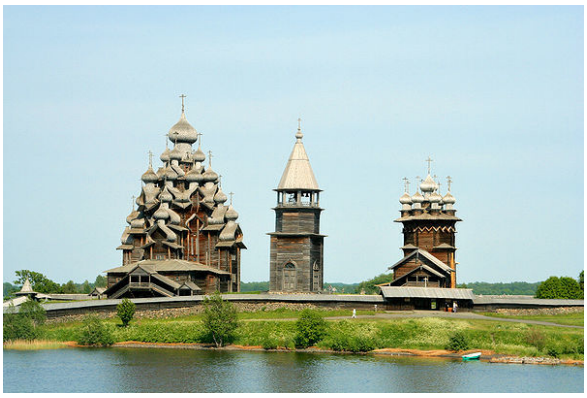
2.1.1 Use of terms in the United Kingdom

In the UK, carpentry is more correctly used to describe the skill involved in **first fixing** of timber items, such as construction of roofs, floors and timber framed buildings, *i.e.*, those areas of construction that are normally hidden in a finished building. An easy way to envisage this is that first fix work is all that is done before plastering takes place. Second fix is done after plastering takes place. **Second fix** work, the construction of items such as skirting boards, architraves, and doors also comes under carpentry. Carpentry is also used to construct the formwork into which concrete is poured during the building of structures such as roads and highway overpasses. In the UK, the skill of making timber formwork for poured, or in situ, concrete, is referred to as **shuttering**.

2.1.2 Use of terms in the United States

Carpentry in the United States is historically defined similarly to the United Kingdom as the “heavier and stronger”[7] work distinguished from a joiner "...who does lighter and more ornamental work than that of a carpenter...” although the "...work of a carpenter and joiner are often combined.”[8] Joiner is less common than the terms *finish carpenter* or *cabinetmaker*. The terms *housewright* and *barnwright* were used historically, now occasionally used by carpenters who work using traditional methods and materials. Someone who builds custom concrete formwork is a *form carpenter*.

2.2 History



Log church building in Russia reached spectacular heights such as this example from the 17th century

Wood is one of mankind’s oldest building materials. The ability to shape wood improved with technological advances from the stone age to the bronze age to the iron age. Some of the oldest archaeological evidence of carpentry are water well casings built using split oak timbers with mortise and tenon and notched corners excavated in eastern Germany dating from about 7,000 years ago in the early neolithic period.[9]

Relatively little information about carpentry is available from pre-history (before written language) or even recent centuries because the knowledge and skills were passed

down person to person, rarely in writing, until the printing press was invented in the 15th century and builders began regularly publishing guides and pattern books in the 18th and 19th centuries. The oldest surviving, complete architectural text is Vitruvius' ten books collectively titled De architectura which discusses some carpentry.

Some of the oldest, surviving, wooden buildings in the world are the temples in China such as the Nanchan Temple built in the year 782, the Greensted Church parts of which are from the 11th century, the stave churchs in Norway from the 12th and 13th centuries.

By the 16th century sawmills were coming into use in Europe.[10] The founding of America was partly based on a desire to extract resources from the new continent including wood for use in ships and buildings in Europe. In the 18th century part of the Industrial Revolution was the invention of the steam engine and cut nails.[11] These technologies combined with the invention of the circular saw led to the development of balloon framing which was the beginning of the decline of traditional timber framing. The 19th century saw the development of electrical engineering and distribution which allowed the development of hand-held power tools, wire nails and machines to mass-produce screws. In the 20th century portland cement came into common use and concrete foundations allowed carpenters to do away with heavy timber sills. Also, drywall came into common use replacing lime plaster on wooden lath. Plywood, engineered lumber and chemically treated lumber also came into use.[12]

For types of carpentry used in America see American historic carpentry.

2.3 Training

Carpentry requires training which involves both acquiring knowledge and physical practice. In formal training a carpenter begins as an *apprentice*, then becomes a *journeyman*, and with enough experience and competency can eventually attain the status of a *master* carpenter. Today pre-apprenticeship training may be gained through non-union vocational programs such as high school shop classes and community colleges.

Informally a laborer may simply work alongside carpenters for years learning skills by observation and peripheral assistance. While such an individual may obtain journeyman status by paying the union entry fee and obtaining a journeyman's card (which provides the right to work on a union carpentry crew) the carpenter foreman will, by necessity, dismiss any worker who presents the card but does not demonstrate the expected skill level.

The Centre Pompidou-Metz museum under construction in Metz, France in 2009. The building possesses one of the most complex examples of carpentry built to date and is composed of 16 kilometers of glued laminated timber for a surface area of 8,000 m².

Carpenters may work for an employer or be self-employed. No matter what kind of training a carpenter has had, some U. S. states require contractors to be licensed which requires passing a written test and having minimum levels of insurance.

2.3.1 Carpentry schools and programs

Formal training in the carpentry trade is available in seminars, certificate programs, high school programs, online classes,[13] associate degree programs, and advanced college degrees[14] in the new construction, restoration, and preservation carpentry fields.[15] Sometimes these programs are called pre-apprenticeship training.

In the modern British construction industry, carpenters are trained through apprenticeship schemes where general certificate of secondary educations (GCSE) in Mathematics, English, and Technology help but are not essential. However, this is deemed the preferred route, as young people can earn and gain field experience whilst training towards a nationally recognized qualification.

There are two main divisions of training: construction-carpentry and cabinetmaking. During pre-apprenticeship, trainees in each of these divisions spend 30 hours a week for 12 weeks in classrooms and indoor workshops learning mathematics, trade terminology, and skill in the use of hand and power tools. Construction-carpentry trainees also participate in calisthenics to prepare for the physical aspect of the work.

Upon completion of pre-apprenticeship, trainees who have successfully passed the graded curriculum (taught by highly experienced journeyman carpenters) are assigned to a local

union and to union carpentry crews at work on construction sites or in cabinet shops as First Year Apprentices. Over the next four years, as they progress in status to Second Year, Third Year, and Fourth Year Apprentice, apprentices periodically return to the training facility every three months for a week of more detailed training in specific aspects of the trade.

2.3.2 Apprenticeships and Journeymen carpenters

Tradesmen in countries such as Germany and Australia are required to fulfill a formal apprenticeship (usually three to four years) to work as a professional carpenter. Upon graduation from the apprenticeship, he or she is known as a journeyman carpenter.

Up through the 19th and even the early 20th century, the journeyman traveled to another region of the country to learn the building styles and techniques of that area before (usually) returning home. In modern times, journeymen are not required to travel, and the term now refers to a level of proficiency and skill. Union carpenters in the United States, that is, members of the United Brotherhood of Carpenters and Joiners of America, are required to pass a skills test to be granted official journeyman status, but uncertified professional carpenters may also be known as journeymen based on their skill level, years of experience, or simply because they support themselves in the trade and not due to any certification or formal woodworking education.

Professional status as a journeyman carpenter in the United States may be obtained in a number of ways. Formal training is acquired in a four-year apprenticeship program administered by the United Brotherhood of Carpenters and Joiners of America, in which journeyman status is obtained after successful completion of twelve weeks of pre-apprenticeship training, followed by four years of on-the-job field training working alongside journeyman carpenters. The Timber Framers Guild also has a formal apprenticeship program for traditional timber framing. Training is also available in groups like the Kim Bồng woodworking village in Vietnam where apprentices live and work to learn woodworking and carpentry skills.

In Canada, each province sets its own standards for apprenticeship. The average length of time is four years and includes a minimum number of hours of both on-the-job training and technical instruction at a college or other institution. Depending on the number of hours of instruction an apprentice receives, he or she can earn a Certificate of Proficiency, making him or her a journeyman, or a Certificate of Qualification, which allows him or her to practice a more limited amount of carpentry. Canadian carpenters also have the option of acquiring an additional Interprovincial Red Seal that allows them to practice anywhere in Canada. The Red Seal requires the completion of an apprenticeship and an additional examination.

2.3.3 Master carpenter

After working as a journeyman for a while, a carpenter may go on to study or test as a master carpenter. In some countries, such as Germany and Japan, this is an arduous and expensive process, requiring extensive knowledge (including economic and legal knowledge) and skill to achieve master certification; these countries generally require master status for anyone employing and teaching apprentices in the craft. In others, 'master carpenter' can be a loosely used term to describe any skilled carpenter.

Fully trained carpenters and joiners will often move into related trades such as shop fitting, scaffolding, bench joinery, maintenance and system installation.

2.4 Materials used

Carpenters traditionally worked with natural wood which has been prepared by splitting (riving), hewing, or sawing with a pit saw or sawmill called lumber (American English) or timber (British English). Today natural and engineered lumber and many other building materials carpenters may use are typically prepared by others and delivered to the job site. In 2013 the carpenters union in America used the term carpenter for a catch-all position. Tasks performed by union carpenters include installing "...flooring, windows, doors, interior trim, cabinetry, solid surface, roofing, framing, siding, flooring, insulation, ...acoustical ceilings, computer-access flooring, metal framing, wall partitions, office furniture systems, and both custom or factory-produced materials, ...trim and molding,... ceiling treatments, ... exposed columns and beams, displays, mantels, staircases...metal studs, metal lath, and drywall..."[16]

2.5 Health and safety

2.5.1 United States

Carpentry is often hazardous work. Types of woodworking and carpentry hazards include Machine hazards, flying materials, tool projection, fire and explosion, electrocution, noise, vibration, dust and chemicals. In the United States the Occupational Safety and Health Administration (OSHA) tries to prevent illness, injury and fire through regulations. However, self-employed workers are not covered

by the OSHA act.[17] OSHA claims that "Since 1970, workplace fatalities have been reduced by more than 65 percent and occupational injury and illness rates have declined by 67 percent. At the same time, U.S. employment has almost doubled."[18] The leading cause of overall fatalities, called the "fatal four", are falls, followed by struck by object, electrocution, and caught-in/between. In general construction "employers must provide working conditions that are free of known dangers. Keep floors in work areas in a clean and, so far as possible, a dry condition. Select and provide required personal protective equipment at no cost to workers. Train workers about job hazards in a language that they can understand."[19] Examples of how to prevent falls includes placing railings and toe-boards at any floor opening which cannot be well covered and elevated platforms and safety harness and lines, safety nets, stair railings and hand rails.

Safety is not just about the workers on the job site. Carpenters work needs to meet the requirements in the Life Safety Code such as in stair building and building codes to promote long term quality and safety for the building occupants.

2.6 Types and occupations

A **finish carpenter** (North America), also called a **joiner** (a traditional name now rare in North America), is one who does finish carpentry, that is, cabinetry, furniture making, fine woodworking, model building, instrument making, parquetry, joinery, or other carpentry where exact joints and minimal margins of error are important. Some large-scale construction may be of an exactitude and artistry that it is classed as finish carpentry.

A **carpenter and joiner** is one who has a much broader skill ranging from joinery, finishing carpentry, building construction and form work.

A **trim carpenter** specializes in molding and trim, such as door and window casings, mantels, baseboards, and other types of ornamental work. Cabinet installers may also be referred to as trim carpenters.

A **cabinetmaker** is a carpenter who does fine and detailed work specializing in the making of cabinets made from wood, wardrobes, dressers, storage chests, and other furniture designed for storage.

A **ship's carpenter** specializes in shipbuilding, maintenance, repair techniques and carpentry specific to nautical needs in addition to many other on-board tasks; usually the term refers to a carpenter who has a post on a specific ship. Steel warships as well as wooden ones need ship's carpenters, especially for making emergency repairs in the case of battle or storm damage.

A **shipwright** builds wooden ships on land.

A **cooper** is someone who makes barrels: wooden staved vessels of a conical form, of greater length than breadth.

A **scenic carpenter** builds and dismantles temporary scenery and sets in film-making, television, and the theater.

A **framer** is a carpenter who builds the skeletal structure or wooden framework of buildings, most often in the platform framing method. Historically, balloon framing was used until the 1950s when fire safety concerns made platform framing inherently better. A carpenter who specializes in building with timbers rather than studs is known as a **timber framer** and does traditional timber framing with wooden joints, including mortise-and-tenon joinery, post and beam work with metal connectors, or pole building framing.

A **luthier** is someone who makes or repairs stringed instruments. The word luthier comes from the French word for lute, "luth".

A **log builder** builds structures of stacked, horizontal logs including houses, barns, churches, fortifications, and more.

A **formwork carpenter** creates the shuttering and falsework used in concrete construction.

In Japanese carpentry, *daiku* is the simple term for carpenter, a *miya-daiku* (temple carpenter) performs the work of both architect and builder of shrines and temples, and a *sukiya-daiku* works on teahouse construction and houses. *Sashimono-shi* build furniture and *tateguya* do interior finishing work.[20]

A **restoration carpenter** is a carpenter who works in historic building restoration, someone who restores a structure to a former state.

A **conservation carpenter** works in architectural conservation, known in the U.S. as a "preservation carpenter" who works in historic preservation, someone who keeps structures from changing.

Green carpentry is the specialization in the use of environmentally friendly,[21] energy-efficient[22] and sustainable[23] sources of building materials for use in construction projects. They also practice building methods that require using less material and material that has the same structural soundness.[24]

2.7 Notable carpenters

2.8 See also

- Atlanta Community ToolBank
- Guild
- Woodworking

- Worshipful Company of Carpenters
- Artisan
- Traditional trades

2.9 References

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[2] "Evidence From Census 2000 About Earnings by Detailed Occupation for Men and Women. Census 2000 Special Reports, May 2004." (PDF). Retrieved 2006-09-02.

[3] Roza, Greg. *A career as a carpenter*. New York: Rosen Pub., 2011. 7. Print.

[4] Vogt, Floyd, and Gaspar J. Lewis. *Carpentry*. 4th ed. Clifton Park, NY: Thomson Delmar Learning, 2006.xvi Print.

[5] The American heritage dictionary of the English language - Etymology of the word "carpenter"

[6] The American Heritage Dictionary of the English Language: Fourth Edition. 2000.

[7] "Carpenter." Def. 1. *Oxford English Dictionary* Second Edition on CD-ROM (v. 4.0) © Oxford University Press 2009

[8] Whitney, William D., ed.. "Carpenter." Def, 1. *The Century Dictionary: An Encyclopedic Lexicon of the English Language* vol. 1. New York. The Century Co. 1895. 830. Print.

[9] Prostak, Sergio. "German Archaeologists Discover World's Oldest Wooden Wells." Breaking Science News SciNews-com. Sci-News.com, 24 Dec. 2012. Web. 26 Feb. 2015. <http://www.sci-news.com/archaeology/article00788.html>.

[10] Davey, Norman. *A history of building materials*. London: Phoenix House, 1961. Print.

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[12] Jester, Thomas C.. *Twentieth-century building materials: history and conservation*. New York: McGraw-Hill, 1995. Print.

[13] "Top Online Carpentry Schools: Accredited Carpentry School Degrees & Degree Programs". *onlineeducation.net*. Retrieved 10 April 2015.

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[15] http://www.preservationnation.org/resources/faq/information-sheets/career-and-education.html

[16] "United Brotherhood Of Carpenters". *carpenters.org*. Retrieved 10 April 2015.

[17] "Workers' Rights". *osha.gov*. Retrieved 10 April 2015.

[18] "Commonly Used Statistics". *osha.gov*. Retrieved 10 April 2015.

[19] "Safety and Health Topics - Fall Protection". *osha.gov*. Retrieved 10 April 2015.

[20] Lee Butler, "Patronage and the Building Arts in Tokugawa Japan", Early Modern Japan. Fall-Winter 2004

[21] "Environmentally Friendly Building Materials". McMullen Carpenters And Joiners. 2009-04-10. Retrieved 2012-07-08.

[22] "A Green Home Begins with ENERGY STAR Blue" (PDF). Energystar. Retrieved 8 September 2012.

[23] "Green Building Basics". Ciwmb.ca.gov. Retrieved 2012-05-21.

[24] "Defining Green-Collar Jobs" (PDF). There is no consensus on how to define green-collar jobs. A very broad interpretation of green jobs would include all existing and new jobs that contribute to environmental quality through improved efficiencies, better resource management, and other technologies that successfully address the environmental challenges facing society. Probably the most concise, general definition is "well-paid, career track jobs that contribute directly to preserving or enhancing environmental quality" (Apollo Alliance 2008, 3). This definition suggests that green-collar jobs directly contribute to improving environmental quality, but would not include low-wage jobs that provide little mobility. Most discussion of green-collar jobs does not refer to positions that require a college degree, but they typically do involve training beyond high school. Many of the positions are similar to skilled, blue-collar jobs, such as electricians, welders, **carpenters**, etc.

2.10 External links

- Professional Carpentry | Houston, Texas
- The Institute of Carpenters (England)
- Carpenters entry in the *Occupational Outlook Handbook* of the Bureau of Labor Statistics of the United States Department of Labor
- Carpenters from Europe and beyond

Chapter 3

Woodworking joints

A worker uses a mortising machine to shape timber framing joints

A worker uses a large circular saw to cut joints.

Joinery is a part of woodworking that involves joining together pieces of wood, to produce more complex items. Some wood joints employ fasteners, bindings, or adhesives, while others use only wood elements. The characteristics of wooden joints - strength, flexibility, toughness,appearance, etc. - derive from the properties of the joining materials and from how they are used in the joints. Therefore, different joinery techniques are used to meet differing requirements. For example, the joinery used to build a house is different from that used to make puzzle toys, although some concepts overlap.

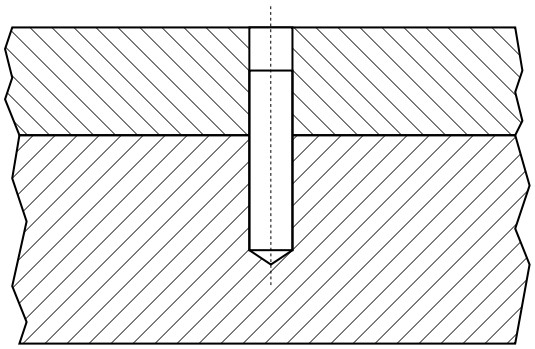
3.1 List of wood joints

3.1.1 Traditional woodworking joints

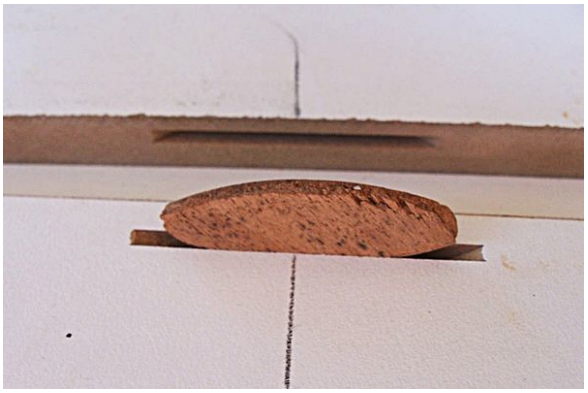
3.1.2 Nontraditional woodworking joints

3.1.3 Traditional ways of improving joints

- Dowel: A small rod is used internal to a joint both to help align and to strengthen the joint. Traditional joints are used with natural timbers as they do not need any other materials other than the timber itself. for example: Butt joints. Dowel joints are also useful for pegging together weaker, cheaper composite materials such as laminate-faced chipboard, and where limited woodworking tools are available (since only simple drilled holes are needed to take the dowels).



A doweled joint



3.1.4 Nontraditional ways of improving joints

- Biscuit joints: A small 'biscuit' is used to help align an edge or butt joint when gluing.
- Domino joiner: A trademarked tool similar to a biscuit joiner, where a piece larger than a biscuit has some of the advantages of dowels, and some of the advantages of biscuits.

3.2 Properties of wood

Many wood joinery techniques either depend upon or compensate for the fact that wood is anisotropic: its material properties are different along different dimensions.

This must be taken into account when joining wood parts together, otherwise the joint is destined to fail. Gluing boards with the grain running perpendicular to each other is often the reason for split boards, or broken joints. Furniture from the 18th century, while made by master craftsmen, did not take this into account. The result is this masterful work suffers from broken bracket feet, which was often attached with a glue block which ran perpendicular to the base pieces. The glue blocks were fastened with both glue and nails, resulting in unequal expansion and contraction between the pieces. This was also the cause of splitting of wide boards, which were commonly used during that period.

In modern woodworking it is even more critical, as heating and air conditioning cause major changes in the moisture content of the wood. All woodworking joints must take these changes into account, and allow for the resulting movement.[2]

3.2.1 Strength

Wood is stronger when stressed along the grain (longitudinally) than it is when stressed across the grain (radially and tangentially). Wood is a natural composite material; parallel strands of cellulose fibers are held together by a lignin binder. These long chains of fibers make the wood exceptionally strong by resisting stress and spreading the load over the length of the board. Furthermore, cellulose is tougher than lignin, a fact demonstrated by the relative ease with which wood can be split along the grain compared to across it.

Different species of wood have different strength levels, and the exact strength may vary from sample to sample.

3.2.2 Dimensional stability

Timber expands and contracts in response to humidity, usually much less so longitudinally than in the radial and tangential directions. As tracheophytes, trees have lignified tissues which transport resources such as water, minerals and photosynthetic products up and down the plant. While lumber from a harvested tree is no longer alive, these tissues still absorb and expel water causing swelling and shrinkage of the wood in kind with change in humidity.[3] When the dimensional stability of the wood is paramount, quartersawn or rift-sawn lumber is preferred because its grain pattern is consistent and thus reacts less to humidity.

3.3 Materials used for joining

- Joints can be designed to hold without the use of glue or fasteners; a pinned mortise and tenon is an example of this.
- Glue is highly effective for joining timber when both surfaces of the joint are edge grain. A properly glued joint may be as strong or stronger than a single piece

Metal plates are often incorporated into the design where the timber alone would not be strong enough for a given load.

Pin-connected post and beam house framing

of wood. However, glue is notably less effective on end-grain surfaces. Animal glue is soluble in water, producing joints that can be disassembled using steam to soften the glue.

- Various mechanical fasteners may be used, the simplest being nails and screws. Glue and fasteners can be used together.

3.4 Traditional joinery

Many traditional wood joinery techniques use the distinctive material properties of wood, often without resorting to mechanical fasteners or adhesives. While every culture in which pieces of wood are joined together to make furniture or structures has a joinery tradition, wood joinery techniques have been especially well documented and celebrated in the Indian, Chinese, European, and Japanese traditions. Because of the actual physical existence of Indian and Egyptian examples, we know that furniture from the first several dynasties show the use of complex joints, like the Dovetail, over 5 thousand years ago. This tradition continued to other later Western styles. The 18th century writer Diederot included over 90 detailed illustrations of wood joints in his comprehensive encyclopedia.[4] While Western techniques focused on concealment of joinery, the Eastern societies, though later, did not attempt to "hide" their joints. The Japanese and Chinese traditions in particular required the use of hundreds of types of joints. The reason was that nails and glues used did not stand up well to the vastly fluctuating temperatures and humid weather conditions in most of Central and South-East Asia.[5] As well, the highly resinous woods used in traditional Chinese furniture do not glue well, even if they are pre-cleaned with solvents and attached using modern glues.

3.5 Nontraditional joinery

Methods that are not considered traditional joinery have come about in modern times, largely to attempt to simplify the job of the woodworker for various reasons. These include biscuit joints and pocket hole joinery.

3.6 See also

- Woodworking
- Cabinet making
- Building construction
- Chinese Wooden Architecture
- Timber framing

3.7 Footnotes

[1] http://sawdustmaking.com/woodjoints/misc.htm

[2] Pro Woodworking Tips.com

[3] Wood Movement, WoodworkDetails.com

[4] Diderot, Denis. "l'Encyclopedie". *The Encyclopedia of Diderot & d'Alembert.* Retrieved 1 April 2015.

[5] Huntley, Michael (20 January 2009), "Michael Huntley demystifies the furniture making techniques of Chinese craftsmen prior to 1900", *Wood Worker's Institute* (GMC Publications)

3.8 References

- Lee A. Jesberger (2007). *Woodworking Terms and Joints*. Pro Woodworking Tips.com
- Bernard Jones (Ed.) (1980). *The Complete Woodworker*. ISBN 0-89815-022-1
- Peter Korn (1993). *Working with Wood*. ISBN 1-56158-041-4
- Sam Allen (1990). *Wood Joiner's Handbook*. Sterling Publishing. ISBN 0-8069-6999-7
- Wolfram Graubner (1992). *Encyclopedia of Wood Joints*. Taunton Press. ISBN 1-56158-004-X
- US Forestry Service (1985) *Water Repellency and Dimensional Stability of Wood* http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr50.pdf

3.9 External links

- Pro Woodworking Tips - Woodworking
- British Woodworking Federation - not for profit woodworking body advice on joinery in the UK

Terms and Joints

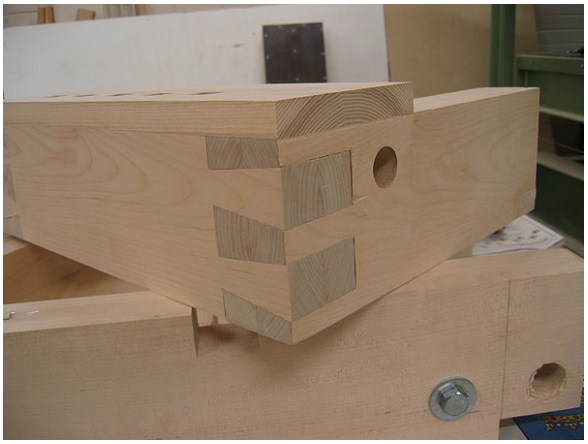
- Dimensioning woodworking and carpentry joints Craftsmanspace
- List of French timber framing joints, in French language

Chapter 4

Dovetail joint

For other uses, see Dovetail (disambiguation).

A **dovetail joint** or simply **dovetail** is a joint technique most commonly used in woodworking joinery (carpentry) including furniture, cabinets, log buildings and traditional timber framing. Noted for its resistance to being pulled apart (tensile strength), the dovetail joint is commonly used to join the sides of a drawer to the front. A series of **pins** cut to extend from the end of one board interlock with a series of **tails** cut into the end of another board. The pins and tails have a trapezoidal shape. Once glued, a wooden dovetail joint requires no mechanical fasteners.



A finished dovetail joint.

Dovetailed woodworking joints on a Romanian church.

The dovetail joint probably pre-dates written history. Some of the earliest known examples of the dovetail joint are in furniture entombed with mummies dating from First Dynasty of ancient Egypt, as well the tombs of Chinese emperors. The dovetail design is an important method of distinguishing various periods of furniture.

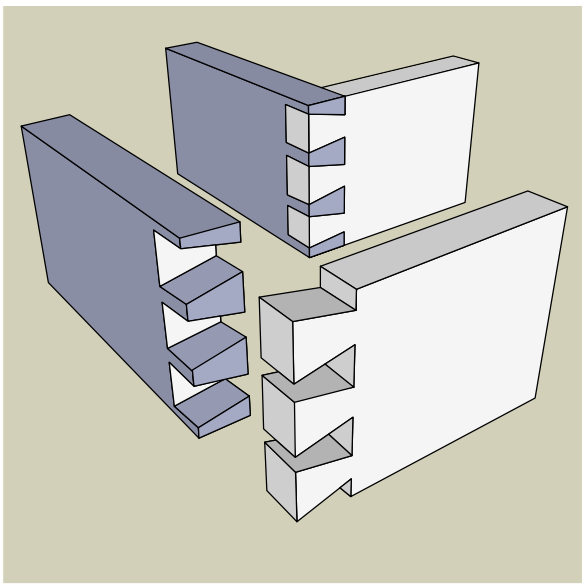
In Europe the dovetail joint is also called a swallow-tail joint or a fantail joint.[1]

4.1 Methods

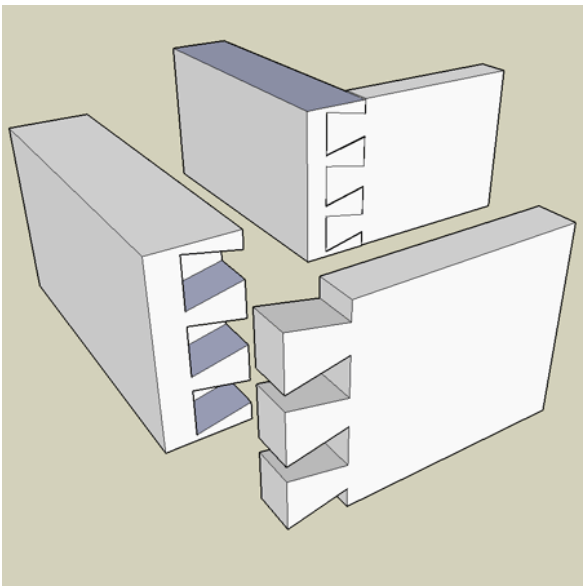
The dovetail joint is very strong because of the way the 'tails' and 'pins' are shaped. This makes it difficult to pull the joint apart and virtually impossible when glue is added. This type of joint is used in box constructions such as drawers, jewellery boxes, cabinets and other pieces of furniture where strength is required. It is a difficult joint to make manually, requiring skilled workmanship. There are different types of dovetail joint and when cut accurately they are very impressive and attractive. The joint is strong especially when used with a good quality glue such as PVA (woodworkers adhesive) or cascamite. The marking out and cutting procedure is outlined below.

The angle of slope varies according to the wood used. Typically the slope is 1:6 for softwoods and a shallower 1:8 slope for hardwoods. Often a slope of 1:7 is used as a compromise.

4.2 Types of dovetail



A through dovetail joint



A half-blind dovetail joint

4.2.1 Through dovetail

The photograph at the top of this page shows a **through dovetail** (also known as **plain dovetail**) joint, where the end grain of both boards is visible when the joint is assembled.[2] Through dovetails are common in carcass and box construction. Traditionally, the dovetails would have often be covered by a veneer. However, dovetails have become a signature of craftsmanship and are generally considered a feature, so they are rarely concealed in contemporary work.

Use for:

- Carcass and box construction

4.2.2 Half-blind dovetail

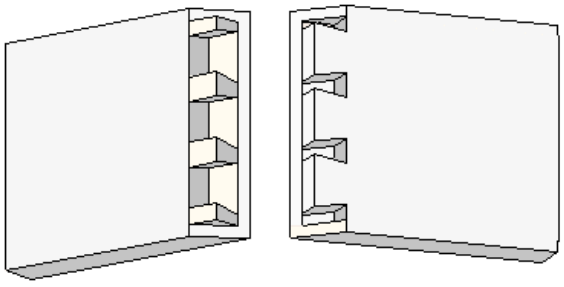
A **half-blind dovetail** is used when the craftsman does not wish end grain to be visible from the front of the item. The tails are housed in **sockets** in the ends of the board that is to be the front of the item so that their ends cannot be seen.

Half-blind dovetails are commonly used to fasten drawer fronts to drawer sides. This is an alternative to the practice of attaching false fronts to drawers constructed using through dovetails.

Use for:

- Attaching drawer fronts

4.2.3 Secret mitred dovetail



A secret mitred dovetail joint

The **secret mitred dovetail** joint (also called a **mitred blind dovetail**, **full-blind dovetail**, or **full-blind mitred dovetail**) is used in the highest class of cabinet and box work. It offers the strength found in the dovetail joint but is totally hidden from both outside faces by forming the outer edge to meet at a 45-degree angle while hiding the dovetails internally within the joint. When used in drawer construction, a “full-blind dovetail” is sometimes referred to as a “French dovetail.”

Use for:

- Fine cabinet or box work where strength is required without a visible joint

The mitred corner dovetail joint is very similar in design, but it has just a single dovetail and is used for picture frames and other similar joins.[3]

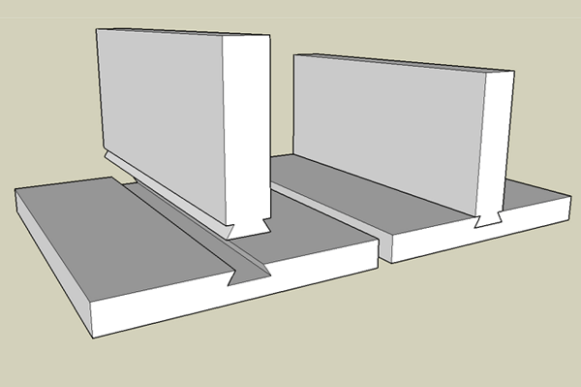
4.2.4 Secret double-lapped dovetail

The **secret double-lapped dovetail** is similar to the secret mitred dovetail, but presents a very thin section of end grain on one edge of the joint.

Use for:

- Carcass and box construction to hide the dovetails completely from view

4.2.5 Sliding dovetail



A sliding dovetail joint

The sliding dovetail is a method of joining two boards at right angles, where the intersection occurs within the field of one of the boards, that is not at the end. This joint provides the interlocking strength of a dovetail. Sliding dovetails are assembled by sliding the tail into the socket. It is common to slightly taper the socket, making it slightly tighter towards the rear of the joint, so that the two components can be slid together easily but the joint becomes tighter as the finished position is reached.

Use for:

- Joining shelves to cabinet sides
- Joining cabinet bottoms to sides
- Joining horizontal partitions to shelves
- Joining adjacent sections of expandable table frames
- Joining drawer fronts to sides
- Joining front rails of web frames to cabinet sides
- Joining neck and body in violins and some guitars

Cast iron dovetail joints in The Iron Bridge

4.3 Non-woodworking dovetails

Dovetails are most commonly, but not exclusively, used in woodworking. Other areas of use are:

- Dovetail slides, for example on a lathe.[4]
- Attaching turbine blades to the shaft in jet engines and other applications.[5]
- Clockmaking: dovetailing a new tooth, when replacing broken teeth in clock gears.
- Masonry: dovetail construction is regarded a major step forward in the design of lighthouses meant for particularly dangerous areas; the Eddystone Lighthouse and Fastnet Lighthouse are examples of the durable quality of dovetail masonry.
- 3d printing: dovetail is commonly used to overcome physical object print size limitation of a 3D printer.[6]

4.4 See also

- Woodworking joints

4.5 References

[1] *Routledge French technical dictionary* **1**. London: Routledge. 1994. ISBN 9780415112253.

[2] "Dovetail Case Joints". *Woodwork Details*. Retrieved February 6, 2015.

[3] "Dovetail Joints: Different Types and Their Uses". *ToolsToday*. Retrieved February 6, 2015.

[4] "How to get the most out of your lathes". *Popular Science* **142** (2): 244. February 1943. Retrieved February 6, 2015.

[5] Hahn, Youngwon; Cofer, John I. (May 1, 2013). "Optimization of Turbine Blade Dovetail Geometry". *NASA Tech Briefs*. Retrieved February 6, 2015.

[6] Martinson, Eiki. "Mechanical Design for 3D Printing - Dovetail Joints". *The Adventures of Eiki Martinson*. Retrieved February 6, 2015.

4.6 Further reading

- Kirby, Ian J. (1999). *The complete dovetail : Handmade furniture's signature joint*. Bethel, CT: Cambium Press. ISBN 9780964399990.

4.7 External links

- Detailed guide from extremehowto.com
- Dovetail Joints from *Manufacturer and Builder*, 1869
- (Video) How to Hand Cut Precision Dovetails — Part 1 of 2: The Pins - from woodtreks.com

Chapter 5

Mortise and tenon

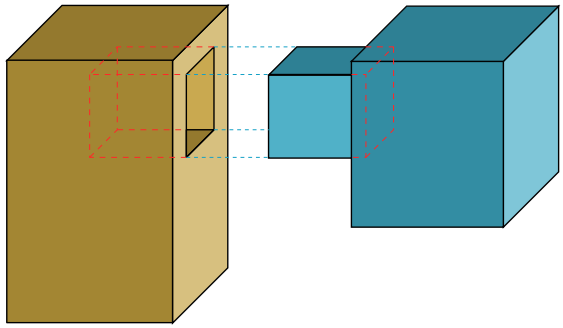
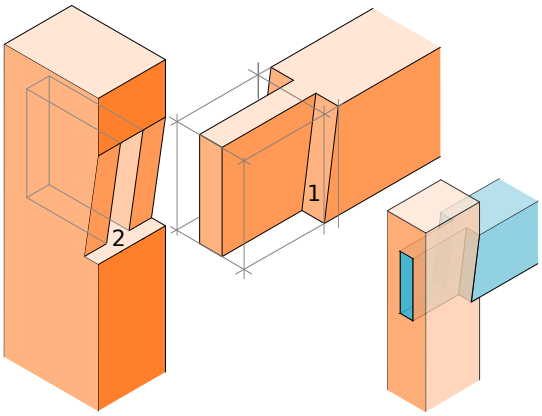


Diagram of a mortise (on left) and tenon joint



1) Through tenon and 2) mortise as a shouldered joint

Through-wedged tenons used on a French granary.

The **mortise**[1] **and tenon** joint has been used for thousands of years by woodworkers around the world to join pieces of wood, mainly when the adjoining pieces connect at an angle of 90°. In its basic form it is both simple and strong. Although there are many joint variations, the basic mortise and tenon comprises two components: the mortise hole and the tenon tongue. The tenon, formed on the end of a member generally referred to as a rail, is inserted into a square or rectangular hole cut into the corresponding member. The tenon is cut to fit the mortise hole exactly and usually has shoulders that seat when the joint fully enters the mortise hole. The joint may be glued, pinned, or wedged to lock it in place.

This joint is also used with other materials. For example, it is a traditional method for stonemasons and blacksmiths.

5.1 Types

A **mortise** is a cavity cut into a timber to receive a tenon. There are several kinds of mortise:[2]

Open mortise a mortise that has only three sides. (See bridle joint).

Stub mortise a shallow mortise, the depth of which depends on the size of the timber; also a mortise that does not go through the workpiece (as opposed to a "through mortise").

Through mortise a mortise that passes entirely through a piece.

Wedged half-dovetail a mortise in which the back is wider, or taller, than the front, or opening. The space

for the wedge initially allows room for the tenon to be inserted; the presence of the wedge, after the tenon has been engaged, prevents its withdrawal. It is sometimes called a “suicide” joint, since it is a “one-way trip”.

Through-wedged half-dovetail a wedged half-dovetail mortise that passes entirely through the piece.

A **tenon** is a projection on the end of a timber for insertion into a mortise. Usually the tenon is taller than it is wide. There are several kinds of tenon:

Stub tenon short, the depth of which depends on the size of the timber; also a tenon that is shorter than the width of the mortised piece so the tenon does not show (as opposed to a “through tenon”).

Through tenon a tenon that passes entirely through the piece of wood it is inserted into, being clearly visible on the back side.

Loose tenon a tenon that is a separate part of the joint, as opposed to a fixed tenon that is an integral part of one of the pieces to be joined.

Biscuit tenon a thin oval piece of wood, shaped like a biscuit[3]

Pegged (or pinned) tenon the joint is strengthened by driving a peg or dowel pin through one or more holes drilled through mortise side wall and tenon;[4] this is common in timber framing joints

Tusk tenon a kind of mortise and tenon joint that uses a wedge-shaped key to hold the joint together.

Teasel (or teazle) tenon a term used for the tenon on top of a jowled or gunstock post, which is typically received by the mortise in the underside of a tie beam. A common element of the English tying joint.

Top tenon the tenon that occurs on top of a post.

Hammer-headed tenon a method of forming a tenon joint when the shoulders cannot be tightened with a clamp.

Half shoulder tenon An asymmetric tenon with a shoulder on one side only. A common use is in framed, ledged and braced doors.

Generally the size of the mortise and tenon is related to the thickness of the timbers. It is considered good practice to proportion the tenon as one third the thickness of the rail, or as close to this as is practical. The haunch, the cut-away part of a sash corner joint that prevents the tenon coming loose, is one third the length of the tenon and one sixth of the width of the tenon in its depth. The remaining two-thirds of the rail, the tenon shoulders, help to counteract lateral forces that might tweak the tenon from the mortise, contributing to its strength. These also serve to hide imperfections in the opening of the mortise.

5.2 Gallery

- Various mortises
- A traditional through, wedged, mortise and tenon joint
- A stub tenon corner joint
- A haunched stub tenon corner joint
- A foxtail wedged tenon joint
- A pinned corner tenon joint
- A modern feather tenon joint (primarily called a loose tenon)

5.3 History

This is an ancient joint dating back 7,000 years. The first examples, tusked joints, were found in a well near Leipzig - the world’s oldest intact wooden architecture.[5] It has also been found joining the wooden planks of the "Khufu ship",[6] a 43.6 m long vessel sealed into a pit in the Giza pyramid complex of the Fourth Dynasty around 2500 BC. The oldest known use dates from the Early Neolithic Linear Pottery culture, where it was used in the constructing of the wooden lining of water wells.[7]

It has also been found in ancient furniture from archaeological sites in the Middle East, Europe and Asia. Many instances are found, for example, in ruins of houses in the Silk Road kingdom of Cadota, dating from the first to the fourth century BC.[8] In traditional Chinese architecture, wood components, such as beams, brackets, roof frames and struts, were made to interlock with perfect fit, without using fasteners or glues, enabling the wood to expand and contract according to humidity.[9] Archaeological evidence from Chinese sites shows that, by the end of the Neolithic, mortise-and-tenon joinery was employed in Chinese construction.[10]

The thirty sarsen stones of Stonehenge were dressed and fashioned with mortise-and-tenon joints before they were erected between 2600 and 2400 BC.

5.4 See also

- Box joint
- Dado
- Dovetail joint

5.5 References

[1] Also spelled *mortice*.

[2] Dekker, Michael. "Mortise-and-Tenon". *Woodwork Details*. Retrieved 2015-02-18.

[3] http://www.popularwoodworking.com/article/Biscuit_Joinery_Basics/?print=1[]

[4] Teague, Matthew (May 2007). "The Pegged Joint, Exposed". *Fine Woodworking* (Taunton Press). Retrieved 2015-02-18. (subscription required (help)).

[5] "The Neolithic Toolkit". Archaeology.org. Retrieved 7 January 2015.

[6] Ward, Cheryl. "World's Oldest Planked Boats," in *Archaeology* (Volume 54, Number 3, May/June 2001). Archaeological Institute of America, .

[7] Early Neolithic Water Wells Reveal the World's Oldest Wood Architecture Tegel W, Elburg R, Hakelberg D, Stäuble H, Büntgen U (2012) Early Neolithic Water Wells Reveal the World's Oldest Wood Architecture. PLoS ONE 7(12): e51374. doi:10.1371/journal.pone.0051374

[8] Roberts, Rachel (2012). "House-building in Ancient Niya". *IDP News* **39**. Retrieved 26 October 2012.

[9] Steinhardt, Nancy W. (2002). *Chinese Architecture* (English Ed. ed.). Yale University Press. p. 1. ISBN 0-300-09559-7.

[10] Xujie, Liu (2002). *Chinese Architecture - The Origins of Chinese Architecture* (English Ed. ed.). Yale University Press. p. 11. ISBN 0-300-09559-7.

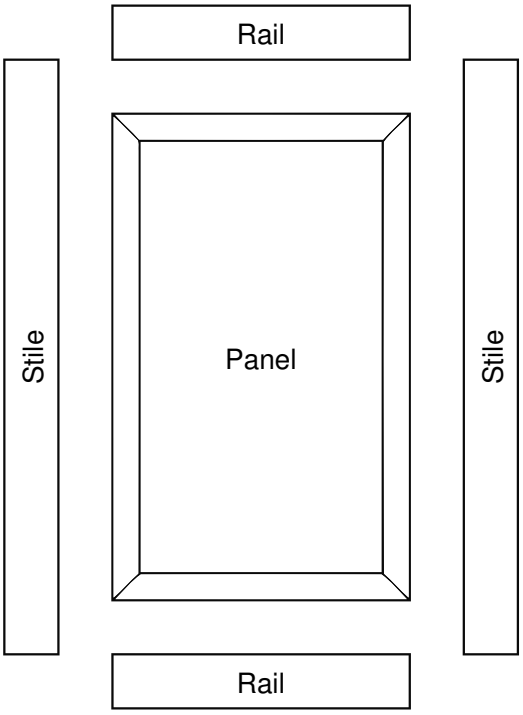
- This article is partly based on a Quicksilver wiki article at A Glossary of Terms For Traditional Timber Framing (Timberbee) under the terms of the GNU Free Documentation License.

5.6 External links

- DIYinfo.org's Timber Joints Wiki - Heaps of practical information on various types of timber joints.

Chapter 6

Frame and panel



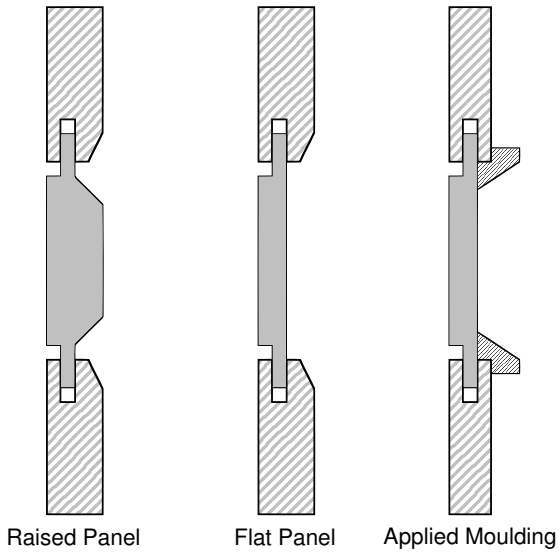
Parts of a five-piece frame and panel door

Frame and panel construction, also called **rail and stile**, is a woodworking technique often used in the making of doors, wainscoting, and other decorative features for cabinets, furniture, and homes. The basic idea is to capture a 'floating' panel within a sturdy frame, as opposed to techniques used in making a slab solid wood cabinet door or drawer front, the door is constructed of several solid wood pieces running in a vertical or horizontal direction [1] with exposed endgrains. Usually, the panel is not glued to the frame but is left to 'float' within it so that seasonal movement of the wood comprising the panel does not distort the frame.

Frame and panel construction at its most basic consists of five members: the panel and the four members which make up the frame. The vertical members of the frame are called **stiles** while the horizontal members are known as **rails**. A basic frame and panel item consists of a top rail, a bottom rail, two stiles, and a panel. This is a common method of constructing cabinet doors and these are often referred to as a **five piece door**.

In larger panels it is common to divide the panel into one or more sections. To house the extra panels, dividing pieces known as **mid rails** and **mid stiles** or **muntins** are added to the frame.

6.1 Panels



Panel styles in frame and panel construction

The panel is either captured in a groove made in the inside edge of the frame members or housed in an edge rabbet made in the rear inside edge. Panels are made slightly

smaller than the available space within the frame to provide room for movement. Wood will expand and contract across the grain, and a wide panel made of solid wood could change width by a half of an inch, warping the door frame. By allowing the wood panel to float, it can expand and contract without damaging the door. A typical panel would be cut to allow 1/4" (5 mm) between itself and the bottom of the groove in the frame. It is common to place some sort of elastic material in the groove between the edge of the panel and the frame before assembly. These items center the panel in the frame and absorb seasonal movement. A popular item for this purpose is a small rubber ball, known as a *spaceball* (a trademarked product). Some cabinet makers will also use small pieces of cork to allow for movement. The panels are usually either **flat** or **raised**.

A flat panel has its visible face flush with the front of the groove in the frame. This gives the panel an inset appearance. This style of panel is commonly made from man-made materials such as MDF or plywood but may also be made from solid wood or tongue and groove planks. Panels made from MDF will be painted to hide their appearance, but panels of hardwood-veneer plywood will be stained and finished to match the solid wood rails and stiles.

A raised panel has a profile cut into its edge so that the panel surface is flush with or proud of the frame. Some popular profiles are the *ogee*, *chamfer*, and *scoop* or *cove*. Panels may be raised by a number of methods - the two most common in modern cabinetry are by coving on the tablesaw or the use of a panel raising cutter in a wood router or spindle moulder.

6.2 Frame

Frames can be constructed by several methods: cope and stick, mortise and tenon, bridle joint, or a simple butt joint. Cope and stick is the most common method, as it is more efficient to manufacture. Mortise and tenon is the strongest, and is often used for large doors which will have greater stresses imposed. Bridle joints are typically used in less formal work, as the exposed endgrain is considered unattractive; while butt joints, being weak, are only used on very small assemblies.

The stiles and rails often have a profile cut into the inside edge of the outside face - usually a smaller version to match the profile of the panel. In some panel styles, a profile may also be cut on the outside edge of the outside face.

In modern cabinetry, the cope and stick joinery is achieved with a set of special router cutters. These cut the profile on the edge of the frame parts and also cut a reverse version of the same profile in the ends of the rail so that they may be slipped over the ends of the stiles and glued in place. If done correctly, the cope cut in the end of the rail will mate perfectly with the sticking profile. When glued together, the resulting joint will have sufficient strength for most cabinet door applications without further reinforcement. For extremely large and heavy doors, the cope and stick joint can be further reinforced with dowels, loose tenons, or by some other method.

For the other methods of frame construction, the inside profile is created either by mitred sticking or by an applied moulding.

In mitred sticking, the profile (known as the sticking) is applied to the edges of both the rail and stile and then a section of the sticking at the ends of each stile is removed leaving a mitred edge which aligns to a similar mitre cut on the ends of the sticking on each rail. This traditional method is more time consuming to complete, hence the popularity of cope and stick for manufactured items.

When applied moulding is to be used, the moulding is applied to the inside edge of the outer face of the frame after the frame and panel have been assembled.

6.3 Assembly Process

The process of making raised panel doors begins with gluing up panels, and then moves into cutting and preparing the frame parts. Next, the panels are cut to size and shaped. Parts and panel are sanded before construction. It is also common to apply a finish to panels prior to assembly so that raw wood is not visible if the panel shrinks. The joints are glued and set into clamps. If the frame and panel items are paint grade they are sometimes nailed at the frame joints on the reverse side. The door then moves on to finish sanding where it is brought to its final thickness, and the outside profile is added if required.

6.4 See also

- Cabinet making
- Cabinet (furniture)

6.5 References

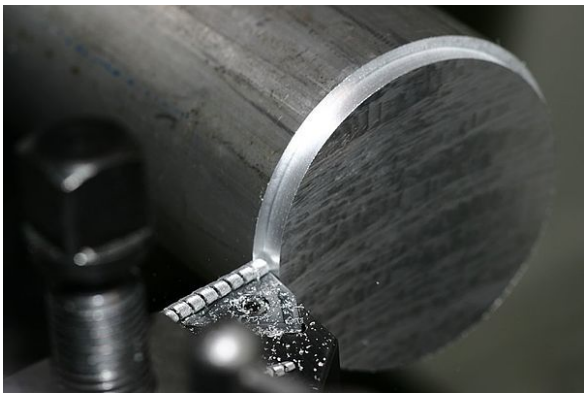
[1] http://cabinets-q-and-a.com/cabinet-door-style.html

Chapter 7

Turning

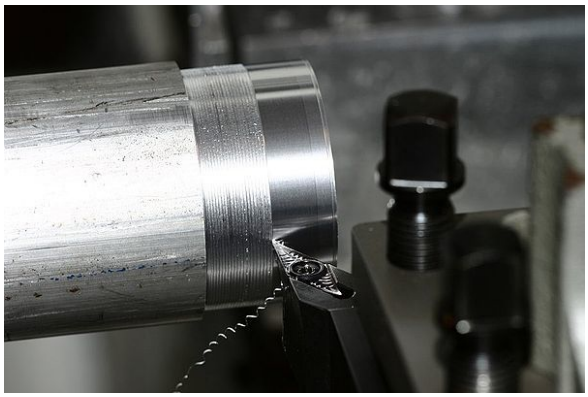
Not to be confused with Turing.
This article is about the machining operation. For the generic use of the word, see rotating.
For other uses of “Turning”, see Turning (disambiguation).

Turning is a engineering machining process in which a cutting tool, typically a non-rotary tool bit, describes a helical toolpath by moving more or less linearly while the workpiece rotates. The tool’s axes of movement may be literally a straight line, or they may be along some set of curves or angles, but they are essentially linear (in the non-mathematical sense). Usually the term “turning” is reserved for the generation of *external* surfaces by this cutting action, whereas this same essential cutting action when applied to *internal* surfaces (that is, holes, of one kind or another) is called "boring". Thus the phrase “turning and boring” categorizes the larger family of (essentially similar) processes. The cutting of faces on the workpiece (that is, surfaces perpendicular to its rotating axis), whether with a turning or boring tool, is called “facing”, and may be lumped into either category as a subset.



Roughing, or rough turning

Parting aluminium



Finish turning

Turning can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using an automated lathe which does not. Today the most common type of such automation is computer numerical control, better known as CNC. (CNC is also commonly used with many other types of machining besides turning.)

When turning, a piece of relatively rigid material (such as wood, metal, plastic, or stone) is rotated and a cutting tool is traversed along 1, 2, or 3 axes of motion to produce precise diameters and depths. Turning can be either on the outside of the cylinder or on the inside (also known as boring) to produce tubular components to various ge-

ometries. Although now quite rare, early lathes could even be used to produce complex geometric figures, even the platonic solids; although since the advent of CNC it has become unusual to use non-computerized toolpath control for this purpose.

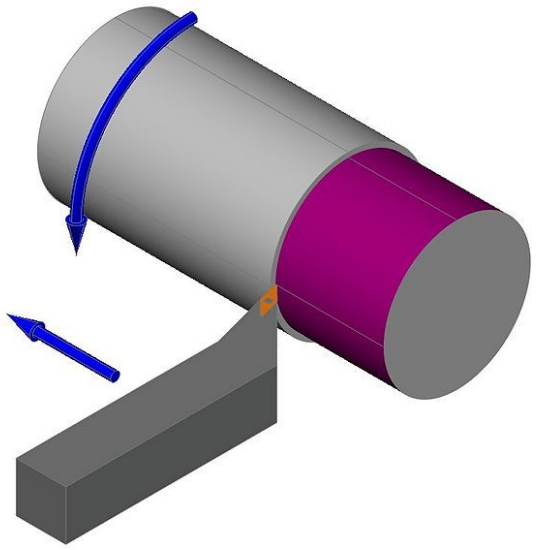
The turning processes are typically carried out on a lathe, considered to be the oldest machine tools, and can be of four different types such as *straight turning*, *taper turning*, *profiling* or *external* grooving. Those types of turning processes can produce various shapes of materials such as *straight*, *conical*, *curved*, or *grooved* workpiece. In general, turning uses simple *single-point cutting* tools. Each group of workpiece materials has an optimum set of tools angles which have been developed through the years.

The bits of waste metal from turning operations are known as chips (North America), or swarf (Britain). In some areas they may be known as *turnings*.

7.1 Turning operations

Turning specific operations include:

Turning



Turning

This operation is one of the most basic machining processes. That is, the part is rotated while a single point cutting tool is moved parallel to the axis of rotation.[1] Turning can be done on the external surface of the part as well as internally (boring). The starting material is generally a workpiece generated by other processes such as casting, forging, extrusion, or drawing.

Tapered turning a) from the compound slide b) from taper turning attachment c) using a hydraulic copy attachment d) using a C.N.C. lathe e) using a form tool f) by the offsetting of the tailstock - this method more suited for shallow tapers.[2]

Spherical generation The proper expression for making or turning a shape is to generate as in to generate a form around a fixed axis of revolution. a) using hydraulic copy attachment b) C.N.C. (computerised numerically controlled) lathe c) using a form tool (a rough and ready method) d) using bed jig (need drawing to explain).[2]

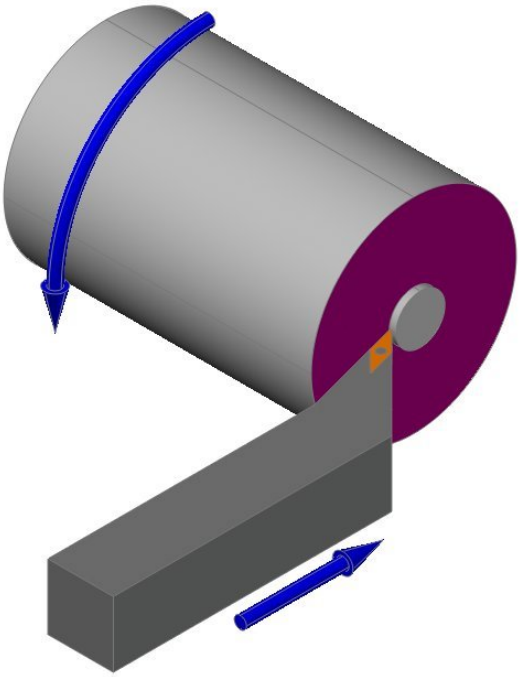
Hard turning Hard turning is a turning done on materials with a Rockwell C hardness greater than 45. It is typically performed after the workpiece is heat treated.[3]

The process is intended to replace or limit traditional grinding operations. Hard turning, when applied for purely stock removal purposes, competes favorably with rough grinding. However, when it is applied for finishing where form and dimension are critical, grinding is superior. Grinding produces higher dimensional accuracy of roundness and cylindricity. In addition, polished surface finishes of Rz=0.3-0.8z cannot be achieved with hard turning alone. Hard turning is appropriate for parts requiring roundness accuracy of 0.5-12 micrometres, and/or surface roughness of Rz 0.8–7.0 micrometres. It is used for gears, injection pump components, hydraulic components, among other applications.[3]

Facing

Facing in the context of turning work involves moving the cutting tool at right angles to the axis of rotation of the rotating workpiece.[1] This can be performed by the operation of the cross-slide, if one is fitted, as distinct from the longitudinal feed (turning). It is frequently the first operation performed in the production of the workpiece, and often the last—hence the phrase “ending up”.

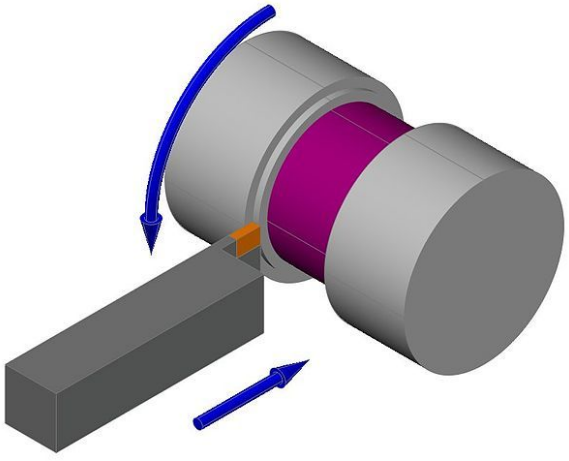
Parting



Facing

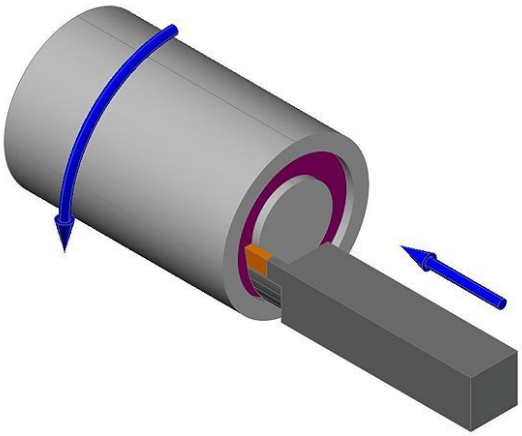
This process, also called **parting off** or **cutoff**, is used to create deep grooves which will remove a completed or part-complete component from its parent stock.

Grooving



External grooving

Grooving is like parting, except that grooves are cut to a specific depth instead of severing a completed/part-complete component from the stock. Grooving can be performed on internal and external surfaces, as well as on the face of the part (face grooving or trepanning).



Face grooving

Non-specific operations include:

Boring Enlarging or smoothing an existing hole created by drilling, moulding etc.i.e. the machining of internal cylindrical forms (generating) a) by mounting workpiece to the spindle via a chuck or faceplate b) by mounting workpiece onto the cross slide and placing cutting tool into the chuck. This work is suitable for castings that are too awkward to mount in the face plate. On long bed lathes large workpiece can be bolted to a fixture on the bed and a shaft passed between two lugs on the workpiece and these lugs can be bored out to size. A limited application but one that is available to the skilled turner/machinist.[2]

Drilling is used to remove material from the inside of a workpiece. This process utilizes standard drill bits held stationary in the tail stock or tool turret of the lathe. The process can be done by separately available drilling machines.

Knurling

Knurling The cutting of a serrated pattern onto the surface of a part to use as a hand grip using a special purpose knurling tool.[2]

Reaming The sizing operation that removes a small amount of metal from a hole already drilled.[2] It is done for making internal holes of very accurate diameters. For example, a 6mm hole is made by drilling with 5.98 mm drill bit and then reamed to accurate dimensions.

Threading Both standard and non-standard screw threads can be turned on a lathe using an appropriate cutting tool. (Usually having a 60, or 55° nose angle) Either externally, or within a bore.[4] Generally referred to as single-point threading.

tapping of threaded nuts and holes a) using hand taps and tailstock centre b)using a tapping device with a slipping clutch to reduce risk of breakage of the tap.[2]

threading operations include a)all types of external and internal thread forms using a single point tool also taper threads, double start threads, multi start threads, worms as used in worm wheel reduction boxes, leadscrew with single or multistart threads. b) by the use of threading boxes fitted with 4 form tools, up to 2" diameter threads but it is possible to find larger boxes than this.[2]

Polygonal turning in which non-circular forms are machined without interrupting the rotation of the raw material.

7.2 Lathes

Main article: Lathe

A lathe is a machine tool used principally for shaping pieces of metal, wood, or other materials by causing the workpiece to be held and rotated by the lathe while a tool bit is advanced into the work causing the cutting action. Lathes can be divided into three types for easy identification: engine lathe, turret lathe, and *special purpose lathes*. Some smaller ones are bench mounted and semi-portable. The larger lathes are floor mounted and may require special transportation if they must be moved. Field and maintenance shops generally use a lathe that can be adapted to many operations and that is not too large to be moved from one work site to another. The engine lathe is ideally suited for this purpose. A trained operator can accomplish more machining jobs with the engine lathe than with any other machine tool. Turret lathes and special purpose lathes are usually used in production or job shops for mass production or specialized parts, while basic engine lathes are usually used for any type of lathe work. Mainly used in production for multitask work.

7.2.1 Workholding methods

Collets

- Chuck: Chucks are a very common workholding method. There are many types, some for round and square stock, and other for irregular shapes.
- Collet: Primarily used for small round workpieces.
- Faceplate: A faceplate, drive dog, and mandrel may be used to turn workpieces such as gear blanks.
- Drive center: Use hydraulic or spring-loaded teeth that "bite" into the end of workpieces and can be used when the entire length of the workpiece must be machined.

7.3 Tooling

Main article: Tool bit

The various angles, shapes, and sizes of a *single-point cutting* tool have direct relation to the resulting surface of a workpiece in machining operations. Different types of angle such as *rake angle*, *side rake angle*, *cutting-edge angle*, *relief angle*, *nose radius* exist and may be different with respect to the workpiece. Also, there are many shapes of *single-point cutting* tools, such as *V-shaped* and *Square.* Usually, a special toolholder is used to hold the cutting tool firmly during operation.

7.4 Dynamics of turning

7.4.1 Forces

The relative forces in a turning operation are important in the design of machine tools. The machine tool and its components must be able to withstand these forces without causing significant deflections, vibrations, or chatter during the operation. There are three principal forces during a turning process:

- The **cutting or tangential force** acts downward on the tool tip allowing deflection of the workpiece upward. It supplies the energy required for the cutting operation.The specific cutting force required to cut the material is called specific cutting force.Cutting force is depends on the material.
- The **axial or feed force** acts in the longitudinal direction. It is also called the feed force because it is in the feed direction of the tool. This force tends to push the tool away from the chuck.
- The **radial or thrust force** acts in the radial direction and tends to push the tool away from the workpiece.

7.4.2 Speeds and feeds

Speeds and feeds for turning are chosen based on cutter material, workpiece material, setup rigidity, machine tool rigidity and spindle power, coolant choice, and other factors.

7.4.3 Feed

- The tool advances into the material in one revolution is called Feed.It is specified as mm per revolution(mm/rev).

7.5 See also

- Engine turning
- Hard turning
- Surface feet per minute
- Woodturning

7.6 References

[1] Todd, Robert H.; Allen, Dell K.; Al ting, Leo (1994), *Manufacturing Processes Reference Guide*, Industrial Press Inc., p. 153, ISBN 0-8311-3049-0.

[2] Workshop Technology by W.A.J. Chapman Ph.D. M.Sc.(Eng.), M.I.Mech.E., M.I.Prod.E. Principal Hatfield College of Technology, Hertfordshire first published 1951 part one, two and three published by Edward Arnold (publishers Limited

[3] Koepfer, Chris, "Hard Turning as an Alternative to Grinding", Production Machining, 1/22/2010. productionmachining.com, accessed 3/4/2010

[4] "Threading On A Lathe : Modern Machine Shop". Mmsonline.com. 2003-01-15. Retrieved 2012-03-13.

7.7 External links

- "Lathe Introduction". Archived from the original on 2010-01-08. Retrieved 2010-01-08.
- Schneider, George. "Turning Tools and Operations." *American Machinist*, January, 2010.

Chapter 8

Woodturning

Detail of woodturning in work

Woodturning is a form of woodworking that is used to create wooden objects on a lathe. Woodturning differs from most other forms of woodworking in that the wood is moving while a stationary tool is used to cut and shape it. Many intricate shapes and designs can be made by turning wood.

There are two distinct methods of turning wood: spindle turning and bowl or faceplate turning. Their key difference is in the orientation of the wood grain, relative to the axis of the lathe. This variation in orientation changes the tools and techniques used. In spindle turning, the grain runs lengthways along the lathe bed, as if a log was mounted in the lathe. Grain is thus always perpendicular to the direction of rotation under the tool. In bowl turning, the grain runs at right angles to the axis, as if a plank were mounted across the chuck. When a bowl blank rotates, the angle that the grain makes with the cutting tool continually changes between the easy cuts of lengthways and downwards across the grain to two places per rotation where the tool is cutting across the grain and even upwards across it. This varying grain angle limits some of the tools that may be used and requires additional skill in order to cope with it.

In spindle turning, the wood is fixed between 2 points. The spur center digs into the wood and is powered by a motor. The other, a hard center or a live center may be a point or set of points in the tail-stock. In face plate turning, the wood is secured with screws to a faceplate or in a chuck or jig. the tail stock and a center may also be used for added support on large pieces with a faceplate. Most bowls, platters and many vessels are face plate turned, while pens, furniture legs, spindles, and some vessels are spindle turned. The method used may differ depending on the shape of the blank and the technique of the turner, and both methods may be used on the same piece.

When wood is cut in such a way that the fibre being cut is not supported by the fibre below it, it tends to separate and tear. This “tear out” exhibits a rough, highly damaged looking surface texture and greatly reduces the value of any product exhibiting it. The direction of cut is different in spindle turning and faceplate turning because cutting in the wrong direction can cause tear out. Spindle turning cuts are made from high points toward the axis on the outside of the piece, and from the axis toward the outside when hollowing. When faceplate turning, the opposite applies.

A turned wood bowl with natural edges

8.1 History

The origin of woodturning dates to around 1300 BC when the Egyptians first developed a two-person lathe. One per-

son would turn the wood with a rope while the other used a sharp tool to cut shapes in the wood. The Romans improved the Egyptian design with the addition of a turning bow. Early bow lathes were also developed and used in Germany, France and Britain. Sometime after the turning bow was developed, a lathe was created that spun when a lever was pumped by hand. Early lathe workers would sometimes use their bare feet to hold cutting tools in place while using their hand to power the lathe. In the Middle Ages a pedal replaced hand-operated turning, freeing both the craftsman's hands to hold the woodturning tools. The pedal was usually connected to a pole, often a straight-grained sapling. The system today is called the "spring pole" lathe (see Polelathe). Spring pole lathes were in common use into the early 20th Century. Up to this point in history, the lathe operated in a reciprocal manner with the workpiece rotating back and forth as the drive mechanism reset to the loaded position in preparation for the next stroke. This required the turner to alternately apply the tool as the blank spun toward the operator and remove it from the blank as it spun away from him. A two-person lathe, called a "great lathe", allowed a piece to turn continuously (like today's power lathes). A master would cut the wood while an apprentice turned the crank on a huge wheel, often several feet in diameter.

The term "bodger" stems from pole lathe turners who used to make the chair legs and spindles. A bodger would typically purchase all the trees on a plot of land, set up camp on the plot, and then fell the trees and turn the wood. Bodgers would set up their lathes in a stand of trees, cutting all of the trees around them. Once all the trees in the immediate vicinity were consumed, the bodger would move his lathe to a new spot within the same wood, to repeat the process. Interestingly, bodgers sometimes used lathes that did not have integral spring pole mechanisms, but rather placed their lathes under a standing tree with a springy branch that was suitable to use as the drive mechanism. This made for a more portable type of lathe for the bodger. The spindles and legs that were produced by the bodger were sold in bulk, for pence per dozen. The bodger's job was considered unfinished because he only made component parts. The term now describes a person who leaves a job unfinished, or does it badly.

During the industrial revolution the lathe was motorized, allowing turned items to be created in less time. The motor also produced a greater rotational speed for the wood, making it easier to quickly produce high quality work. Today most commercial woodturning is done by computer-operated machinery allowing for mass-production that can be created with precision and without the cost of employing craftsmen. Despite this, there is still a demand for hand-turned products. Woodturning is also a hobby enjoyed by many people.

Modern professional woodturners are typically either "production" turners producing large quantities of functional pieces, or artistic turners producing smaller numbers of pieces, often enhanced after turning by carving, piercing, coloring, applying pyrography, gilding, or a number of other techniques to produce objects for the art market.

8.2 Tools

Gouges for woodturning

Turning tools are generally made from three different types of steel;Carbon steel, High speed steel (HSS), and more recently powdered metal. Comparing the three types, high speed steel tools maintain their edge longer, requiring less frequent sharpening than carbon steel, but not as long as powdered metal tools. The harder the type of high speed steel used, the longer the edge will maintain sharpness. Powdered steel is even harder than HSS, but takes more effort to obtain an edge as sharp as HSS, just as HSS is harder to get as sharp as Carbon Steel. Unlike other edged woodworking tools, woodturning tools require more frequent sharpening, because the wood passes at a great speed. To maintain a clean cut, the sharpness of the tools edge must be maintained. Sharpening is usually accomplished with the aid of mechanical devices such as powered sharpening wheels and abrasives. This sharpening process requires either skill of the craftsman, or one of the many available sharpening jigs, which facilitate maintaining a specific bevel on the tool. As with any mechanical sharpening method, overheating or blueing is a danger to be avoided as it will ruin the steel's temper, rendering the steel too soft to maintain a sharp edge. When this happens, the blued area must then be ground away to expose fresh steel and the tool must then have the bevel reestablished and the edge rehoned. High speed steel is not prone to blueing (overheating) whereas carbon steel blues easily, requiring frequent quenching in water or oil to avoid losing temper.

Types

- roughing gouge - a wide fluted gouge used to initially round a wooden spindle, and to roughly shape it. Generally not intended for cutting end grain due to the large cut it takes and the relatively weak tang connecting the blade to the handle. Unsafe for making bowls or any faceplate work.
- spindle gouge or detail gouge - a shallow fluted gouge used to create details on spindles, including beads (raised portions of the turning typically semi-circular in cross section) and coves (relieved portions of the turning).
- bowl gouge - a deep fluted gouge used to turn the outside and inside of bowls and vessels. Often has a thicker shaft and longer handle than a spindle gouge because it has to cut farther away from the hand rest and deal with the forces of turning a large bowl.
- skew chisel - a wide, steeply pointed chisel with the edge running at an angle to the length of the tool. Used to smooth flat spindles, cut beads, and add details. Skew chisels are only used on spindle work (never on faceplate work) and are honed after sharpening to create a razor edge.
- parting tool - a pointed tool used to separate (part off) work from the lathe, and to create a straight edge separating large and small diameter sections - wide parting tools also called bedans are used to create evenly sized spindle sections.
- hollowing tool - many different types of tools used to cut out the deep sections of steep bowls, vases and hollow vessels. Often with very long handles, to maintain enough leverage when working in a deep vessel, far away from the hand rest.
- scraper - a tool that scrapes the wood fibres instead of cutting - these are used to smooth off wooden items cut with other tools, and to shape items that are not possible or difficult to shape with gouges. A sharp scraper has a burr at the edge which cuts the wood, only a dull scraper actually scrapes.
- bowl saver - a tool used to core out the inside part of a bowl, allowing the waste piece to be used to create a smaller bowl, and to limit the amount of wood chips created when hollowing out a bowl.
- auger - a drill bit used to drill a hole partway or all the way through a wooden item. For cutting the hole for a lamp cord, or as the first step when hollowing out a bowl or vessel
- chatter tool - a flexible scraper used to add decorative chatter marks to turned items
- wire - a simple wire, sometimes with handles attached at either side, for the purpose of burning lines into the piece with friction.
- there are also several tool types for special purposes, as well as tools that are a combination design of the above tools, i.e. skew/chisel combinations, thread cutting tools, ring cutting tools, medium fluted gouges, etc.

8.3 Other techniques

- Eccentric turning - turning a single piece multiple times, upon different axes each time.
- Oval or elliptical turning - turning a piece using an accessory mounted to the headstock that changes the center of rotation of the piece in time with the rotation, so that a cutting tool held in a fixed position on the tool-rest cuts an oval rather than a round path on the workpiece
- Therming - mounting a carrier between centers, and then mounting the small workpiece(s) to the carrier, so that the axis of the headstock/tail-stock does not pass through any of the workpieces, and each workpiece gets cut only on one face. As noted in Wood-turning Methods by Mike Darlow, the etymology of the term “therming” comes via a corruption of the name of the Greek god Hermes, who was often represented as a statue set atop a plinth with a construction characteristic of thermed work.
- Segmented turning - a method of woodturning where the wood blank is constructed from many individual pieces of wood (segments) which are glued together before being turned. Many interesting patterns can be generated through the process of gluing and shaping on the lathe.
- Green or wet turning - turning wood while its moisture content is above equilibrium. Often done when the wood is newly felled. May be turned to finished thickness, in which case the differential shrinkage of the wood will result in a finished piece that is not perfectly round. Alternatively, it may be “rough turned”. Rough turning involves turning the piece only to its general shape, leaving enough thickness so that after turning it can be allowed to dry to equilibrium moisture content and distort. The advantage over first drying the wood then turning is that a rough turned piece dries faster, will probably distort instead of split as solid

wood tends to, and that wet wood turns better, since it creates less dust. Rough turning is inexact science: turning wood too thick will lead to splits, turning wood too thin will lead to distortion that cannot be removed, because not enough thickness is left. Once dry, it is mounted on the lathe a second time and turned to its final form. Rough turning is typically used on most functional work and some artistic pieces.

- Natural edge work - pieces which include the outside of the tree trunk or limb as the edge of the piece. Typically artistic turnings, usually bowls or hollow vessels, and usually green turned to final dimension. May include the bark or not, but pieces with bark should not have any bark damaged or missing.
- Ornamental turning - also known as OT, a method in which the piece is mounted upon a rocking headstock, and a spinning tool is used to cut out exotic and decorative patterns. The device is called a rose engine lathe
- Plywood is produced by turning a log called a *peeler* and removing thin sheets (plies) which are then glued together.

8.4 Safety

When woodturning, it is important to wear certain personal protective equipment (PPE). Loose clothing should not be worn, all jewellery should be removed, and long hair should be tied back. Wood shavings generated during turning will also need to be periodically removed.

- **Eye protection** is a necessity when woodturning. There are several PPE available for eye protection such as safety goggles, glasses and visors, some of which feature built-in respirators. Although all of these are adequate, for the highest level of protection, a visor that protects the entire head from dust and debris should be worn.
- **Respiratory equipment** and Dust collection systems are also important when woodturning or doing any type of woodworking that creates dust. This can range from a simple disposable dust mask, to a full face helmet with built in respirator. Most stand alone respiratory equipment will interfere with dust shields and visors, so devices that incorporate both are available. Many woods create dust that is actually a health hazard. For example, cocobolo (granadillo) dust is known to be toxic (toxic shock). Many people are sensitive to oils carried in walnut, locust, and oak sawdust. Long term exposure to fine wood dust has also been linked with an increased risk of developing cancer.
- **Ear protection** Compared to other power tools, a lathe is a quiet machine. Ear protection should be used if noise is excessive, this may be due to motor (fan) noise from a shop dust collector, or the combination of wood and tool being used.
- **Hand/Skin protection** Gloves should not be used with rotating equipment, since there's always a risk of getting tangled in the machine. Nevertheless, some woods provide splinters that not only puncture skin, but also cause festering sores and/or skin irritation. Polishes and finishes used in woodturning can also be harmful or irritant to skin, often containing organic solvents such as methanol, turpentine and toluene. This subject continues to be debated in the community.
- **Foot protection**. Protective footwear, often leather steel-toe boots, is required for any type of shop activity.

A good way to check the safety before starting the lathe is 'SAFER':

- S - Speed - check the rpm speed, slower for big, heavy things, faster for smaller lighter things.
- A - Aside - make sure you are standing to the side of the blank's 'firing line' (not in front of the wood).
- F - Fixings - check that the wood, tool-rest, tail-stock etc. are correctly attached.
- E - Eye protection - make sure you're wearing sufficient eye protection.
- R - Revolve - Check that the wood can turn around without encountering any obstructions.

Safe usage of a lathe also depends on the operator knowing proper techniques and being aware of the limitations of both the machine and the workpiece. For example, using a high spindle speed with an unbalanced workpiece may cause the lathe to vibrate dangerously. Spinning a large workpiece too fast may cause it to explode. Inappropriate use of tools such as gouges and skew chisels can cause a *catch*, where the tool bites suddenly and aggressively into the wood in an uncontrolled manner. This exerts very large forces on the workpiece, the tool, the lathe and the operator, often causing the workpiece to break apart or tear free from the lathe or pulling the tool out of the operator's hands and throwing it through the air.

8.5 See also

- Turning
- Wood as a medium

8.6 References

8.7 External links

- Ornamental Turners International
- Ornamental Turning
- The Irish Woodturners' Guild
- The Dublin 15 IWG Chapter - Craobh Cuig Deag
- The American Association of Woodturners
- Association of Woodturners of Great Britain
- The National Association of Woodworkers inc. New Zealand
- The British Woodturners Association
- The Register of Professional Turners

Chapter 9

Segmented turning

Segmented turning is turning on a lathe where the initial workpiece is composed of multiple glued-together parts. The process involves gluing up several pieces of wood to create patterns and visual effects in turned projects.

Segmented turning is also known as polychromatic turning.

A ring-constructed turning

In traditional wood turning, the template is a single piece of wood. The size, grain orientation and colors of the wood, will frame how it can be turned into an object like a bowl, platter, or vase. With segmented turning, the size and patterns are limited only by imagination, skill and patience.

While the vast majority of segmented turnings are vessels of one sort or another, strictly speaking, any turned object comprising multiple pieces of glued wood could be classified as a segmented turning. Examples include pens, salt and pepper mills, and rolling pins. By cutting and reassembling pieces after they are turned, unique forms can be created, crossing over to pure art. See for example the work of Malcolm Tibbetts.

In addition to design skills, segmented turning demands precision woodworking skills as well as turning skills. Design and construction of a bowl blank—the wood piece mounted on the lathe for turning a vessel—requires angled miter joints cut to tolerances of as little as a tenth of one degree or better.

There are essentially two different techniques for constructing a bowl blank, ring construction and stave construction.

Ring construction is the most common. A ring-constructed blank comprises rings glued in a cylindrical stack. Though a platter or shallow bowl could be made from a single ring, stacking many rings is more typical. Apart from a lid or a base made and added after the fact, the height of the finished piece is a function of number of rings, and the height of each ring, which of course can vary for effect. Each ring comprises three or more pieces cut and glued to form a triangle, square, pentagon, hexagon, etc. The more pieces in a ring, the more challenging for the turner, because there are more opportunities for precision errors—gaps and misalignments in the joints between pieces. The individual pieces making up a ring themselves are often assembled from smaller pieces of contrasting or complementary colors to achieve striking patterns in the finished piece. This too adds to the complexity and challenge for the turner.

Native American pottery, basket, and textile designs, particularly from the southwest U.S., frequently inspire form and design features. These patterns are often geometric in design and thus are easier to recreate than more fluid forms found in nature.

Stave constructions are assembled like barrels—cylinders constructed from multiple long, vertically oriented pieces. As a rule, the grain in a ring-constructed turning runs horizontally in the finished piece, while the grain in a stave-constructed turning runs vertically, from top to bottom.

Another category of segmented turning called Open Segmented Turning is similar to ring construction but small

gaps are left between the segments. Successive rings are offset so the segments interlock with the ring above and below. This type of segmentation seems very delicate and is somewhat transparent but it is generally quite strong. This concept was introduced by Yosh Sugiyama in the early 1980s. For example see the work of William Smith.

A segmented turning can combine ring construction, stave construction, and solid, non-segmented wood as well in a single piece. However, wood expands and contracts in the direction perpendicular to its grain as a function of its moisture content, itself a function of ambient humidity. In this case, during design and assembly, the turner has to be mindful of the impact on long term structural integrity of assembling the constituent pieces into incompatible, non-parallel grain directions.

Examples of bowls from boards

An important variation of the ring construction technique is known as "bowl from a board." Imagine a flat, square board bisected to create two identical rectangles, like two twin beds placed side-by-side to form a king-sized, square bed. Rings are created by cutting concentric semicircles from each of the two boards, one concentric half-ring a mirrored-shape of a half-ring from the other. The semicircles are typically cut with a bandsaw, but a scrollsaw, jigsaw, or coping saw would work. The blade of the saw used to cut the semicircles is set at an angle from the vertical, typically 45-60 degrees, such that when each mirrored pair is glued together to form a complete ring, the rings are shaped like cross sections of a cone. The rings are then stacked to create a cone-shaped blank. An incredible variety of visual effects can be achieved as a function of how the boards are constructed before the concentric rings are cut.

There are ongoing discussions as to whether turning is a trade, craft, or an art form. Turning in its original form was certainly utilitarian. If your last name is "Turner" chances are there was a production wood turner some generations ago in your family tree. Many turners produce spindle work for furniture, architectural work, toys, and of course, bowls. But in recent years, many artists use turned pieces as a canvas for carving, pyrography, gold leaf work, inlay, stain and painting.

9.1 See also

- Woodturning
- Woodworking
- Wood as a medium

9.2 Artists

- Malcolm Tibbetts's Website
- Steve Bernstein's Website
- Traditional Woodturning from Sherwood Forest
- MarleyTurned Website
- Greg Sayers Website
- Bob Pritchard's Website
- Dennis Edwards Website

9.3 Software and Instruction

- Segmented Turning web site for segmented software.
- Woodturner PRO web site for segmented software.
- Segmented Turning Videos: Calculations, Cutting Tips, Glue-Up Procedures Clamping Alternative - from woodtreks.com
- The Segmented Turner How-To's, Tips, Videos and more.
- Segmented woodturning projects Segmented woodturning instructions.
- /Denny Edwards Segmented woodturning videos.

Chapter 10

Furniture

For other uses, see Furniture (disambiguation).

Furniture is the mass noun for the movable objects intended to support various human activities such as seating (e.g., chairs, stools and sofas) and sleeping (e.g., beds). Furniture is also used to hold objects at a convenient height for work (as horizontal surfaces above the ground, such as tables and desks), or to store things (e.g., cupboards and shelves). Furniture can be a product of design and is considered a form of decorative art. In addition to furniture's functional role, it can serve a symbolic or religious purpose. It can be made from many materials, including metal, plastic, and wood. Furniture can be made using a variety of woodworking joints which often reflect the local culture.

A dining table for two

Archeological research shows that Neolithic people used stone to build cupboards, dressers, beds, shelves and seats. Ancient furniture from the 8th-century BC includes tables and serving stands. The furniture of the Middle Ages was usually heavy, oak, and ornamented. Furniture design expanded during the Italian Renaissance of the fourteenth and fifteenth century. The seventeenth century, in both Southern and Northern Europe, was characterized by opulent, often gilded Baroque designs. The nineteenth century is usually defined by revival styles. The first three-quarters of the twentieth century are often seen as the march towards Modernism. One unique outgrowth of post-modern furniture design is a return to natural shapes and textures.[1]

10.1 History

Furniture has been a part of the human experience since the development of non-nomadic cultures. Evidence of furniture survives from the Neolithic Period and later in antiquity in the form of paintings, such as the wall Murals discovered at Pompeii; sculpture, and examples have been excavated in Egypt and found in tombs in Ghiordes, in modern-day Turkey.

10.1.1 Neolithic period

Skara Brae house Orkney Scotland evidence of home furnishings i.e. a dresser containing shelves.

A range of unique stone furniture has been excavated in

Skara Brae, a Neolithic village located in Orkney. The site dates from 3100–2500 BC and due to a shortage of wood in Orkney, the people of Skara Brae were forced to build with stone, a readily available material that could be worked easily and turned into items for use within the household. Each house shows a high degree of sophistication and was equipped with an extensive assortment of stone furniture, ranging from cupboards, dressers and beds to shelves, stone seats, and limpet tanks. The stone dresser was regarded as the most important as it symbolically faces the entrance in each house and is therefore the first item seen when entering, perhaps displaying symbolic objects, including decorative artwork such as several Neolithic Carved Stone Balls also found at the site.

10.1.2 Classical world

Ancient furniture has been excavated from the 8th-century BC Phrygian tumulus, the Midas Mound, in Gordion, Turkey. Pieces found here include tables and inlaid serving stands. There are also surviving works from the 9th-8th-century BC Assyrian palace of Nimrud. The earliest surviving carpet, the Pazyryk Carpet was discovered in a frozen tomb in Siberia and has been dated between the 6th and 3rd century BC. Recovered Ancient Egyptian furniture includes 3rd millennium BC beds discovered at Tarkhan as place for the deceased, a c. 2550 BC gilded bed and two chairs from the tomb of Queen Hetepheres I, and many examples (boxes, beds, chairs) from c. 1550 to 1200 BC from Thebes. Ancient Greek furniture design beginning in the 2nd millennium BC, including beds and the klismos chair, is preserved not only by extant works, but by images on Greek vases. The 1738 and 1748 excavations of Herculaneum and Pompeii revealed Roman furniture, preserved in the ashes of the 79 A.D. eruption of Vesuvius, to the eighteenth century.

10.1.3 Early modern Europe

The furniture of the Middle Ages was usually heavy, oak, and ornamented with carved designs. Along with the other arts, the Italian Renaissance of the fourteenth and fifteenth century marked a rebirth in design, often inspired by the Greco-Roman tradition. A similar explosion of design, and renaissance of culture in general, occurred in Northern Europe, starting in the fifteenth century. The seventeenth century, in both Southern and Northern Europe, was characterized by opulent, often gilded Baroque designs that frequently incorporated a profusion of vegetal and scrolling ornament. Starting in the eighteenth century, furniture designs began to develop more rapidly. Although there were some styles that belonged primarily to one nation, such as

Florentine cassone *from the 15th century*

Palladianism in Great Britain or Louis Quinze in French furniture, others, such as the Rococo and Neoclassicism were perpetuated throughout Western Europe.

10.1.4 19th century

The furniture maker by Ludwig Deutsch

The nineteenth century is usually defined by concurrent revival styles, including Gothic, Neoclassicism, Rococo, and the EastHaven Movement. The design reforms of the

late century introduced the Aesthetic movement and the Arts and Crafts movement. Art Nouveau was influenced by both of these movements.

10.1.5 Early North American

This design was in many ways rooted in necessity and emphasizes both form and materials. Early Americanchairs and tables are often constructed with turned spindles and chair backs often constructed with steaming to bend the wood. Wood choices tend to be deciduous hardwoods with a particular emphasis on the wood of edible or fruit bearing trees such as Cherry or Walnut.

10.1.6 Modernism

Red and Blue Chair (1917), designed by Gerrit Rietveld

The first three-quarters of the twentieth century are often seen as the march towards Modernism. Art Deco, De Stijl, Bauhaus, Wiener Werkstätte, and Vienna Secession designers all worked to some degree within the Modernist idiom. Born from the Bauhaus and Art Deco/Streamline styles came the post WWII "Mid-Century Modern" style using materials developed during the war including laminated plywood, plastics and fiberglass. Prime examples include furniture designed by George Nelson Associates, Charles and Ray Eames, Paul McCobb, Florence Knoll, Harry Bertoia, Eero Saarinen, Harvey Probber, Vladamir Kagan and Danish modern designers including Finn Juhl and Arne Jacobsen. Postmodern design, intersecting the Pop art movement, gained steam in the 1960s and 70s, promoted in the 80s by groups such as the Italy-based Memphis movement. Transitional furniture is intended to fill a place between Traditional and Modern tastes.

Stainless Steel Table with FSC Teca Wood - Brazil Ecodesign

10.1.7 Ecodesign

Great efforts from individuals, governments, and companies has led to the manufacturing of products with higher sustainability known as Ecodesign. This new line of furniture is based on environmentally friendly design. Its use and popularity are increasing each year.[2]

10.1.8 Contemporary

One unique outgrowth of post-modern furniture design is Live edge, heralding a return to natural shapes and textures within the home.[3]

10.1.9 Asian history

Asian furniture has a quite distinct history. The traditions out of India, China, Pakistan, Indonesia (Bali and Java) and Japan are some of the best known, but places such as Korea, Mongolia, and the countries of South East Asia have unique facets of their own.

The use of uncarved wood and bamboo and the use of heavy lacquers are well known Chinese styles. It is worth noting that Chinese furniture varies dramatically from one dynasty to the next.

Sendai-dansu for kimono, zelkova wood, note the elaborate iron-work, handles on side for transportation, and lockable compartment

Traditional Japanese furniture is well known for its minimalist style, extensive use of wood, high-quality craftsmanship and reliance on wood grain instead of painting or thick lacquer. Japanese chests are known as Tansu, known for elaborate decorative iron work, and are some of the most sought-after of Japanese antiques. The antiques available generally date back to the Tokugawa era and Meiji era.

10.2 Types of furniture

Main article: List of furniture types

10.3 Types of wood to make furniture

Main article: List of woods

All different type of woods have unique signature marks, that can help in easy identification of the type. There are hardwoods and softwoods. Both are used in furniture manufacturing, and each have their own specific uses.[4] Most commonly, quality furniture is made out of hardwood which is made from oak, maple, mahogany, teak, walnut, cherry and birch. High quality wood will have been air dried to rid it of its moisture.[5]

10.4 Standards for design, functionality and safety

- EN 527 Office furniture - Work tables and desks
- EN 581 Outdoor furniture - Seating and tables for camping, domestic and contract use
- EN 1730 Furniture - Tables - Test methods for the determination of stability, strength and durability– withdrawn and superseded by BS EN 1730:2012. All testing methods used in European Standards are now to be found in a single document [6]
- EN 13150 Workbenches for laboratories - Safety requirements and test methods
- BS 4875 Furniture. Strength and stability of furniture. Methods for determination of stability of non-domestic storage furniture (British Standard)
- EN 1335 Office furniture - Office work chair
- EN 1728 Furniture - Seating - Test methods for the determination of strength and durability– updated in 2012:
  - All testing methods used in European Standards are now to be found in a single document,
  - Clarified and simplified test methods,
  - Includes a static load test for headrests.
- ANSI/BIFMA X 5.1 Office Seating
- EN 1335 Office furniture - Office work chair
- DIN 4551 Office furniture; revolving office chair with adjustable back with or without arm rests, adjustable in height
- NEN 1812 Furniture standard from the Netherlands
- EN 747 Furniture – Bunk beds and high beds – Test methods for the determination of stability, strength and durability
- GB 28007-2011 Children's furniture - General technical requirements for children's furniture designed and manufactured for children between 3 and 14 years old[7]
- BS 5852: 2006 Methods of test for assessment of the ignitability of upholstered seating by smouldering and flaming ignition sources

10.5 See also

- Casters which make some furniture moveable
- Furniture designer

10.6 References

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[5] Abe Abbas. "Judge Quality in Wood Furniture". About.com. Retrieved 9 May 2015.

[6] "Revisions to European Furniture Standards: bunk beds, chairs and tables" SGS SafeGuards, Retrieved 12/2012

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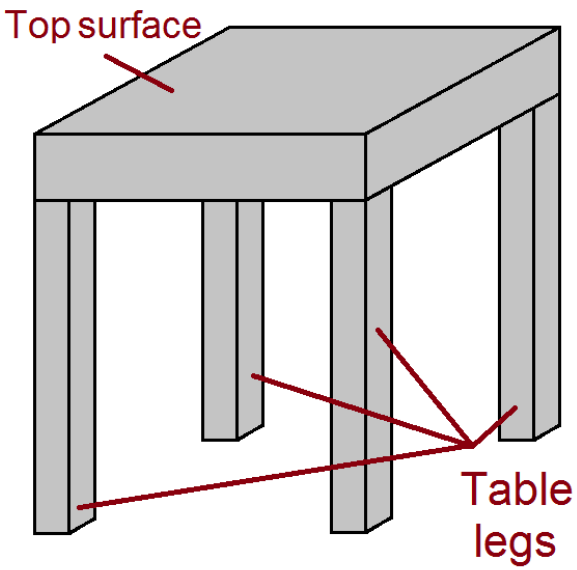
10.7 External links

- Images of furniture design available from the Visual Arts Data Service (VADS) - including images from the Frederick Parker Chair Collection, Design Council Archives, and the Design Council Slide Collection.
- History of Furniture Timeline From Maltwood Art Museum and Gallery, University of Victoria
- Illustrated History Of Furniture
- Home Economics Archive: Tradition, Research, History (HEARTH)
  An e-book collection of over 1,000 books on home economics spanning 1850 to 1950, created by Cornell University's Mann Library. Includes several hundred works on furniture and interior design in this period, itemized in a specific bibliography.
- *American Furniture in The Metropolitan Museum of Art*, a fully digitized 2 volume exhibition catalog

Chapter 11

Table (furniture)



Structure of a prototypical table, resembling a Parsons table design

A **table** is a form of furniture with a flat horizontal upper surface used to support objects, for storage, show, and/or manipulation.[1] Some common types of table are the dining room table, which is used for seated persons to eat meals; the coffee table, which is a low table used in living rooms to display items or serve refreshments; and the bedside table, which is used to place an alarm clock and a lamp. Another common type of table is a desk, which is typically used to hold items that one would need to do work, such as papers, textbook, or computers. The surface must be held stable. For reasons of simplicity, this is usually done by support from below by either a column, a "base", or at least three columnar "stands". In special situations, table surfaces may be supported from a nearby wall, or suspended from above.

Common design elements include:

- top surfaces of various shapes, including rectangular, rounded or semi-circular
- legs arranged in two or more similar pairs
- several geometries of folding table that can be collapsed into a smaller volume
- heights ranging up and down from the most common 18–30 inches (46–76 cm) range, often reflecting the height of chairs or bar stools used as seating for people making use of a table, as for eating or performing various manipulations of objects resting on a table
- presence or absence of drawers
- expansion of the surface by insertion of *leaves* or locking hinged *drop leaf* sections into horizontal position.

Desks are tables specifically intended for information-manipulation tasks, including writing and use of interactive electronics.

11.1 Etymology

The term *table* is derived from a merger of French *table* and Old English *tabele*, ultimately from the Latin word *tabula*, "a board, plank, flat top piece". In Late Latin, *tabula* took over the meaning previously reserved to *mensa* (preserved in Spanish and Portuguese *mesa* "table"). In Old English, the word was *bord*, replaced by *table* for this meaning.[2]

11.2 Shape, height, and function

Tables come in a wide variety of materials, shapes, and heights dependent upon their origin, style, and intended use. Most tables are composed of a flat surface and a base with one or more supports (legs). A table with a single, central foot is a pedestal table. Long tables often have extra legs for support.

Table tops can be in virtually any shape, although rectangular, square, round (e.g., the round table), and oval tops are the most frequent. Others have higher surfaces for personal use while either standing or sitting on a tall stool.

Many tables have tops that can be adjusted to change their height, position, shape or size, either with foldable extensions or sliding parts that can alter the shape of the top. Some tables are entirely foldable for easy transportation, e.g., camping. Small tables in trains and aircraft may be fixed or foldable, although they are sometimes considered as simply convenient shelves rather than tables.

Tables can be freestanding or designed for placement against a wall. Tables designed to be placed against a wall are known as **console tables**, from French *console* "bracket", and may be bracket-mounted (traditionally), like a shelf, or have legs, which sometimes imitate the look of a bracket-mounted table.

11.3 Types

A combination of a table with two benches (picnic table) as often seen at camping sites and other outdoor facilities

A formally laid table set with a dinner service

Tables of various shapes, heights, and sizes are designed for specific uses:

- **Dining room** tables[3] are designed to be used for formal dining.
- **Bedside tables**, **nightstands**, or **night tables**.[4] are small tables used in a bedroom. They are often used for convenient placement of a small lamp, alarm clock, glasses, or other personal items.
- **Gateleg tables**.[5] have one or two hinged leaves supported by hinged legs.
- **Coffee tables** [6] are low tables designed for use in a living room, in front of a sofa, for convenient placement of drinks, books, or other personal items.
- **Refectory tables** [7] are long tables designed to seat many people for meals.
- **Drafting tables**[8] usually have a top that can be tilted for making a large or technical drawing. They may also have a ruler or similar element integrated.
- **Workbenches** are sturdy tables, often elevated for use with a high stool or while standing, which are used for assembly, repairs, or other precision handwork.
- **Nested tables**[9] are a set of small tables of graduated size that can be stacked together, each fitting within the one immediately larger. They are for occasional use (such as a tea party), hence the stackable design.

11.4 Specialized types

Historically, various types of tables have been popular for other uses:

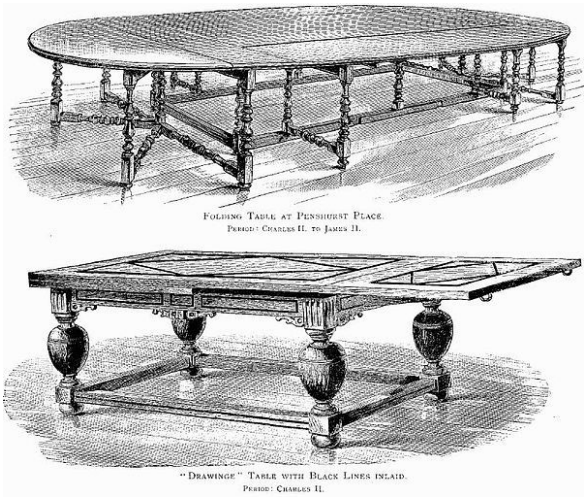
- **Loo tables** were very popular in the 18th and 19th centuries as **candlestands**, **tea tables**, or small dining tables, although they were originally made for the popular card game called loo or lanterloo. Their typically round or oval tops have a tilting mechanism, which enables them to be stored out of the way (e.g., in room corners) when not in use. A further development in this direction was the "birdcage" table, the top of which could both revolve and tilt.
- **Pembroke tables** were first introduced during the 18th century and were popular throughout the 19th century. Their main characteristic was a rectangular or oval top with folding or **drop leaves** on each side. Most examples have one or more drawers and four legs sometimes connected by stretchers. Their design meant they could easily be stored or moved about and conveniently opened for serving tea, dining, writing, or other occasional uses.

- **Sofa tables** are similar to Pembroke tables and usually have longer and narrower tops. They were specifically designed for placement directly in front of sofas for serving tea, writing, dining, or other convenient uses. Generally speaking, a sofa table is a tall, narrow table used behind a sofa to hold lamps or decorative objects.
- **Work tables** were small tables designed to hold sewing materials and implements, providing a convenient work place for women who sewed. They appeared during the 18th century and were popular throughout the 19th century. Most examples have rectangular tops, sometimes with folding leaves, and usually one or more drawers fitted with partitions. Early examples typically have four legs, often standing on casters, while later examples sometimes have turned columns or other forms of support.
- **Drum tables** are round tables introduced for writing, with drawers around the platform.
- **End tables** are small tables typically placed beside couches or armchairs. Often lamps will be placed on an end table.
- **Billiards tables** are bounded tables on which billiards-type games are played. All provide a flat surface, usually composed of slate and covered with cloth, elevated above the ground.
- **Chess tables** [10] are a type of games table that integrates a chessboard.
- **Table tennis tables** are usually masonite or a similar wood, layered with a smooth low-friction coating. they are divided into two halves by a low net, which separates opposing players.
- **Poker tables** or **card tables** are used to play poker or other card games.
- **Seating tables** are tables used as chairs.

11.5 Standards for design, functionality and safety

- EN 527 Office furniture - Work tables and desks
- EN 581 Outdoor furniture - Seating and tables for camping, domestic and contract use
- EN 1730 Furniture - Tables - Test methods for the determination of stability, strength and durability
- EN 13150 Workbenches for laboratories - Safety requirements and test methods
- BS 4875 Furniture. Strength and stability of furniture. Methods for determination of stability of non-domestic storage furniture (British Standard)

11.6 History



Large 17th-century English folding tables

Some very early tables were made and used by the Egyptians, and were little more than stone platforms used to keep objects off the floor. They were not used for seating people. Food and drinks were usually put on large plates deposed on a pedestal for eating. The Egyptians made use of various small tables and elevated playing boards. The Chinese also created very early tables in order to pursue the arts of writing and painting.

The Greeks and Romans made more frequent use of tables, notably for eating, although Greek tables were pushed under a bed after use. The Greeks invented a piece of furniture very similar to the guéridon. Tables were made of marble or wood and metal (typically bronze or silver alloys), sometimes with richly ornate legs. Later, the larger rectangular tables were made of separate platforms and pillars. The Romans also introduced a large, semicircular table to Italy, the *mensa lunata*.

Furniture during the Middle Ages is not as well known as that of earlier or later periods, and most sources show the types used by the nobility. In the Eastern Roman Empire, tables were made of metal or wood, usually with four feet and frequently linked by x-shaped stretchers. Tables for eating were large and often round or semicircular. A combination of a small round table and a lectern seemed very popular as a writing table.[11] In western Europe, the invasions and internecine wars caused most of the knowledge inherited from the classical era to be lost. As a result of the

necessary movability, most tables were simple trestle tables, although small round tables made from joinery reappeared during the 15th century and onward. In the Gothic era, the chest became widespread and was often used as a table.

Refectory tables first appeared at least as early as the 17th century, as an advancement of the trestle table; these tables were typically quite long and wide and capable of supporting a sizeable banquet in the great hall or other reception room of a castle.

11.7 Gallery

11.8 Pedestal tables

- Single pedestal
- Small single pedestal
- Dropleaf single pedestal
- Oval single pedestal
- Multiple pedestal

11.9 See also

- Folding table
- Kitchen table
- Nightstand
- Parsons table
- Picnic table
- Table tennis
- Trestle table
- TV tray table

11.10 References

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11.11 Further reading

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- Heyward, Helena (1980). *Grande Encyclopédie Illustrée des Meubles* (in French). Paris: Flammarion. ISBN 2-85961-073-1.

11.12 External links

- History of Table
- Antike Tisch-Kultur.de (German) - Galleries of ancient tables
- National Museum of Australia - First Fleet table - Pembroke table

Chapter 12

Chest (furniture)

Mexican Colonial era chest at the Franz Mayer Museum.

Early 19th Century American pine blanket chest or sugar chest, painted to look like curly maple

A **chest** (also called **coffer** or **kist**) is one of the oldest forms of furniture. It is typically a rectangular structure with four walls and a liftable lid, for storage. The interior space may be subdivided. The early uses of an antique chest or coffer included storage of fine cloth, weapons, foods and valuable items.

A cassone is a kind of carved or painted chest associated with late Medieval and Renaissance Italy. Cassones, also called marriage chests, were often used to carry the dowry goods in a marriage ceremony.

Painted wakis, yellowwood

A simple chest, called a wakis (wagon-kist) was commonly used in the Cape Colony as a seat on a wagon. To make it more usable, it often had a wooden support along the centre of the top so that the seated driver would not slide off so easily. In addition to this use, they were also used for storage at home; keeping clothes, food and other commodities safe. They were frequently made with one or more sides sloping downwards, although the top was always horizontal. Many are made of very good woods, like yellowwood and survived well. Some manufacturers also painted the front of the kist with relatively simply designs reminiscent of, and presumably originating from Europe bauernmalerei.

In Medieval and early Renaissance times in Europe low chests were often used as benches while taller chests were used as side tables. By placing a chest on the side on any kind of rough table, the inner surface of its lid could be used as a proper writing surface while the interior could house writing implements and related materials, as was the case with the Bargueño desk of Spain. Many early Portable

desks were stacked chests, with the top one having its lid on the side, to serve as a writing surface when opened.

In fantasy, fables, and games, "treasure chests" are frequently used as a plot device to contain treasure such as gold or jewels. The meaning can be a lot of things. The classical is a reward for a protagonist. In some stories a form of MacGuffin, a literary device which exists solely to drive forward a plot. A “toy chest” is a type of chest that usually carries children’s toys, like dolls or building blocks.

In some Slavonic countries, for example, in Ukraine, chests were a family relic, especially in peasant families. Each Ukrainian girl received her own chest at the age of 15 for her future bride’s dowry. Peeping in the girl’s chest was considered impolite. Coffers were an indicator of a family’s wealth. Ukrainian girls and women also used them to keep their garments and some personal items - towels, jewelry, tools for embroidering etc. A big collection of Ukrainian traditional chests dated by the 18-20th cc. is kept in the Radomysl Castle (Zhytomyr Region, Ukraine).

12.1 See also

- Cabinetry
- Chest of drawers, a piece of furniture often referred to as a chest.
- Hope chest
- Trunk, a piece of luggage, similar to a chest

12.2 External links

- ARTESO, reproductions of piece of furniture and arts of the Middle Ages
- antique chest of drawers, Chest of drawers from the Georgian, Regency, Victorian and Edwardian periods
- The Official Site of The Radomysl Castle

Chapter 13

Marquetry

The image on the cover of this box was made using the technique of marquetry.

In contrast, this Tilt-top table is veneered in a parquetry pattern by Isaac Leonard Wise, circa 1934.

Marquetry (also spelled as **marqueterie**) is the art and craft of applying pieces of veneer to a structure to form decorative patterns, designs or pictures. The technique may be applied to case furniture or even seat furniture, to decorative small objects with smooth, veneerable surfaces or to freestanding pictorial panels appreciated in their own right. Parquetry is very similar in technique to marquetry. Parquetry utilizes pieces of veneer in simple repeating geometric shapes to form tiled patterns such as would cover a floor (*parquet*), or forming basketweave or brickwork patterns, trelliswork and the like.

Marquetry (and parquetry too) differs from the more ancient craft of inlay, or intarsia, in which a solid body of one material is cut out to receive sections of another to form the surface pattern. The word derives from a Middle French word meaning “inlaid work”.

13.1 Materials

The veneers used are primarily woods, but may include bone, ivory, turtle-shell (conventionally called "tortoiseshell"), mother-of-pearl, pewter, brass or fine metals. Marquetry using colored straw was a specialty of some European spa resorts from the end of the 18th century. Many exotic woods as well as common European varieties can be employed, from the near-white of boxwood[1] to the near-black of ebony, with veneers that retain stains well, like sycamore, dyed to provide colors not found in nature.

The simplest kind of marquetry uses only two sheets of veneer, which are temporarily glued together and cut with a fine saw, producing two contrasting panels of identical design, (in French called *partie* and *contre-partie*, “part” and

"counterpart").

Two Lovers - example of sand-shading and shellac-inking

Marquetry as a modern craft most commonly uses knife-cut veneers. However, the knife-cutting technique usually requires a lot of time. For that reason, many marquetarians have switched to fret or scroll saw techniques. Other requirements are a pattern of some kind, some brown gummed tape (IE as the moistened glue dries it causes the tape to shrink and so the veneer pieces are pulled closer together), PVA glue and a base-board with balancing veneers on the alternate face to compensate stresses. Finishing the piece will require fine abrasive paper always backed by a sanding block. Either ordinary varnish, special varnishes, modern polyurethane -oil or water based- good waxes and even the technique of french polish are different methods used to seal and finish the piece.

Sand shading is a process used to make a picture appear to be more three-dimensional. A piece of veneer to be incorporated into a picture is partially submerged into hot sand for a few seconds.

Another process is engraving fine lines into a picture and filling them with a mixture of India Ink and Shellac.

13.2 History

The technique of veneered marquetry had its inspiration in 16th century Florence (and at Naples). Marquetry elaborated upon Florentine techniques of inlaying solid marble slabs with designs formed of fitted marbles, jaspers and semi-precious stones. This work, called *opere di commessi*, has medieval parallels in Central Italian "Cosmati"-work of inlaid marble floors, altars and columns. The technique is known in English as pietra dura, for the "hardstones" used: onyx, jasper, cornelian, lapis lazuli and colored marbles. In Florence, the Chapel of the Medici at San Lorenzo is completely covered in a colored marble facing using this demanding jig-sawn technique.

Techniques of wood marquetry were developed in Antwerp and other Flemish centers of luxury cabinet-making during the early 16th century. The craft was imported full-blown to France after the mid-seventeenth century, to create furniture of unprecedented luxury being made at the royal manufactory of the Gobelins, charged with providing furnishings to decorate Versailles and the other royal residences of Louis XIV. Early masters of French marquetry were the Fleming Pierre Golle and his son-in-law, André-Charles Boulle, who founded a dynasty of royal and Parisian cabinet-makers (*ébénistes*) and gave his name to a technique of marquetry employing *tortoiseshell* and brass with pewter in arabesque or intricately foliate designs. *Boulle* marquetry dropped out of favor in the 1720s, but was revived in the 1780s. In the decades between, carefully matched quarter-sawn veneers sawn from the same piece of timber were arranged symmetrically on case pieces and contrasted with gilt-bronze mounts. Floral marquetry came into favor in Parisian furniture in the 1750s, employed by cabinet-makers like Bernard van Risenbergh, Jean-Pierre Latz and Simon-François Oeben. The most famous royal French furniture veneered with marquetry are the pieces delivered by Jean Henri Riesener in the 1770s and 1780s. The *Bureau du Roi* was the most famous amongst these famous masterpieces.

Marquetry was not ordinarily a feature of furniture made outside large urban centers. Nevertheless, marquetry was introduced into London furniture at the Restoration of Charles II in 1660, the product of immigrant Dutch 'inlayers', whose craft traditions owed a lot to Antwerp. Panels of elaborately scrolling "seaweed" marquetry of box or holly contrasting with walnut appeared on table tops, cabinets, and long-case clocks. At the end of the 17th century, a new influx of French Huguenot craftsmen went to London, but marquetry in England had little appeal in the anti-French, more Chinese-inspired high-style English furniture (miscalled 'Queen Anne') after *ca* 1720. Marquetry was revived as a vehicle of Neoclassicism and a 'French taste' in London furniture, starting in the late 1760s. Cabinet-makers associated with London-made marquetry furniture, 1765–1790, include Thomas Chippendale and less familiar names, like John Linnell, the French craftsman Pierre Langlois, and the firm of William Ince and John Mayhew.

Although marquetry is a technique separate from inlay, English marquetry-makers were called "inlayers" throughout the 18th century. In Paris, before 1789, makers of veneered or marquetry furniture (*ébénistes*) belonged to a separate guild from chair-makers and other furniture craftsmen working in solid wood (*menuisiers*).

Modern marquetry: a tangram table by Silas Kopf, with trompe l'oeil images of paper and brush made entirely of different shades of flat veneer

Tiling patterning has been more highly developed in the Islamic world than anywhere else, and many extraordinary examples of inlay work have come from Middle Eastern countries such as Lebanon and Iran.

At Tonbridge and Royal Tunbridge Wells, England, souvenir "Tunbridge wares"— small boxes and the like— made from the mid-18th century onwards, were veneered with panels of minute wood mosaics, usually geometric, but which could include complicated subjects like landscapes. They were made by laboriously assembling and gluing thin strips and shaped rods, which then could be sliced crossways to provide numerous mosaic panels all of the same design.

Marquetry was a feature of some centers of German cabinet-making from c. 1710. The craft and artistry of David Roentgen, Neuwied, (and later at Paris as well) was unsurpassed, even in Paris, by any 18th-century marquetry craftsman.

Marquetry was not a mainstream fashion in 18th-century Italy, but the neoclassical marquetry of Giuseppe Maggiolini, made in Milan at the end of the century is notable.

The classic illustrated description of 18th century marquetry-making was contributed by Roubo to the *Encyclopédie des Arts et Métiers,* 1770. The most thorough and dependable 20th-century accounts of marquetry, in the context of Parisian cabinet-making, are by Pierre Verlet.

13.3 New techniques

During the 80's Georges Vriz developed a new technique called piercing. The idea is to layer two veneer layers on top of each other and sand through the top one, to the point of fiber transparency. This technique has been used mainly

Modern marquetry cabinet made from Tasmanian timbers.

in France, by professionals and students of the Ecole Boulle. In the US the technique has been used at the American School of French Marquetry by one of the teachers, the artist Patrice Lejeune. The school staff is also proposing a new name for this technique : "Given that 'piercing' is an unfortunate mistake in the veneering world, we chose to use the word "Fusion" instead, by which term the artist expresses his intention of sanding through the veneer as a decorative, textural effect, not as a mistake." At the American School of French Marquetry, Patrice Lejeune uses a technique he calls "sprinkling": by using waste - sawdust, shavings, scrapings etc. - as pigments, to create a range of diverse effects. Arguably this is no longer marquetry in the pure sense of the term, since it spills over into textured painting, even collage (to a limited extent) but, as a byproduct of modern marquetry making, we decided to include it in this thread. This technique also was invented by Georges Vriz, who employed it on a series of large panels exhibited in Paris at the Ecole de la Bonne Graine in 1996.

Amongst new techniques applied to marquetry we may include laser cutting, where the design is drawn or imported as a CAD or vector file and each piece is cut separately; each different species of wood -and thickness- may need a specific adjustment of the beam's power; the offset will determine the gap between the pieces and, in some cases, the beam will leave a dark edge due to the very high heat required by the process.

13.4 See also

- Woodworking
- Lath Art
- Khatam

13.5 References

[1] Boxwood turns golden-tan as it ages.

13.6 External links

- A Short History of Marquetry Includes a glossary.
- *The Gubbio Studiolo and its conservation, volumes 1 & 2*, from The Metropolitan Museum of Art Libraries (fully available online as PDF), which contains material on marquetry

Chapter 14

Cabinetry

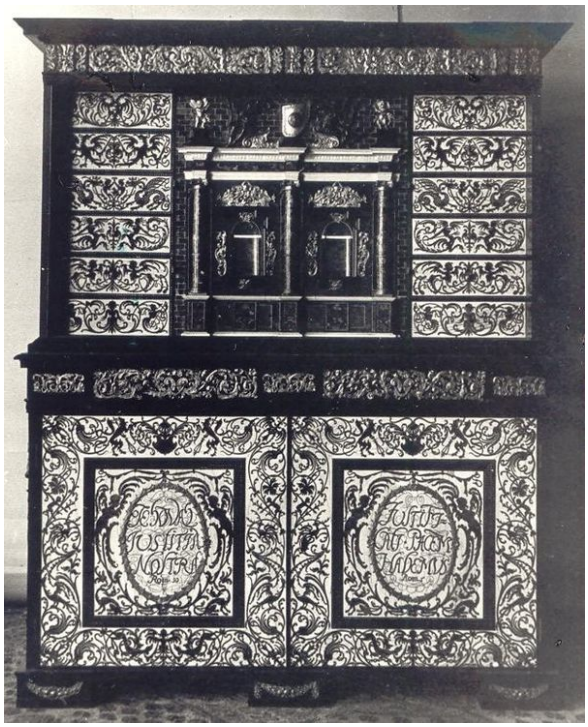
Cabinet

A **cabinet** is a box-shaped piece of furniture with doors or drawers for storing miscellaneous items. Some cabinets stand alone while others are built into a wall or are attached to it like a medicine cabinet. Cabinets are typically made of wood or, now increasingly, of synthetic materials. Commercial grade cabinets, which differ in the materials used, are called casework.

Cabinets usually have one or more doors on the front, which are mounted with door hardware, and occasionally a lock. Many cabinets have doors and drawers or only drawers. Short cabinets often have a finished surface on top that can be used for display, or as a working surface, such as the countertops found in kitchens.

A cabinet intended for clothing storage is usually called a *wardrobe* or an *armoire*, or (in some countries) a *closet* if built in.

14.1 History



Tortoise-shell cabinet of Polish king John III Sobieski, looted by the Germans from the Wilanów Palace during World War II[1]

Before the advent of industrial design, cabinet makers were responsible for the conception and the production of any piece of furniture. In the last half of the 18th century, cabinet makers, such as Thomas Sheraton, Thomas Chippendale, Shaver and Wormley Bros. Cabinet Constructors, and George Hepplewhite, also published books of furniture forms. These books were compendiums of their designs and those of other **cabinet makers**.

With the industrial revolution and the application of steam power to cabinet making tools, mass production techniques were gradually applied to nearly all aspects of cabinet mak-

ing, and the traditional cabinet shop ceased to be the main source of furniture, domestic or commercial. In parallel to this evolution there came a growing demand by the rising middle class in most industrialised countries for finely made furniture. This eventually resulted in a growth in the total number of traditional cabinet makers.

Before 1650, fine furniture was a rarity in Western Europe and North America. Generally, people did not need it and for the most part could not afford it. They made do with simple but serviceable pieces.

The arts and craft movement which started in the United Kingdom in the middle of the 19th century spurred a market for traditional cabinet making, and other craft goods. It rapidly spread to the United States and to all the countries in the British Empire. This movement exemplified the reaction to the eclectic historicism of the Victorian era and to the 'soulless' machine-made production which was starting to become widespread.

After World War II woodworking became a popular hobby among the middle classes. The more serious and skilled amateurs in this field now turn out pieces of furniture which rival the work of professional cabinet makers. Together, their work now represents but a small percentage of furniture production in any industrial country, but their numbers are vastly greater than those of their counterparts in the 18th century and before.

14.2 Schools of design

14.2.1 Scandinavian

This style of design is typified by clean horizontal and vertical lines. Compared to other designs there is a distinct absence of ornamentation. While Scandinavian design is easy to identify, it is much more about the materials than the design.

14.2.2 French Provincial

This style of design is very ornate. French Provincial objects are often stained or painted, leaving the wood concealed. Corners and bevels are often decorated with gold leaf or given some other kind of gilding. Flat surfaces often have artwork such as landscapes painted directly on them. The wood used in French provincial varied, but was often originally beech.[2]

Crafted by Hughes Sambin (1570-1600), double cabinet features the combination of architectural elements and relief carving that is characteristic of French furniture of the period.

14.2.3 Early American Colonial

This design emphasises both form and materials. Early American chairs and tables are often constructed with turned spindles and chair backs often constructed using steaming to bend the wood. Wood choices tend to be deciduous hardwoods with a particular emphasis on the wood of edible or fruit-bearing trees such as cherry or walnut.[3]

14.2.4 Rustic

The rustic style of design sometimes called “log furniture” or "log cabin" is the least finished. Design is very utilitarian yet seeks to feature not only the materials used but in, as much as possible, how they existed in their natural state.

For example, a table top may have what is considered a "live edge" that allows you to see the original contours of the tree that it came from. It also often uses whole logs or branches including the bark of the tree. Rustic furniture is often made from pine, cedar, fir and spruce. Also see Adirondack Architecture.

14.2.5 Mission Style

Mission Design is characterized by straight, thick horizontal and vertical lines and flat panels. The most common material used in Mission furniture is oak. For early mission cabinetmakers, the material of choice was white oak, which they often darkened through a process known as "fuming".[4] Hardware is often visible on the outside of the pieces and made of black iron. It is a style that became popular in the early 20th century; popularized by designers in the Arts and Crafts and Art Nouveaux movements.

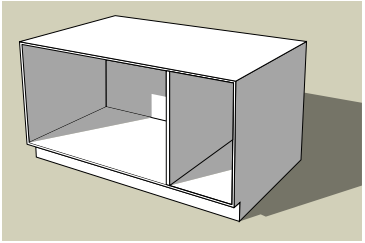
14.2.6 Oriental

Also known as Asian Design, this style of furniture is characterized by its use of materials such as bamboo and rattan. Red is a frequent color choice along with landscape art and Chinese or other Asian language characters on the pieces.

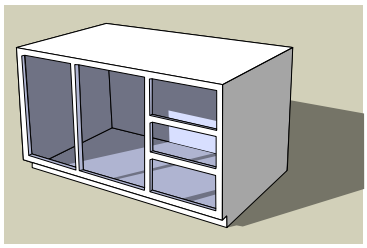
14.2.7 Shaker

Shaker furniture design is focused on function and symmetry. Because it is so influenced by an egalitarian religious community and tradition it is rooted in the needs of the community versus the creative expression of the designer. Like Early American and Colonial design, Shaker craftsmen often chose fruit woods for their designs. Pieces reflect a very efficient use of materials.

14.3 Types of cabinetry



A frameless cabinet



A cabinet with a face frame

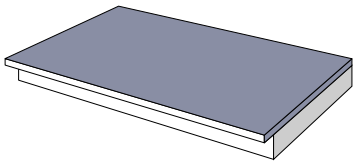
The fundamental focus of the cabinet maker is the production of cabinetry. Although the cabinet maker may also be required to produce items that would not be recognized as cabinets, the same skills and techniques apply.

A cabinet may be built-in or free-standing. A built-in cabinet is usually custom made for a particular situation and it is fixed into position, on a floor, against a wall, or framed in an opening. For example modern kitchens are examples of built-in cabinetry. Free-standing cabinets are more commonly available as off-the-shelf items and can be moved from place to place if required. Cabinets may be wall hung or suspended from the ceiling.

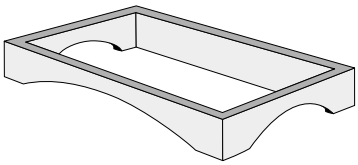
Cabinets may have a face frame or may be of frameless construction (also known as *European* or *euro-style*). Face frame cabinets have a supporting frame attached to the front of the cabinet box. This face frame is usually 1½ inches in width. Mounted on the cabinet frame is the cabinet door. In contrast, frameless cabinet have no such supporting front face frame, the cabinet doors attach directly to the sides of the cabinet box. The box's side, bottom and top panels are usually 5/8 to 3/4 inches thick, with the door overlaying all but 1/16 inch of the box edge.[5] Modern cabinetry is often frameless and is typically constructed from man-made sheet materials, such as plywood, chipboard or MDF. The visible surfaces of these materials are usually clad in a timber veneer, plastic laminate, or other material. They may also be painted.

14.4 Cabinet components

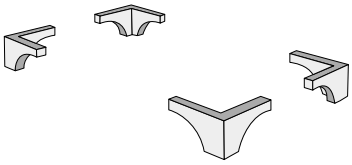
14.4.1 Bases



Enclosed cabinet base with a kick space



Scrolled base



Bracket feet

Cabinets which rest on the floor are supported by some base. This base could be a fully enclosed base (i.e. a plinth), a scrolled based, bracket feet or it could be a set of legs.

14.4.2 Adjustable feet

A type of adjustable leg has been adopted from the European cabinet system which offers several advantages. First off, in making base cabinets for kitchens, the cabinet sides would be cut to 34½ inches, yielding four cabinet side blanks per 4 foot by 8 foot sheet. Using the adjustable feet, the side blanks are cut to 30 inches, thus yielding six cabinet side per sheet.

These feet can be secured to the bottom of the cabinet by having the leg base screwed onto the cabinet bottom. They can also be attached by means of a hole drilled through the cabinet bottom at specific locations. The legs are then attached to the cabinet bottom by a slotted, hollow machine screw. The height of the cabinet can be adjusted from inside the cabinet, simply by inserting a screwdriver into the slot and turning to raise or lower the cabinet. The holes in the cabinet are capped by plastic inserts, making the appearance more acceptable for residential cabinets. Using these feet, the cabinets need not be shimmed or scribed to the floor for leveling. The toe kick board is attached to the cabinet by means of a clip, which is either screwed onto the back side of the kick board, or a barbed plastic clip is inserted into a saw kerf, also made on the back side of the kick board. This toe kick board can be made to fit each base cabinet, or made to fit a run of cabinets.[6]

Kitchen cabinets, or any cabinet generally at which a person may stand, usually have a fully enclosed base in which the front edge has been set back 75 mm or so to provide room for toes, known as the kick space. A scrolled base is similar to the fully enclosed base but it has areas of the base material removed, often with a decorative pattern, leaving feet on which the cabinet stands. Bracket feet are separate feet, usually attached in each corner and occasionally for larger pieces in the middle of the cabinet.

14.4.3 Compartments

A cabinet usually has at least one compartment. Compartments may be open, as in open shelving; they may be enclosed by one or more doors; or they may contain one or more drawers. Some cabinets contain secret compartments, access to which is generally not obvious.

Modern cabinets employ many more complicated means (relative to a simple shelf) of making browsing lower cabinets more efficient and comfortable. Such means include (names may be heavily colloquialised):

- The lazy susan, a shelf which rotates around a central axis, allowing items stored at the back of the cabinet to be brought to the front by rotating the shelf. These are usually used in corner cabinets, which are larger and deeper and have a greater “dead space” at the back than other cabinets.

14.4.4 Cabinet insert hardware

An alternative to the lazy susan, particularly in base cabinets, is the blind corner cabinet pull out unit. These pull out and turn, making the attached shelving unit slide into the open area of the cabinet door, thus making the shelves accessible to the user. These units make usable what was once dead space.

Other insert hardware includes such items as mixer shelves that pull out of a base cabinet and spring into a locked position at counter height. This hardware makes lifting these somewhat heavy mixers and mechanically helping with the process of positioning the unit for use. More and more components are being designed to enable specialized hardware to be used in standard cabinet carcasses.

14.4.5 Tops

Most cabinets incorporate a top of some sort. In many cases, the top is merely to enclose the compartments within and serves no other purpose—as in a wall hung cupboard for example. In other cabinets, the top also serves as a work surface—a kitchen countertop for example.

14.5 See also

- List of furniture designers
- List of furniture types

- Woodworking
- Amish furniture
- Ébéniste (French for “cabinet-maker”)

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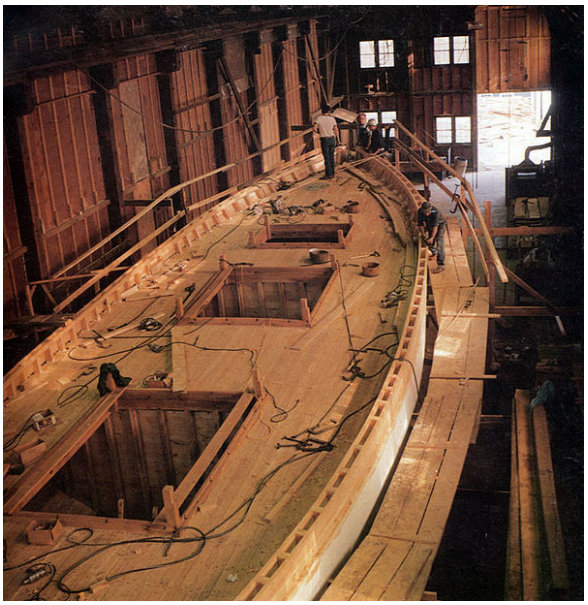
Chapter 15

Boat building



The schooner Appledore II *under construction.*

Boat building, one of the oldest branches of engineering, is concerned with constructing the hulls of boats and, for sailboats, the masts, spars and rigging.

Boat building in Greece.

Side view of the wooden frame.

15.1 Parts

- Anchor- a heavy, pick like device, attached to a boat's stem by a warp and chain. Common types are Plow or Fisherman and Danforth. Modern anchors are made of steel but in pre-industrial societies rocks were used. The chain is added to the lower anchor end to add weight and prevent chafing of the rope warp on rocks or shellfish beds.

- Angel also virgin or maiden. A Norsemen invention used in sailing long ships from about the 10th century AD that predates blocks. They served the purpose of a block/jamb cleat in one unit. It was a flat section of wood about 150 high x 120 wide shaped like an angel/butterfly used in attaching stays to the hull. The V-shape at the lower part of the "wings" acted as a V jam cleat.

- Bitts - Two short strong posts often made of steel, located on the fore and aft side decks of a heavily built boat or ship, that are designed to take heavy mooring lines.

- Bilge - the lowest part of the hull interior, under the sole. Often water and or fuel tanks are placed in the bilges to lower the centre of gravity.
- Bilge keel - a longitudinal, external, underwater member used to reduce a ship's tendency to roll. In Britain twin bilge keels are often used on small boats moored in estuaries with a large tidal range so the boat stay upright when dried out. With their much shallower draft yachts of this type can be sailed in shallow waters. Not as hydro dynamically efficient as a fin keel.
- Bilge pump - a pump, either manual or electric with the inlet set at the lowest point in the bilges where water will collect when the boat is upright. The inlet is protected by a screen to stop blockages
- Block a fitting with a circular wheel inside 2 cheeks designed to hold the turn of a rope. Originally made of wood, they are now made of plastic, stainless steel or carbon fibre. They are mainly used in rigging in pairs or quads to allow a single person to operate a sail that creates a lot of force. Similar to a pulley or sheave.
- Bow - The front and generally sharp end of the hull. It is designed to reduce the resistance of the hull cutting through water and should be tall enough to prevent water from easily washing over the deck of the hull.
- Bowsprit - A spar that extends forward from the foredeck, outboard of the hull proper. Common in square rigged ships where they were used to attach the outer or flying jib. In modern sailboats they are often made of lightweight carbon and used for attaching the luff of lightweight down-wind sails.
- Breasthook - A roughly triangular piece of wood fitted immediately aft of the stem and between the two inwales or sheer clamps usually in a wooden dinghy.
- Bulkhead - The internal transverse walls of the hull.
- Bulwarks - The upstanding part of the topsides, above the deck, providing safe footing when a boat is heeled.
- Cam cleat- a mechanical cleat with 2 spring loaded cam jaws, usually made of hard plastic, that clamp onto a sheet. The sheet can be easily pulled forward and upwards to release it but is held tight in the cam jaws when unattended.
- Catsheads - A short timber(or pair of timbers) that protrudes approximately at right angles from the foredeck of a square rigged sailing ship. Its purpose is to support the weight of the anchor and keep the anchor secure and outboard of the hull to avoid damaging the hull planking.
- Capstan A vertical metal or wooden winch secured to the foredeck of a ship, used for hoisting the anchor. Capstans may be manually operated or powered hydraulically or electrically. A traditional wooden capstan is fitted with removable wooden arms fitted into sockets on which the seaman push. Seashanties were often chanted to keep the seamen together as they pushed.
- Carlin - A longitudinal strip parallel to, but inboard of, the inwale (sheer clamp). It supports the inboard edge of the side deck and the side of the cabin cladding.
- Chainplate - A strip of strong metal, often stainless steel, through-bolted to the topsides and a frame and protruding above deck level to take the load of a stay in a sail boat.
- Centre board - (also dagger board) an elongated underwater appendage that fits vertically in the slot of a centre case and extends below the hull. It can be retracted so the boat can float in very shallow water. The board has a length to breadth ratio of about 4;1. The board is tapered to a hydrodynamic (teardrop) shape in plan section to promote laminar flow of the water. This shape prevents stalling or eddying when sailing to windward. Together with the sails it lifts the hull in the windward direction. Common materials are wood often reinforced with fibreglass or carbon to obtain more stiffness and abrasion resistance. When sailing to windward the board is fully down but is retracted about half way when sailing directly down wind. When sailing to windward an efficient board prevents most leeway (sideways movement).
- Chines - Are the abrupt change of angle where the topside meets the bottom of a hull. In a power or fast sail boat boat the chine deflect spray down wards when the hull is travelling at speed. A multi chine hull has 4 or more chines to allow an approximation of a round bottomed shape using flat panels. It also refers to the longitudinal structural members inside the hull which support the edges of these panels. Traditionally these were called chine logs especially in Eastern USA.
- Cleat - A fitting designed to tie off ropes. Often T shaped.
- Coaming - any vertical surface on a ship designed to deflect or prevent entry of water
- Cockpit - The seating area towards the stern of a small decked vessel where the rudder controls are located.
- Counter stern - a traditional stern construction with a long overhang and a shorter, upright, end piece. The stern is rounded when in plan-view. The counter is usually decked over.

- Companion way-in a small yacht this is the short ladder that leads from the cockpit to cabin or saloon. Often it is detachable for access to the engine or storage. In a large vessel it is a permanent ladder between decks. A companion way usually has non slip treads and handholds.

- Crosstree- two short metal arms that are attached to a mast athwartwise about mid height. Mast side stays are tensioned by running through the outboard end of the arms, often forming a diamond shape. Similar to a spreader.

- Deck - The top surface of the hull keeps water and weather out of the hull and allows the crew to operate the boat more easily. It stiffens the hull. Temporary frames (or moulds) can be removed and kept for another boat.

- Deck beam - A heavy timber running athwartwise(across)from the top of a frame under the deck. It usually has a gentle convex (upward) curve for extra strength, extra head height below deck along the centre line and to allow water to run off the deck when the boat is upright.

- Dolphin striker - A short spar fitted mid-way and vertically downwards, midway along a bowsprit that holds the bobstay and prevents the outboard end of the bowsprit riding upwards under the load of a tensioned headsail.

- Dorade - A ventilation intake consisting of a cowling connected to a short vertical tube connected to a deck mounted scuppered (Dorade) box, usually made from teak. The cabin intake is offset to prevent water entering the cabin. The upper section swivels to stop breaking seas entering the dorade. Named after the 1931 yacht Dorade where it was first used.

- Epoxy resin -a chemical fluid widely used in advanced wooden boat building since the 1980s in a variety of forms,principally glue,as a filler (with a variety of powders or sawdust)and as a moisture resistant barrier on both the interior and exterior of a wooden hull. The method was popularized by the WEST system. Sometimes used in conjunction with various cloths such as fibreglass, kevlar or carbon fibre. A thinned mixture of resin is used to penetrate the fibres of light weight woods such as Balsa and Western red cedar forming a waterproof barrier, far superior to single pot paint or varnish. In small boat and kayak construction Epoxy resin is often used in conjunction with lightweight 3 or 4mm thick Okoume (Gaboon)plywood to form very light strong hulls. Typically few nails or screws are needed as the resin is so strong. Slow drying and far stronger but more difficult to sand than Polyester resin. Typically applied with a roller,throw away brushes and radiused flat tongue depressor for coving using thickened epoxy. Softens and weakens slightly at high ambient temperatures so vessels in tropical waters should be lighter coloured.

- Fairlead-A U shape or circular fitting often positioned near the bow that leads an anchor warp or a sheet to a cleat or winch. The anchor fairlead is usually bronze or stainless steel as it must take the regular abrasion of the warp and chain. The anchor fairlead is usually set on the change of angle between the deck and the topside to prevent wear and tear.

- Fiddle-or fiddle rail. A low rail about 40mm high, either of solid wood or lathe turned fiddles that is designed to stop things sliding off a table at sea when the boat is heeled.

- Foil-name for the T or L shaped hydro planning appendage that lifts a hull out of the water while sailing.The vertical component is similar to a convention dagger board but much narrower due to the high sailing speed of foiling craft. 120 mm is typical in a foiling Moth of 3.3m length. The vertical component is a symmetrical NASA foil shape. The main vertical foil is often angled forward to prevent air being sucked down the leading edge and creating a disturbed water flow. The winglets or blades are asymmetrical NASA foil shapes like a plane wing. In most foiling boats the whole wing can moved up or down -either automatically and/or partly controlled by a crew member to adjust the amount of lift needed. This depends mainly on wind and boat speeds. Winglets with a wider cross section give more lift at lower speeds but have more drag as speed increases whereas narrower ones have less lift but less drag at higher speed. Foils are usually made of lightweight carbon fibre because of its extreme strength and stiffness.

- Frame - the transverse structure that gives a boat its cross-sectional shape. Frames may be solid or peripheral. They may be made of wood, plywood, steel, aluminium or composite materials. They may be removed after construction to save weight or to be reused or left in-situ. In ancient shipbuilding the frames were put in after the planking but now most boats are built with the frames first. This gives greater control over the shape. “Lofting” is the process used to create life-size drawings of frames so they can be manufactured. Today frames can be cut directly from a computer programme by a robot, with extreme accuracy. In old heavily built, square rigged ships, the frames were made up of 4 individual timbers called futtocks, as it was impossible to make the shape from a single

piece of wood. The futtock closest to the keel was the ground futtock and the other pieces were called upper futtocks.

- Freeboard- the distance between the water line and the deck when loaded. Boats using sheltered waters can have low free board but seagoing vessels need high freeboard.
- Furling headsail -a jib or other headsail that automatically rolls around a semi rigid forestay when a line is pulled. The lower section of the furling gear has a spring loaded retrieval system that rolls up the headsail. These are often used in cruising boats or when a yacht is sailed short-handed. The operating lines are operated from the safety of the cockpit avoiding crew working on the exposed foredeck. On very large yachts the furling gear is attached to an electric motor for ease of use.
- Garboard - The strake immediately adjacent to the keel in a traditional wooden boat.
- Gimbaled stove/compass-a pivoting apparatus that allows a stove or compass to swing in two planes at the same time so that it remains more or less level. This makes the compass needle steady and easier to read and allows food to be cooked (carefully) in seaway.
- Gooseneck - a universal joint, usually made of stainless steel, that joins the boom to the mast. Many goose necks can be raised or lowered on a short section of track fixed to the mast.
- Grab rail- a length of strong wood, often mahogany, or stainless steel tube, with short legs, through bolted to a cabin top, so that crew making their way forward on a sloping and wet side deck have a firm handhold.
- Gudgeon- a stainless steel fitting, attached to a rudder head, in pairs, with parallel holes in which the rudder pintle pivots .
- Gunwale - The upper, outside longitudinal structural member of the hull.
- Hatch - A lifting or sliding opening into the cabin or deck for the loading of cargo or people.
- Heads - marine toilet. An abbreviation of the term catsheads which was the normal place of toileting in square rigger days. Always used in the plural.
- Horn Cleat - see cleat
- Hull - The main body of a ship or other vessel, including the bottom, sides, and deck.
- Hydrofoil-An inverted T or an L-shaped keel/dagger board device, with hydro dynamic lifting ability, that extends vertically downwards under the hull. As boat speed increases the hull lifts completely out of the water so drag is reduced and hull speed dramatically increased. The AC 72 ft catamaran New Zealand reached 40 knots in 17 knots of wind with almost no heeling, using hydrofoils in September 2012.[1] Sometimes called foiling or foil sailing. Most commonly used in 11 feet Moth sail boats. Also used in powerboats.
- Innerliner - The cockpit or deck mold of the inside or top of a GRP boat, fitted inside and joined to the (outside) hull.
- Inwale - The upper, inner longitudinal structural member of the hull, to which topside panels are fixed. In USA this is usually called the sheer clamp.
- Jib stick- A short, light spar used to hold out the jib when sailing almost directly down wind or in light airs when the jib may otherwise collapse or flap. The out board end may have a U shape to take the jib sheet or a point to go into the clew. The inboard end may be held or fastened to some convenient point such as a side stay or a purpose made fitting.
- Keel - The main central member along the length of the bottom of the boat. It is an important part of the boat's structure which also has a strong influence on its turning performance and, in sailing boats, resists the sideways pressure of the wind
- Keelson - An internal beam fixed to the top of the keel to strengthen the joint of the upper members of the boat to the keel.
- King plank - A flat, notched (nibbed) timber laid over the foredeck beams between the front of a cockpit or cabin and the stem. The notches or nibbs are designed so that the tapering deck planks do not end in a point which could be a weak point.
- Knee - A short L shaped piece of wood that joins or strengthens boat parts that meet at about 60 to 120 degrees. It may be a natural crook (e.g. apple, oak, pohutukawa) or sawn from a larger length of timber or laminated in a wooden vessel. Commonly seen on thwarts to join topsides or keelsons to join transoms. A hanging knee fits upside down e.g. underneath a thwart rather than on top. Hanging knees often support carlins where a full frame would be inconvenient.
- Locker - an enclosed space to store sails, anchors, personal effects, tools and supplies

- Mast - A vertical pole on a ship which supports sails or rigging. If a wooden, multi-part mast, this term applies specifically to the lowest portion.
- Mast step - A socket, often strengthened, to take the downward thrust of the mast and hold it in position. May be on the keel or on the deck in smaller craft.
- Moon pool - An opening in the bottom of the hull giving access to the water below, allowing access to the sea. Similar to wet porch.
- Mizzen-the permanent mast and sail set aft in a sailboat with 2 or more masts.
- Newel Post- turned wooden posts, from floor to ceiling, to one side of the cabin in a yacht. Serves as a handhold when a boat is at sea.
- Oar A wooden pole flattened at the outboard-end so it grips the water when pulled. Oars are normally used in pairs to propel a rowboat forward. Differs from a paddle by being longer and gaining leverage by passing through a rowlock which acts as a fulcrum to produce forward motion. Modern oars are often made from plastic or hollow carbon fibre in racing oars. A single oar can be leveraged against a U shape notch in the stern of a row boat to scull. The sculler stands and moves the oar in a sideways motion to produce forward motion in calm waters. A balanced oar is one that has weight added (either by extra wood or lead inside the handle)to the inboard end to balance the additional outboard length. In a rowing dinghy with 7–8 feet oars the balance point is about 12 inches outboard of the rowlocks.
- Painter-a short rope tied to the bow of a small boat, which can be held by a person. Used to control a boat while unloading from a trailer or loading/unloading from a beach.
- Parrot beak-a stainless steel fitting on the end of a spinnaker pole, consisting of a mounting with a retractable spring loaded pin that is controlled remotely by way of a cord. When the cord is pulled it releases the spinnaker sheet so the spinnaker can be recovered by crew on deck.
- Pintle a short section of stainless steel rod, about 6-12mm in diameter, mounted on a stainless steel bracket, that is bolted to the transom of a sail boat, so that the pin is inserted in the gudgeon hole.
- Planing Plank - a narrow, flat bottom keel about 150mm wide on a high speed deep or medium V powered planning craft. In flat water the craft would plane on this narrow plank giving increased speed. In choppy water the ride was unsettled. Steering accuracy when cornering was difficult as the craft swung wide. A concept used in power craft in the 1970s and 1980s but replaced by deeper V hulls with angles of more than 21 degrees from the 1990s.
- Prod- a very strong, light, hollow tapered pole, often made of carbon fibre, attached to the bow of a modern racing yacht, enabling it to carry a spinnaker or other down-wind sail with the luff in line with the centreline of the boat. In some yachts, such as the modern 49er, the prod is retracted through a hole in the bow when sailing upwind. Larger prods, such as on an AC72, are secured by dolphin strikers to prevent the prod bending upwards or breaking.
- Ratlines (sometimes *ratlins*) - Groups of side stays on a square rigged ship that have horizontal lines placed for feet, enabling crew to rapidly ascend to the yards.
- Rib - A thin strip of pliable timber laid athwart-wise inside the hull, from inwale to inwale, at regular close intervals to strengthen the exterior planking. The rib is often steamed to increase flexibility. The rib is traditionally fixed to the planking by rivets or copper nails bent over on the inside. This method is still used in small clinker built dinghies and similar craft. Ribs are attached after the planking is constructed. Ribs differ from frames or futtocks in being far smaller dimensions and bent in place compared to frames or futtocks which are normally sawn to shape, or natural crooks that are shaped to fit with an adze, axe or chisel.
- Rigging- wire or rod used to hold up a mast. Since the 1960s stainless steel wire has become universal in the developed world. Elsewhere galvanized wire or even rope may be used because of its availability and cheapness.3 types of stainless steel wire are commonly used. Type 1 x 19 is a non-flexible wire used for standing rigging such as stays. Type 7 x 7 is a semi flexible wire used for luff wires in sails, halyards (sometimes plastic coated) trapeze wires and light halyards. Type 7 x 19 is used for all halyards, wire sheets, vangs and strops that must run through a pulley (sheave). The common way of attaching wire is to form a small loop at the end which is fixed in place by clamping a soft metal swage over the free ends. Talurite is a common brand of swagging. The wire loop is then fastened to a rigging screw with a bow shackle to the chain plate. Kevlar rope is sometimes used in place of wire in small sailboats.
- Rowlock - Pronounced Rolick. A 'U' shaped metal device that secures an oar and acts as a fulcrum during the motion of rowing. Sometimes called an oarlock

in the USA. The Rowlock is attached with a swivelling pin to the gunwale in a row boat. Commonly made from galvanized steel, bronze or plastic. Before the availability of metal the oar was normally levered against 2 wooden pins called Thole pins inserted in the gunwale. Tholepins are still used in some third world nations. In a narrow row boat the rowlocks are held well outboard in a lightweight outrigger (rigger) which is often equipped with a locking pin to hold the oar securely.

- Rudder - A steering device usually at the rear of the hull created by a turn-able blade on a vertical axis
- Sampson post - A strong vertical post used to support a ship's windlass and the heel of a ship's bowsprit.
- Scuppers - Gaps in the bulwarks which enables sea or rain water to flow off the deck.
- Shackle - a small, U shape, stainless steel or galvanized steel secured with a screw type pin at the open end of the U. Some types have spring loaded pins that snap shut.
- Sheave box - a plastic or stainless steel box that holds a pulley that is fixed in position such as on a mast head so that the angle of the rope (halyard)is restricted.
- Sheer - The generally curved shape of the top of the hull when viewed in profile. The sheer is traditionally lowest amidships to maximize freeboard at the ends of the hull. Sheer can be reverse, higher in the middle to maximize space inside, or straight or a combination of shapes.
- Sensor - A small electronic component which can be embedded in a hull skin, keel, rudder, mast, oar or sail of a very-high-performance craft to measure the laminar flow of air or water. Pioneered in New Zealand using technology from Formula 1 racing. Now used in rowing skiffs or racing oars to determine forces such as bending load and optimum angle of attack of the blade. Larger craft such as America Cup boats have readout displays on board so minute changes in sail angle can be related to speed and then duplicated at a later date.
- Sheet - A rope used to control the position of a sail e.g. the main sheet controls the position of the main sail.
- Skeg - A long tapering piece of timber fixed to the underside of a keel near the stern in a small boat to aid directional stability, especially in a kayak or rowboat.
- Spar - A length of timber, aluminium, steel or carbon fibre of approximately round or pear shape that is used to support sails. Such as a mast, boom, gaff, yard, bowsprit, prod, boomkin, pole or dolphin striker .
- Sole-the floor of a cabin or cockpit. Often the cabin floor is made in sections that can be lifted quickly to gain access to the bilges in the event of a leak. Cockpit floors on yachts are often self-draining so that water will drain out even when the vessel is sailing at an extreme angle. In many high speed skiffs the craft is fitted with a sole angled aft to rapidly drain the spray through an open transom. Often this type of sole is called a false floor.
- Spinnaker- sometimes called a kite in Australia or New Zealand. A large, lightweight, down-wind sail used on fore and aft rigged yachts such as sloops to dramatically increase sail area. The sail is hoisted by a halyard attached by a ring to the head of the sail. The windward, luff, corner is secured by a sheet often called a preventer. The preventer runs through a parrot beak attached to the end of a spinnaker pole. Until recently the pole was usually secured by a parrot beak to a ring on the lower mast. The leeward, clew, corner is controlled by a sheet. In double luff (parallel sided) spinnakers, the 2 sheets are interchangeable. In some very modern racing yachts the pole is replaced by a prod which is fixed in place at the bow. Some spinnakers are single luff, which are flatter and with a longer luff enabling them to be carried more easily on a reach. In small planning sailboats such as 18 ft skiffs, huge spinnakers cause dramatic increases in speed and spectacular, on the edge, sailing.
- Spreaders- two angled, metal struts, attached about mid height on a mast, for the purpose of keeping the side stays taunt. Spreaders are usually swept rearwards approximately in line of the side stay between the hounds and the chain plate. They help hold the mast straight (in column) when under heavy load such as when carrying a spinnaker on a tight reach.
- Spring - The amount of curvature in the keel from bow to stern when viewed side on. The modern trend is to have less spring in order to have less disturbance to water flow at higher speeds to aid planing.
- Stanchions - A series of narrow but strong posts, often made of marine grade stainless steel, designed to hold life lines around the outer edge of a deck. Stanchions are often attached to both the deck and a toe rail or bulwark for added strength.
- Stainless steel- mild steel to which small percentages of copper, chromium and sometimes nickel are added to make a very strong steel that is does not rust much. Marine grade stainless steel 316 containing more nickel, is even more rust resistant. Can be made into rod, tubes, sheet or pressed into a wide variety of shapes for marine fittings.

- Stays/shrouds - Standing or running rigging which hold a spar in position e.g. sidestay, forestay, backstay. Formerly made of rope, these days usually stainless steel wire.

- Stem - A continuation of the keel upwards at the front of the hull

- Stern - The back of the boat

- Stern sheets a flat area or deck, inboard of the transom in a small boat. It may contain hatches to access below decks or provide storage on deck for life saving equipment.

- Strake - A strip of material running longitudinally along the vessel's side, bilge or bottom. Sometimes called a stringer.

- Stringer-Batten in USA. A long relatively thin, knot free length of wood, running fore and aft, often used to reinforce planking on the inside of the hull, especially when thin planking is used.See strake

- Synthetic rope - There are 4 common ropes in use. Polyester, also called Dacron or Terylene, is a strong, low stretch rope, usually plaited (braided) used for running rigging. Nylon is a strong, but elastic rope, used for mooring lines and anchor warps as it resists shock loads. It is usually laid (twisted) so that it is easier to grip when hauling. Polypropylene is a light, cheap, slippery rope, that floats. It is much weaker than the previous ropes. It weakens when exposed to sunlight. It is usually laid construction. Commonly used on commercial fishing boats using nets. Kevlar is an extremely strong fibre that is now made into ropes with almost no stretch. Expensive. Suited to halyards instead of stainless steel wire. Often used on racing yachts to replace polyester when powerful winches are used. Kevlar ropes can be much smaller in diameter than polyester for the same strength. This saves windage on a racing yacht. Usually braided.

- Taff rail-a railing, often ornate, at the extreme stern of a traditional square rigged ship. In light air conditions an extra sail was set on a temporary mast from the taff rail.

- Thwart - A seat, usually transverse, that is used to maintain the shape of the topsides in a small boat.

- Tiller- A handle made of wood, steel or carbon fibre that is attached to the top of a rudder, often via a post, which enables the helmsman to steer the boat.

- Tiller extension-A long, lightweight handle attached to the forward end of the tiller which enables the helmsman to steer from a position from the side deck or outboard of a side deck on a high performance yacht. For example from a trapeze.

- Toe rail - A upright longitudinal strip of timber fastened to the fore deck near the sheer. It is placed so that crew working on the foredeck can brace their toe or foot against it especially when the boat is heeled.

- Topping Lift-a rope running from the aft end of the boom, through a block at the masthead and down to a cleat at the foot of the mast. Used for holding the boom up when the mainsail is not being used.

- Topsides - The side planking of a boat from the waterline to the sheer.

- Transom - A wide, flat or slightly curved, sometimes vertical board at the rear of the hull, which, on small power boats, is often designed to carry an outboard motor. Transoms increase width and also buoyancy at the stern. On outboard boats the stern is often the widest point to provide displacement to carry a large outboard and to resist the initial downward thrust of a planning craft. Sometimes the term tuck is used in a sail boat.

- Trapeze- a wire and belt device allowing a crew member to lie near horizontal with their feet braced against the gunwhale in order to counter act the healing force of the wind acting on the sails of a centre board racing yacht. A thin stainless steel wire is attached to the mast at about 3/4 height and to a belt worn by the crew member via a hook. When tacking the sailor must swing in, unhook, move to the other side of the yacht and reattach the hook on the opposite tack. Agility is required. The crew holds the tail of the jib sheet for trimming and balance. In a few classes the helmsman and/or helmsman and all crew, use trapezes.

- Wand-a devise fitted to a foiling yacht to give control over the ride height and "z" factor(foil rise and fall). Consists of a carbon tube that pivots from the bow attached to an internal wire or rod that is attached to arod in the centre (main) foil). The rod runs to the main foil blades (wings)to control their angle.The wand can be set fixed but since about 2009 a dial is fitted that allow the skipper to adjust the foil blade angles/wand height. Some craft are fitted with dual wands for more precise control.

- Washboard - a panel that slides vertically in small boat's companionway acting as a removable door

- Warp-anchor rope. Traditionally made of natural fibre such as hemp, modern warps are made of stronger, lighter, synthetic fibre, often laid nylon, which is elastic so absorbing shock loads which would otherwise pull out the anchor. Warps are normally at least 3 times the depth of the water. In strong wind and/or current the warp should be at least 6 times the water depth.
- Water tank - a large irregular shaped container(s), often made of stainless steel, that is usually fitted into the bilges of a voyaging boat. The tank often has a deck mounted inlet, a vent pipe and a pump to move water to taps, showers etc. Mounted low in the hull, it adds significantly to stability when full.
- Winch-a geared mechanical device used on yachts for trimming (adjusting)sail sheets, for hoisting large sails with halyards, for hauling in an anchor or on a boat trailer for hauling a boat out of the water. The normal turret winch is set on the aft side deck for trimming headsails and or a spinnaker. Manual trimming winches are operated by grinding the handle in a circle initially, then pulling back and forwards on a short lever while a second person tails (pulls to keep tension on the sheet)to obtain optimum force. Some winches are self-tailing or the sheet can be cleated to prevent slippage. On larger yachts winches can be operated by electric motors. Typically on America's cup yachts large pedestal winches are used which can be operated by two people at the same time. Because of the force needed, especially in tacking duels, winch grinders are usually very large and strong men.
- Wind pennant-a small wind indicator balanced on a pivot, usually fitted to the mast head, to indicate wind direction. Can be made of plastic, stainless steel or sail cloth.
- Wheelhouse - a permanent, raised shelter, with large windows, often located midships or aft, from which the helmsman steers. Usually contains all the boats controls, instruments and electronics. It gives the helmsman good visibility 360 degrees and keeps them out of bad weather and spray. The wheelhouse may be open aft or have access to the side decks so when operating short-handed the helmsman can attend lines.
- Yard - A horizontal spar on a square rigged ship fitted to the forward side of a mast, holding a square sail forward of the shrouds. Each square sail hangs from its own yard. Sails are furled by seamen who bend over the yard and use both hands to haul up the sail. The sail is trimmed to the wind by braces leading from the yard arms (ends of the yard) aft (or forward) to another mast, or down to the deck. Compare to "gaff" and "boom", which attach to the aft side of the mast and hold a "fore-and-aft" sail aft of the shrouds. A square sail trims to either side of athwartships, and a fore-and-aft sail trims to either side of fore-and-aft.

15.2 Construction materials and methods

Damaged boat mid-reconstruction; carvel planking partially removed.

Caulking irons and oakum.

15.2.1 Wood

The traditional boat building material used for hull and spar construction. It is buoyant, widely available and easily worked. it is a popular material for small boats (of e.g. 6-metre (20 ft) length; such as dinghies and sailboats). Its abrasion resistance varies according to the hardness and density of the wood and it can deteriorate if fresh water

Caulking a wooden boat.

A sheet plywood sailboat during construction.

or marine organisms are allowed to penetrate the wood. Woods such as Teak, Totara and some cedars have natural chemicals which prevent rot whereas other woods, such as Pinus radiata, will rot very quickly. The hull of a wooden boat usually consists of planking fastened to frames and a keel. Keel and frames are traditionally made of hardwoods such as oak while planking can be oak but is more often softwood such as pine, larch or cedar.

Plywood is especially popular for amateur construction but only marine ply using waterproof glues and even laminates should be used. Cheap construction plywood often has voids in the interior layers and is not suitable to boat building as the voids trap moisture and accelerate rot as well as physically weaken the plywood. No plywood is rot resistant and should be coated with epoxy resin and/or a good paint system. Varnish and Linseed oil should not be used on the exterior of a hull for waterproofing. Varnish has about 60% of the water resistance of a good paint system. Only boiled linseed oil should be used on a boat and only in the interior as it has very little water resistance but it is very easy to apply and has a pleasant smell. Note that used linseed rags should not be left in a pile as they can catch fire. A valuable 200 year old waka (Maori canoe)caught fire in New Zealand in June 2014 when restorers left rags piled overnight. Raw linseed oil is not suited to boats as it stays damp and oily for a long time. Mildew will grow well on raw linseed oil treated timber but not on boiled linseed oil. More recently introduced tropical woods as mahogany, okoumé, iroko, Keruing, azobé and merbau.[2] are also used. With tropical species, extra attention needs to be taken to ensure that the wood is indeed FSC-certified.[3][4] Teak or iroko is usually used to create the deck and any superstructure. Glue, screws, rivets and/or nails are used to join the wooden components. Before teak is glued the natural oil must be wiped off with a chemical cleaner, otherwise the joint will fail.

Some types of wood construction include:

- **Carvel**, in which a smooth hull is formed by edge joined planks attached to a frame. The planks may be curved in cross section like barrel staves. Carvel planks are generally caulked with oakum or cotton that is driven into the seams between the planks and covered with some waterproof substance. It takes its name from an archaic ship type and is believed to have originated in the Mediterranean. A number of boat building texts are available which describe the carvel planking method in detail.[5]

- **Clinker** is a technique originally identified with the Norsemens in which wooden planks are fixed to each other with a slight overlap that is beveled for a tight fit. The planks may be mechanically connected to each other with copper rivets, bent over iron nails, screws or in modern boats with adhesives. Often, steam bent wooden ribs are fitted inside the hull.

- Strip planking is yet another type of wooden boat construction similar to carvel.[6] It is a glued construction method which is very popular with amateur boatbuilders as it is quick, avoids complex temporary jig work and does not require shaping of the planks.[7]

- Sheet plywood boat building uses sheets of **plywood panel**s usually fixed to longitudinal long wood such the chines,inwhales(sheer clamps)or intermediate stringers which are all bent around a series of frames. By attaching the ply sheets to the longwood rather than directly to the frames this avoids hard spots or an unfair hull. Plywood may be laminated into a round hull or used in single sheets. These hulls generally have one or more chines and the method is called Ply on Frame construction.[8] A subdivision of the sheet plywood boat building method is known as the stitch-and-glue method,[9] where pre-shaped panels of plywood are edge glued and reinforced with fibreglass without the use of a frame.[10] Metal or plastic ties, nylon fishing line or copper wires pull curved flat

panels into three-dimensional curved shapes. These hulls generally have one or more chines. Marine grade plywood of good quality is designated "WBP" (which stands for water- and boiled-proof) or more usually BS 1088. Australian plywood manufacturers and suppliers have issued warnings that some Asian nations are selling ply stamped BS 1088 which does not meet international standards. Specifically,they say outer plies are too thin (should be 1.2 mm or 0.047 in minimum)or are very thin (less than 0.5 mm or 0.020 in)or high grade surface ply such as Okoume is combined with a much heavier and wider inner cores. Most high grade marine Okoume (Gaboon) ply uses light weight poplar inner cores. Often the 1088 stamp is blurred in the poor Asian ply so it is not clear. In Australia and New Zealand a higher grade marine ply than BS1088 is AS2272. It requires both faces to be "A" quality,with even thickness plies. The most common plywood used for this grade is plantation grown Hoop Pine which is fine grained, very smooth, moderately light (at 570 kg/m^3 or 36 lb/cu ft it is the same weight as Meranti ply and about 13% heavier than genuine poplar cored BS1088 Okoume). Hoop pine has a very high stress rating of F17 indicating high strength. Meranti (Lauan) ply has a stress rating of F14 and Okoume ply F8. Okoume ply is commonly coated with epoxy to increase strength and impact resistance as well as to exclude water. Both types of plywood construction are very popular with amateur builders, and many dinghies such as the Vaurien, Cherub, Moth and P class (ply on frame construction) and FJs, FDs and Kolibris (stitch-and-glue method) have been built from it.[11][12] Another variation is tortured ply where very thin(3 mm or 0.12 in) and flexible (often Okoume)preshaped panels ply are bent into compound curves and sewn together. Little or no framework or longitudinal wood is used. This method is mainly confined to kayaks.

- Cold-Molding is a composite method of wooden boat building that uses 2 or more layers of thin wood, called veneers, oriented in different directions, resulting in a strong monocoque structure, similar to a fibreglass hull but substantially lighter. Usually composed of a base layer of strip planking followed by multiple veneers, cold-molding is popular in small, medium and very large, wooden super-yachts. Using different types of wood the builder can lighten some areas such as bow and stern and strengthen other high stress areas. Sometimes cold molded hulls are protected either inside or out or both with fibreglass or similar products for impact resistance especially when lightweight, soft timber such as cedar is used. This method lends itself to great flexibility in hull shape.

15.2.2 Steel (and before that iron)

Either used in sheet or alternatively, plate [13] for all-metal hulls or for isolated structural members. It is strong, but heavy (despite the fact that the thickness of the hull can be less). It is generally about 30% heavier than aluminium and somewhat more heavy than polyester. The material rusts unless protected from water (this is usually done by means of a covering of paint). Modern steel components are welded or bolted together. As the welding can be done very easily (with common welding equipment), and as the material is very cheap, it is a popular material with amateur builders. Also, amateur builders which are not yet well established in building steel ships may opt for DIY construction kits. If steel is used, a zinc layer is often applied to coat the entire hull. It is applied after sandblasting (which is required to have a cleaned surface) and before painting. The painting is usually done with lead paint (Pb_3O_4). Optionally, the covering with the zinc layer may be left out, but it is generally not recommended. Zinc anodes also need to be placed on the ship's hull. Until the mid-1900s, steel sheets were riveted together.

A punt under construction.

Wooden boats being built during the Klondike Gold Rush.

15.2.3 Aluminium

Aluminium is either used in sheet for all-metal hulls or for isolated structural members. Many sailing spars are frequently made of aluminium after 1960. The material requires special manufacturing techniques, construction tools and construction skills. It is the lightest material for building large boats (being 15-20% lighter than polyester and 30% lighter than steel). Aluminium is very expensive in most countries and it is usually not used by amateur builders. While it is easy to cut, aluminium is difficult to weld, and also requires heat treatments such as precipitation strengthening for most applications. Corrosion is a concern with aluminium, particularly below the waterline. It is most commonly used in small pleasure and fishing power boats that are not kept permanently in the water.

15.2.4 Fiberglass (Glass-reinforced plastic or GRP)

Typically used for production boats because of its ability to reuse a female mold as the foundation for the shape of the boat. The resulting structure is strong in tension but often needs to be either laid up with many heavy layers of resin-saturated fiberglass or reinforced with wood or foam in order to provide stiffness. GRP hulls are largely free of corrosion though not normally fireproof. These can be solid fiberglass or of the sandwich (cored) type, in which a core of balsa, foam or similar material is applied after the outer layer of fiberglass is laid to the mold, but before the inner skin is laid. This is similar to the next type, composite, but is not usually classified as composite, since the core material in this case does not provide much additional strength. It does, however, increase stiffness, which means that less resin and fiberglass cloth can be used in order to save weight. Most fibreglass boats are currently made in an open mold, with fibreglass and resin applied by hand (hand-lay-up method). Some are now constructed by vacuum infusion where the fibres are laid out and resin is pulled into the mold by atmospheric pressure. This can produce stronger parts with more glass and less resin, but takes special materials and more technical knowledge. Older fibreglass boats before 1990 were often not constructed in controlled temperature buildings leading to the widespread problem of fibreglass pox, where seawater seeped through small holes and caused delamination. The name comes from the multiude of surface pits in the outer gelcoat layer which resembles smallpox. Sometimes the problem was caused by atmospheric moisture being trapped in the layup during construction in humid weather.

15.2.5 Composite material

Originally “composite” referred to a timber carvel skin fastened to iron frame and deck beams. This allowed sheet copper anti-fouling to be employed without the risk of galvanic corrosion of the hull fabric. It was employed for fast cargo vessels so that they were not slowed by marine fouling. This use is now obsolete. While GRP, wood, and even concrete hulls are technically made of composite materials, the term “composite” is often used for plastics reinforced with fibers other than (or in addition to) glass. Cold-molded refers to a type of building one-off hulls using thin strips of wood applied to a series of forms at 45-degree angles to the centerline. This method is often called double-diagonal because a minimum of two layers is recommended, each occurring at opposing 45-degree angles. “Cold-molding” is now a relatively archaic term because the contrasting “hot-molded” method of building boats, which used ovens to heat and cure the resin, has not been widely used since World War II . Now almost all curing is done at room temperature. Other composite types include sheathed-strip, which uses (usually) a single layer of strips laid up parallel to the sheer line. The composite materials are then applied to the mold in the form of a thermosetting plastic (usually epoxy, polyester, or vinylester) and some kind of fiber cloth (fiberglass, kevlar, dynel, carbon fiber, etc.), hence the finished hull is a “composite” of fiber and resin. These methods often give strength-to-weight ratios approaching that of aluminum, while requiring less specialized tools and skills.

15.2.6 Steel-reinforced cement (ferrocement)

Strong, long lasting and very heavy. First developed in the mid 19th Century in France. Used for building warships. Extensively refined in New Zealand shipyards in the 1960s and the material became popular among amateur builders of cruising sailboats in the 1970s and 1980s, because the material cost was cheap, although the labour time element was high. The weight of a finished ferro-cement boat is much higher than most wooden boats. As such they are often built for slower, more comfortable sea passages. Hulls built properly of ferro-cement are more labor-intensive than steel or fiberglass, so there are few examples of commercial shipyards using this material. The inability to mass-produce boats in ferro-cement has led there to there being few examples around. Many ferro-cement boats built in back yards can have a rough, lumpy look, which has helped to give the material a poor reputation. The ferro-cement method is easy to do, but it is also easy to do wrong. This has led to some disastrous 'home-built' boats. Properly designed, built and plastered ferro-cement boats have smooth hulls with fine lines. Amateur builders are advised to use a pro-

fessional plaster to produce a smooth finish. Most ferrocement hulls are designed as heavy displacement. See also concrete ship, concrete canoe.

15.3 Hull types

Further information: Hull (watercraft)

To build a boat, the type of hull used is of vital importance; for example, going to sea requires a hull which is more stable than a hull used for sailing rivers (which can be more flat/round). Some types include:

- Smooth curve hull - As its name implies, the hulls of these vessels are rounded and don't usually have any chines or corners.
- Chined and hard chined hulls - These are hulls made up of flat panels (commonly made of plywood, or more traditionally with planking) which meet at a sharp angle known as the chine. Chined hulls range from simple flat-bottomed boats where the topsides and bottom meet at about 110 degrees (such as banks dories and sharpies) to skiffs where the bottom is arced rather than flat. Multi-chine plywood hulls allow a round hull shape to be approximated.
- Flat-bottomed hull - The flat-bottomed hull has advantages, such as the ability to travel in shallower water and being cheap and easy to build, though it is much less stable in rough waters than other hull types.
- Displacement hulls - These are hulls which have a shape which does not promote planing. Displacement hulls are often heavy and lack sufficient power -either motor or sail to achieve planning. They travel through the water at a limited rate which is defined by the waterline length.
- Planing hulls - These are hulls with a shape that allows the boat to rise higher and higher out of the water as the speed increases. They are commonly fine bowed. Sail boats that plane are flat-bottomed aft. Because sail boats sail heeled over, the flat surface can be achieved with v or arc bottom shapes. Hydroplanes are very light, flat bottomed, high powered speed boats that plane easily on flat water but quickly become unstable in any waves. Powerboats designed for rough water are usually deep V-bottomed with a deadline angle of about 20-23 degrees. The most common form is to have at least one chine to allow for stability when cornering and for a supportive surface on which to ride while planing. Planing hulls allow much higher speeds to be achieved, and are not limited by the waterline length the way displacement hulls are. They require more energy in the form of large sails or high power motors plus light weight to achieve these speeds.

15.4 Boat building tools and use

Boat building uses many or the same tools that are common house tools such as hammers, cross cut saws, power drills, benches and vices. For building small boats under 5m some specialized tools are needed such as clamps (cramps) either G clamps or spring clamps. A minimum of 4 6inch(150mm) and 10 4inch(100mm) G clamps, plus 20 2 inch(50mm) steel spring clamps is need for ply on frame designs. More is better with clamps. Flat and round surform rasps are useful tools for shaping wood and ply. A drill set from 2-10mm, several speedbore drills for larger holes 12-25mm, (1/2inch-1 inch) rotary sanding backing pads and a range of replacement sanding pads from coarse (40grit) to fine (180grit), counter sinking drills for screws, a right angle set square, a set of manual screw drivers with blades to match screws being used are essential. A heavy craft knife, an 8m(25 ft) tape, flat and round files for metal and wood, a short(torpedo) level and a set of 3 chisels from 6 to 25mm are needed. Power tools make a job much easier and are relatively cheap. An 7 1/4inch (185mm) circular saw with a fine 40 tooth tungsten carbide blade, a jigsaw with a dust blower with a set of fine, medium and coarse tooth metal and wood blades is good for cutting plywood panels to shape, a rotary oscillating sander with medium and fine pads and a cordless drill for driving screws all save time and energy. A steam box is excellent for making planks easier to bend although hot wet rags are a messy, but easy substitute. A fine tooth hacksaw is not only essential for cutting metal such as trimming stainless steel bolts to the correct length but is handy for ultra-fine cuts in thin wood. A fine-tooth tenon saw is used to cut across the grain to produce a reasonably fine, accurate cut. Some boat builders have started using Japanese draw saws for fine cuts but while these are excellent they tend to be very expensive. A No 4 smoothing plane is essential but an electric plane is very useful (but extremely loud) for making rudder blades and centre boards. A much longer No. 7 plane is needed if the design calls for a wooden spars as used in many modern “traditional” yachts.

In boat building lots of sanding requires using either dry sandpaper, or wet and dry paper, to achieve a reasonable paint or varnish finish. Sandpaper is graded from 40 (very coarse) to 400 (ultrafine). Wet and dry sandpaper lasts longer than dry sandpaper. Wet and dry is best used on paint finishes, while dry paper is best used on dry wood. About 2 sheets of sandpaper for every foot of hull length

is a good guide. Less sheet sandpaper is needed if power sanders are used. Spatula applicators, with a flexible stainless steel blade, are used to apply filler. A knife type and a flat 3"(75mm) type will cover most needs.

Silicon bronze screws are normally used in boat building but can be hard to locate. Brass fasteners are commonly available but apart from being softer and weaker the common brass alloys are much more prone to corrosion through depletion of their zinc content. Stainless steel screws may be used for attaching fittings to the hull above the water line. Type 316 stainless steel is the only stainless steel recommended. Even 316 may get stained with surface rust but this does not penetrate the surface. Staining comes from being in contact with other steels such as the anchor or incorrect cleaning in the factory. Staining near wields should be removed as it can pit. Experienced boat builders are reluctant to use even 316 below the water line in a boat permanently in salt water. This especially applied to long thin fastenings such as screws in boats that have motors. Sacrificial anodes are used to help prevent corrosion underwater but experts will inspect a sample of long thin screws or bolts annually to check for corrosion.

Epoxy resins and hardeners are universally used in boat building due to their superior holding power and ease of use.[14] In its thickened state it is used as a strong filler and for a range of joints that do away with more traditional fastenings. A large supply of cheap wooden tongue depressors is useful for mixing and applying epoxy resin. The curved ends are useful for shaping coved joints with epoxy. Silicon bronze ring nails are excellent for permanent fastening of wood and ply as they are strong and easily driven. Many small boats are almost entirely fastened by epoxy resin. In stitch and glue construction the hull panels are temporarily held together with either copper wire, nylon fishing line or plastic cable ties, until the epoxy cures, after which the stitching material is removed. Polyester filler is a quick setting (20mts), softer filler, suited to very small holes and scratches and is far more easily sanded to a fair shape than harder, stronger epoxy filler which takes 24 hours to set hard.

Boat building requires enough space, under cover, so that the builder can easily move around the hull during construction, or the boat can be built on a trailer so the hull can be moved out of the shelter for construction sessions. It also requires space at the bow and stern not only for working but for sighting down the gunwale and chine lines to check they are fair. Have the bow at the garage door end for this reason. This is especially important in stitch and glue construction where no jig is used, as the ply panels are very floppy until the glue sets.

Water based paint is far easier and cheaper to apply, as undercoat, to produce a good smooth finish with a fraction of the time and effort of enamel paints but harder and slower drying enamel is best for the top coat on the outside of the hull which is subject to a lot of bumps and scraps. Limit varnishing to smaller areas, such as grab rails, hatches, toe rails and trim, unless you have lots of patience and a very dust free environment for varnishing. Use only Marine Gloss varnish on the outside, as interior varnish will peel off very quickly in hot sun and rain. Marine varnish has UV inhibitors to slow down peeling and fading. Never varnish a deck as it is slippery when wet. Even top quality marine varnish is not as water resistant as paint so you must apply at least 4 coats minimum. Often perfectionists will apply 8 coats or more to get a glass like, reflective finish. Never varnish submerged parts like rudders.

Boats take a long time to build as there are almost no right angles. Amateurs working at night or in weekends commonly take a year to build a 12–16 ft (3.6–5m) craft. Builders with handyman skills will find that over time their skills will increase. For amateurs, starting with a boat built on a jig (temporary wooden frame)is useful as making the jig is all about right angles and basic carpentry skills. Sail boats require about 25% more time than a dinghy type because of the need for built in buoyancy, centreboard case, centreboard, rudder, mast, boom and a range of special fittings such as chain plates, gudgeons, blocks cleats and tracks.

Essential safety gear needed is closed in footwear, very high grade air protectors (especially if using a high revving electric plane or router),eye shields when cutting or grinding metal, disposable gloves when gluing, close fitting clothes that will not get caught in drills. Good light is essential. Boat builders should not work when they are tired and should keep the work floor clean so they don't trip over tools or wood or electric leads. A fan is handy for extra ventilation if the work space does not have many opening windows or doors. Many boat builder like smaller tools to be bright coloured tools so they can see them easily amongst saw dust.[15]

Other useful power tools are a belt sander, especially if using recycled timber or for finishing rough sawn timber. A thicknesser/planer is only needed if building many boats or larger vessels, as it is usually cheaper to pay a joiner to do this for a small amount of timber. A bench saw is useful if you buy larger sectioned timber, which may be considerably cheaper and need to saw it to the correct size, but again a timber yard will do this for a small charge.[16]

15.5 Boat Building Training

The boat building in the traditional sense is still alive, though there are very few institutions offering the courses.

Some of them are:

- International Boatbuilding Training College (IBTC), Lowestoft, UK [17]
- International Yacht Restoration School (IYRS) – Rhode Island, USA [18]
- Northwest School of Wooden Boat Building – Washington, USA [19]
- Arques School - California, USA
- Great Lakes Boat Building School - Michigan, USA
- The Apprentice Shop - Maine, USA
- The Landing School - Maine, USA [20]
- Antique Boat Museum - New York, USA
- Boat Building Academy - Lyme Regis, UK [21]
- Falmouth Marine School - Falmouth, UK
- Technical school for Boat Builders (Landesberufsschule für Bootsbauer) - Lübeck, Germany [22]

15.6 Gallery

Traditional boat building in India.[23]

-
- View of a Boat at Bheemunipatnam (being manufactured)

Traditional wooden boat building in Vietnam. Photos taken January 2009.

- Small boatyard horizontal band saw, Hoi An.
- Small boat using the planks first method. Hoi An.
- Boat nearing completion with frames added. Hoi An.
- Plank on frame construction. Quy Nhon.
- Almost completed offshore fishing hull, Quy Nhon.
- Plank fixing, trenails and red lead paint, Quy Nhon.
- Repaired frames, barge hull. Sa Dec, Mekong Delta.

15.7 See also

- Center for Wooden Boats
- Do it yourself
- E.G. van de Stadt
- Future boat developments
- Lofting
- Marine propulsion
- Messabout
- Outboard motor
- Propeller
- Sail
- Sailboat design and manufacturing
- Sail-plan
- Shipbuilding
- Slipway
- Spaulding Wooden Boat Center
- Stephens Bros. Boat Builders
- Sterndrive
- Stitch and glue
- Strip-built

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[17]

[18]

[19] Boat Building in Washington

[20] Landing School Maine

[21] UK

[22]

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15.9 External links

- WoodenBoat Publications — publisher of construction plans and techniques for traditional boat building methods.
- A website for the home boat builder.
- Hull Identification Number Information & Laws — a website dedicated to the science behind boat HIN's.
- Details of classic boat construction, Larry Pardey.
- Puddle Duck Racer The easiest boat in the world to build – a wealth of information for beginning boat builders and sailors

Chapter 16

Timber framing

Timber framing and **"post-and-beam" construction** are methods of building with heavy timbers rather than dimensional lumber such as 2"x4"s. Traditional timber framing is the method of creating structures using heavy squared-off and carefully fitted and joined timbers with joints secured by large wooden pegs (larger versions of the mortise and tenon joints in furniture). It is commonplace in wooden buildings from the 19th century and earlier. The method comes from making things out of logs and tree trunks without modern high tech saws to cut lumber from the starting material stock. Using axes, adzes, and draw knives, hand-powered auger drill bits (bit and brace), and laborious woodworking, artisans or farmers could gradually assemble a building capable of bearing heavy weight without excessive use of interior space given over to vertical support posts. Since this building method has been used for thousands of years in many parts of the world, there are many styles of historic framing. These styles are often categorized by the type of foundation, walls, how and where the beams intersect, the use of curved timbers, and the roof framing details. Three basic types of timber frames in English-speaking countries are the box frame, cruck frame, and aisled frame.

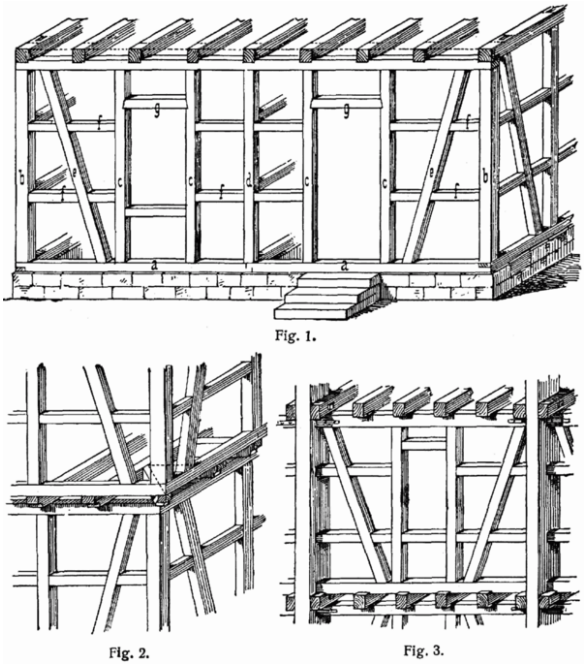


Illustration of timber framing from the Lexikon der gesamten Technik (1904)

The market square of Dornstetten (Germany), showing an ensemble of half-timbered buildings

16.1 The box frame

A simple timber frame made of straight vertical and horizontal pieces with a common rafter roof without purlins. The term box frame is not well defined and has been used for any kind of framing other than cruck framing. The distinction presented here is the roof load is carried by the exterior walls. Purlins are also in a simple timber frame.

16.2 The cruck frame

A cruck is a pair of crooked or curved timbers[1] which form a bent (U.S.) or crossframe (UK), the individual timbers each called a blade. More than 4,000 cruck frame build-

A "true" or "full" cruck half-timbered building in Weobley (Herefordshire, England). The cruck blades are the tall, curved timbers which extend from near the ground to the ridge.

ings have been recorded in the UK. There are several types of cruck frames (more information follows in English Style below and at the main article Cruck):

- True cruck or full cruck: blades, straight or curved, extend from ground or foundation to the ridge acting as the principal rafters. A full cruck does not need a tie beam.
- Base cruck: tops of the blades truncated by the first transverse member such as by a tie beam.
- Raised cruck: blades land on masonry wall, extend to ridge.
- Middle cruck: blades land on masonry wall, truncated by collar.
- Upper cruck: blades land on tie beam, very similar to knee rafters.
- Jointed cruck: blades made from pieces joined near eaves in a number of ways.
- End cruck is not a style but on the gable end of a building.
- Half timbered houses, Marbach am Neckar, Germany
- Half timbered houses, Miltenberg im Odenwald, Germany
- Rural old railway station timber framing style in Metelen, Germany

Interior of a two-aisled market hall

16.3 Aisled frame

Aisled frames have one or more rows of interior posts. These interior posts typically carry more structural load than the posts in the exterior walls. This is the same concept of the aisle in church buildings, sometimes called a hall church, where the center aisle is technically called a nave. However a nave is often called an aisle, and three-aisled barns are common in the U.S., Netherlands, and Germany. Aisled buildings are wider than the simpler box framed or cruck framed buildings, and typically have purlins supporting the rafters. In northern Germany this construction is known as variations of a Ständerhaus.

16.4 Half-timbered

Half-timbered wall with three kinds of infill, wattle and daub, brick, and stone. The plaster coating which originally covered the infill and timbers is mostly gone. This building is in the central German city of Bad Langensalza.

Half-timbering refers to a structure with a frame of load-bearing timber, creating spaces between the timbers called panels or in German *Fächer*, which are then filled-in with some kind of non-structural material known as *infill*. The frame is often left exposed on the exterior of the building.[2]

16.4.1 Infill materials

The earliest known type of infill, called opus craticum by the Romans, was a wattle and daub type construction.[3] *Opus craticum* is now confusingly applied to a Roman stone/mortar infill also. Similar methods to wattle and daub were also used and known by various names as clam staff and daub, cat-and-clay, or torchis (French) to name only three.

Wattle and daub was the most common infill in ancient times. The sticks were not always technically wattlework (woven) but also individual sticks installed vertically, horizontally or at an angle into holes or grooves in the framing. The coating of daub has many recipes but generally was a mixture of clay and chalk with a binder such as grass or straw and water or urine.[4] When the manufacturing of bricks increased, brick infill replaced the less durable infills and became more common. Stone laid in mortar as an infill was used in areas where stone rubble and mortar were available.

Other infills include bousillage, fired brick, un-fired brick such as adobe or mudbrick, stones sometimes called pierrotage, planks as in the German standerbohlenbau, timbers as in standerblockbau, or rarely cob without any wooden support.[5] The wall surface on the interior were often "ceiled" with wainscoting and plastered for warmth and appearance.

Brick infill sometimes called nogging became the standard infill after the manufacturing of bricks made them more available and less expensive. Half-timbered walls may be covered by siding materials including plaster, weatherboarding, tiles, or slate shingles.[6]

The infill may be covered by other materials, including weatherboarding or tiles.[6] or left exposed. When left exposed both the framing and infill were sometimes done in a decorative manner. Germany is famous for its decorative half-timbering and the figures sometimes have names and meanings. The decorative manner of half-timbering is promoted in Germany by the German fachwerk road, several planned routes people can drive to see notable examples of *fachwerk* buildings.

Gallery of infill types:

- Decorative fired-brick infill with owl-holes
- Ordinary brick infill left exposed.
- Stone infill called Opus incertum by the Romans
- Some stone infill left visible
- The wattle and daub was covered with a decorated layer of plaster.
- Like wattle and daub but with horizontal stakes.
- Here the plaster infill itself is sculpted and decorated.

Gallery of some named figures and decorations:

- Simple saltires or St. Andrews crosses in Germany.
- Two curved saltires also called St. Andrews crosses during repairs to a building in Germany. The infill has been removed.
- Several forms of *man* figures are found in Germany, this one is called a *wild man*.
- A figure called an Alemannic woman
- Wild man (center), half-man (at the corners).
- Relief carvings adorn some half-timbered buildings.
- The foot braces? are carved with sun discs (Sonnenscheiben).

The collection of elements in half timbering are sometimes given specific names:

- Upper German Fachwerk (Alemannisches Fachwerk)
- An example of fachwerk in Franconia (Fränkisches Fachwerk). Image: I, Metzner
- Fachwerk in Upper Franconia is very detailed
- Close studding is found in England and in France
- Square panel half-timbering with fired brick infill. Square paneling is typical of the Low German house, and is found in England.
- Cruck framing can be built with half-timber walls. This house is in the *Ryedale Folk Museum* in England.

16.4.2 History of the term

The term half-timbering is not as old as the German name *fachwerk* or the French name *colombage*, but it is the standard English name for this style. One of the first people to publish the term *half-timbered* was Mary Martha Sherwood (1775–1851), who employed it in her book, *The Lady of the Manor*, published in several volumes from 1823 to 1829.

She uses the term picturesquely: "...passing through a gate in a quickset hedge, we arrived at the porch of an old half-timbered cottage, where an aged man and woman received us."[7] By 1842, *half-timbered* had found its way into *The Encyclopedia of Architecture* by Joseph Gwilt (1784–1863). This juxtaposition of exposed timbered beams and infilled spaces created the distinctive "half-timbered", or occasionally termed, "Tudor", style, or "black-and-white".

16.4.3 Oldest examples

The most ancient known half-timbered building is called the House of Opus craticum. It was buried by the eruption of Mount Vesuvius in 79 AD in Herculaneum, Italy. Opus craticum was mentioned by Vitruvius in his books on architecture as a timber frame with wattlework infill[8] however the same term is used to describe timber frames with an infill of stone rubble laid in mortar the Romans called Opus incertum.[9]

16.4.4 Alternate meanings

A variation of the second meaning of half-timbered*: the ground floor is log and the upper floor is framed (half-timbered in the first sense). Kluge House, Montana, U.S.A. Image: Library of Congress, Prints & Photographs Division, MONT,25-HEL,1-2*

A less common meaning of the term "half-timbered" is found in the fourth edition of John Henry Parker's *Classic Dictionary of Architecture* (1873) which distinguishes full-timbered houses from half-timbered, with half timber houses having a ground floor in stone[10] or logs such as the Kluge House which was a log cabin with a timber framed second floor.

16.5 Structure

Joints in an ancient French roof, the wooden pegs hold the mortise and tenon joinery together.

Projecting ("jettied") upper storeys of an English half-timbered village terraced house, the jetties plainly visible

Traditional timber framing is the method of creating framed structures of heavy timber jointed together with various joints, commonly and originally with lap jointing, and then later pegged mortise and tenon joints. Diagonal bracing is used to prevent "racking", or movement of structural vertical beams or posts.[11]

This is a part of a timber frame, before pegs are inserted

Originally, German (and other) master carpenters would peg the joints with allowance of approximately an inch (25 mm), enough room for the wood to move as it *seasoned*, then cut the pegs, and drive the beam home fully into its socket.

To cope with variable sizes and shapes of hewn (by adze or axe) and sawn timbers, two main carpentry methods were employed: scribe carpentry and square rule carpentry.

Scribing or coping was used throughout Europe, especially from the 12th century to the 19th century, and subsequently imported to North America where it was common into the early 19th century. In a scribe frame, timber sockets are fashioned or "tailor-made" to fit their corresponding timbers; thus each timber piece must be numbered (or "scribed").

Square-rule carpentry was developed in New England in the 18th century. It used housed joints in main timbers to allow for interchangeable braces and girts. Today, standardised timber sizing means that timber framing can be incorporated into mass-production methods as per the joinery industry, especially where timber is cut by precision computer numerical control (CNC) machinery.

16.5.1 Jetties

For more details on this topic, see Jettying.

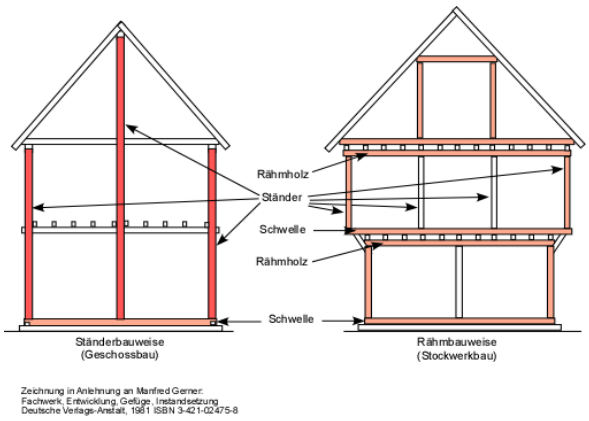
A *jetty* is an upper floor which requires a structural cantilevered horizontal beam called a bressummer or *jetty bressummer* to bear the weight of the new wall, projecting outward from the preceding floor or storey.

In an era when houses were taxed with respect to ground-floor area (square footage) extensive jettying was employed to create higher storeys of greater area.

In the city of York in the United Kingdom, the famous street known as The Shambles exemplifies this, where jettied houses seem to almost touch above the street.

16.5.2 Timbers

The completed frame of a modern timber-frame house



Ridge-post framing (left) and storey framing (right, with jetties)

Historically, the timbers would have been hewn square using a felling axe and then surface-finished with a broadaxe. If required, smaller timbers were ripsawn from the hewn baulks using pitsaws or frame saws. Today it is more common for timbers to be bandsawn, and the timbers may sometimes be machine-planed on all four sides.

The vertical timbers include:

- posts (main supports at corners and other major up-

rights),

- wall studs (subsidiary upright limbs in framed walls), for example, close studding.

The horizontal timbers include:

- sill-beams (also called ground-sills or sole-pieces, at the bottom of a wall into which posts and studs are fitted using tenons),
- noggin-pieces (the horizontal timbers forming the tops and bottoms of the frames of infill panels),
- wall-plates (at the top of timber-framed walls that support the trusses and joists of the roof).

When *jettying*, horizontal elements can include:

- the jetty bressummer (or breastsummer): the main sill (horizontal piece) on which the projecting wall above rests, and which stretches across the whole width of the jetty wall. The bressummer is itself *cantilevered* forward, beyond the wall below it.
- the *dragon-beam* which runs diagonally from one corner to another, and supports the corner posts above and supported by the corner posts below.
- the jetty beams or joists which conform floor dimensions above but are at right angles to the *jetty-plates* that conform to the shorter dimensions of "roof" of the floor below. Jetty beams are mortised at 45° into the sides of the dragon beams. They are the main constituents of the cantilever system, and determine how far the jetty projects
- the jetty-plates, designed to carry the jetty beams. The jetty plates themselves are supported by the corner posts of the recessed floor below.

The sloping timbers include:

- trusses (the slanting timbers forming the triangular framework at gables and roof),
- braces (slanting beams giving extra support between horizontal or vertical members of the timber frame),
- herringbone bracing (a decorative and supporting style of frame, usually at 45° to the upright and horizontal directions of the frame).

16.5.3 Post construction and frame construction

There were two different systems of the position of posts and studs:

- In the older manner, called *post construction*, the vertical elements continue from the groundwork to the roof. This post construction in German is called *geschossbauweise* or *ständerbauweise*.
- In the advanced manner, called *frame construction*, each storey is constructed like a case, and the whole building is constructed like a pile of such cases. This frame construction in German is called *rähmbauweise*.

Ridge-post framing is a structurally simple and ancient post and lintel framing where the posts extend all the way to the ridge beams. Germans call this firstsäule or hochstud.

16.5.4 Modern features

Interior of a modern hand-hewn post and beam home.

In the United States and Canada, timber-frame construction has been revived since the 1970s, and is now experiencing a thriving renaissance of the ancient skills. This is largely due to such practitioners as Steve Chappell, Jack Sobon, and Tedd Benson, who studied old plans and techniques and revived a long-neglected technique. Once a handcrafted skill passed down, timber-frame construction has now been modernized with the help of modern industrial tools such as the CNC machines. These machines and mass-production techniques have assisted growth and made for more affordable frames and shorter lead-times for projects.

Timber-framed structures differ from conventional wood-framed buildings in several ways. Timber framing uses fewer, larger wooden members, commonly timbers in the

Porch of a modern timber-framed house

A Huf Haus near West Linton in Scotland

range of 15 to 30 cm (6” to 12”), while common wood framing uses many more timbers with dimensions usually in the 5 to 25 cm (2” to 10”) range. The methods of fastening the frame members also differ. In conventional framing, the members are joined using nails or other mechanical fasteners, whereas timber framing uses the traditional mortise and tenon or more complex joints that are usually fastened using only wooden pegs.[12] Modern complex structures and timber trusses often incorporate steel joinery such as gusset plates, for both structural and architectural purposes.

Recently, it has become common practice to enclose the timber structure entirely in manufactured panels such as SIPs (structural insulated panels). Although the timbers can only be seen from inside the building when so enclosed, construction is less complex and insulation is greater than in traditional timber building. Structural Insulated Panel construction uses composite members consisting of “an insulating foam core sandwiched between two structural facings, typically oriented strand board,” according to the Structural Insulated Panel Association.[13] SIPs reduce dependency on bracing and auxiliary members, because the panels span considerable distances and add rigidity to the basic timber frame.

An alternate construction method is with concrete flooring with extensive use of glass. This allows a very solid construction combined with open architecture. Some firms have specialized in industrial prefabrication of such residential and light commercial structures such as Huf Haus as low-energy houses or – dependent on location – zero-energy buildings.

Straw-bale construction is another alternative where straw bales are stacked for non-load-bearing infill with various finishes applied to the interior and exterior such as stucco and plaster. This appeals to the traditionalist and the environmentalist as this is using “found” materials to build.

Mudbricks also called adobe are sometimes used to fill in timber frame structures. They can be made on site and offer exceptional fire resistance. Such buildings must be designed to accommodate the poor thermal insulating properties of mudbrick however, and usually have deep eaves or a verandah on 4 sides for weather protection.

16.6 History and traditions

Anne Hvides Gaard, Svendborg, Denmark, from 1560

The techniques used in timber framing date back to Neolithic times, and have been used in many parts of the world during various periods such as ancient Japan, continental Europe as well as Neolithic Denmark, England, France, Germany parts of the Roman Empire and Scotland.[14] The timber framing technique has historically been popular in climate zones which favour deciduous hardwood trees, such as oak. Its most northernmost areas are Baltic countries and southern Sweden. Timber framing is rare in Russia, Finland, northern Sweden, and Norway, where tall and straight lumber, such as pine and spruce, is readily available and log houses were favoured instead.

Half-timbered construction in the Northern European vernacular building style is characteristic of medieval and early

modern Denmark, England, Germany, and parts of France and Switzerland, where timber was in good supply yet stone and associated skills to dress the stonework were in short supply. In half-timbered construction timbers that were riven (split) in half provided the complete skeletal framing of the building.

Europe is full of timber-framed structures dating back hundreds of years, including manors, castles, homes, and inns, whose architecture and techniques of construction have evolved over the centuries. In Asia you will find timber-framed structures, many of them temples, that have stood for centuries.[15]

Some Roman carpentry preserved in anoxic layers of clay at Romano-British villa sites demonstrate that sophisticated Roman carpentry had all the necessary techniques for this construction. The earliest surviving (French) half-timbered buildings date from the 12th century.

Important resources for the study and appreciation of historic building methods are open-air museums.

16.6.1 Topping out ceremony

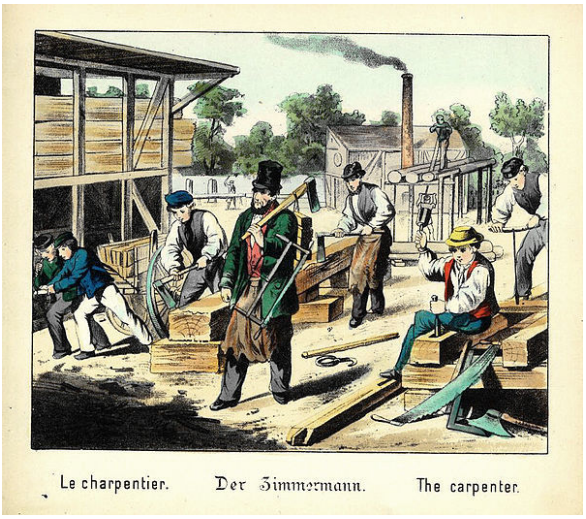
The topping out ceremony is a builders' rite, an ancient tradition thought to have originated in Scandinavia by 700 AD.[16] In the U.S. a bough or small tree is attached to the peak of the timber frame after the frame is complete as a celebration. Historically it was common for the master carpenter to give a speech, make a toast, and then break the glass. In Northern Europe it is more common to use a wreath made for the occasion rather than a bough. In Japan the "ridge raising" is a religious ceremony called the jotoshiki.[17] In Germany it is called the Richtfest (German language site).

16.6.2 Carpenters marks

Carpenters marks is a general term for markings left on the timbers of wooden buildings during construction.

- Assembly or marriage marks and were used to identify the individual timbers. Assembly marks include numbering to identify the pieces of the frame. The numbering can be similar to Roman numerals except the number four is IIII and nine is VIIII. These marks are chiseled, cut with a race knife (a tool to cut lines and circles in wood), or saw cuts. The numbering can also be in Arabic numerals which are often written with a red grease pencil or crayon. German and French carpenters made some unique marks. (Abbundzeichen (German assembly marks)).
- Layout marks left over from marking out identify the locations to cut joints and bore peg holes. Also carpenters marked the location on a timber where they leveled the timber as a part of the building process are called "level lines" and sometimes made a mark two feet from a critical location called a "two foot mark". These marks are typically scratched on the timber with an awl-like tool until later in the 19th century when they started using pencils to make layout marks.
- Occasionally carpenters or owners marked a date and/or their initials in the wood, but not like masons left masons marks.
- Boards on the building may have "tally marks" cut into them which were numbers used to keep track of quantities of lumber (timber).
- Other markings in old buildings are called "ritual marks" which were often signs the occupants felt would protect them from harm.

16.6.3 Tools



German carpenters in 1880. The tools, from left to right, are: a cart loaded with timbers, rough hewing with felling axes; in the green coat is the master carpenter carrying his tools including a frame saw; on the ground a ring dog (precursor to the cant dog and peavey); in the background sawyers pit sawing on trestles; on right carpenters striking a mortising chisel with a mallet and boring a hole with a T-auger; lower right on ground a two-man crosscut saw, steel square, broadaxe, and (hard to see) a froe.

Many historic hand tools used by timber framers for thousands of years have similarities but vary in shape. Electrically powered tools first became available in the 1920s in the U.S. and continue to evolve. See the list of timber

framing tools for basic descriptions and images of unusual tools (The list is incomplete at this time).

16.6.4 British tradition

The timber-framed Staple Inn in Holborn, London

Some of the earliest known timber houses in Europe have been found in Great Britain, dating to Neolithic times; Balbridie and Fengate are some of the rare examples of these constructions.

Molded plaster ornamentation, *pargetting*[18] further enriched some English Tudor architecture houses. Half-timbering is characteristic of English vernacular architecture in East Anglia,[19] Warwickshire,[20][21] Worcestershire,[22] Herefordshire,[23][24] Shropshire,[25][26] and Cheshire,[27] where one of the most elaborate surviving English examples of half-timbered construction is Little Moreton Hall.[28]

In South Yorkshire, the oldest timber house in Sheffield, the "Bishops' House" (c. 1500), shows traditional half-timbered construction.

In the Weald of Kent and Sussex,[29] the half-timbered structure of the Wealden hall house,[30] consisted of an open hall with bays on either side and often jettied upper floors.

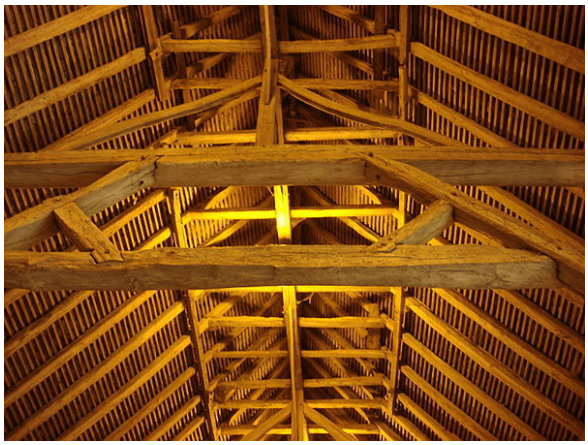
Half-timbered construction traveled with British colonists to North America in the early 17th century but was soon abandoned in New England and the mid-Atlantic colonies for clapboard facings (an East Anglia tradition). The original English colonial settlements, such as Plymouth, Massachusetts and Jamestown, Virginia had timber-framed buildings, rather than the log cabins often associated with the American frontier. Living history programs demonstrating the building technique are available at both these locations.

- Farmhouse in Wormshill, England
- Historic timber-framed houses in Warwick, England

Many of the surviving streets lined with almost-touching houses are known as The Shambles, and are very popular tourist attractions.

16.6.5 English Styles

Historic timber frame construction in England (and the rest of the United Kingdom) showed regional variation [31] which has been divided into "eastern school", "western school", and the "northern school", although the characteristic types of framing in these schools can be found in the other regions (except the northern school).[32] A characteristic of the eastern school is close studding which is a half-timbering style of many studs spaced about the width of the studs apart (for example six inch studs spaced six inches apart) until the middle of the 16th century and sometimes wider spacing after that time. Close studding was an elite style found mostly on expensive buildings. A principal style of the western school is the use of square panels of roughly equal size and decorative framing utilizing many shapes such as lozenges, stars, crosses, quatrefoils, cusps, and many other shapes.[32] The northern school sometimes used posts which landed on the foundation rather than on a sill beam, the sill joining to the sides of the posts and called an interrupted sill. Another northern style was to use close studding but in a herring-bone or chevron pattern.[32]



Roof structure of the Barley Barn, Cressing Temple, Essex

As houses were modified to cope with changing demands there sometimes were a combination of styles within a single timer frame construction.[33] The major types of historic framing in England are 'cruck frame',[33] box frame,[33] and aisled construction. From the box frame, more complex framed buildings such as the Wealden House and Jettied house developed.

The cruck frame design is amongst the earliest, and was [33] in use by the early 13th century, with its use continuing to the present day, although rarely after the 18th century.[33] Since the 18th century however, many existing cruck structures have been modified, with the original cruck framework becoming hidden. Aisled barns are of two or three aisled types, the oldest surviving aisled barn being the barley barn at Cressing Temple[32] dated to 1205-1235.[34]

Jettying was introduced in the 13th century and continued to be used through the 16th century.[32]

Generally speaking, the size of timbers used in construction, and the quality of the workmanship reflect the wealth and status of their owners. Small cottages often used quite small cross-section timbers which would have been deemed unsuitable by others. Some of these small cottages also have a very 'home-made' - even temporary - appearance. Many such example can be found in the English shires. Equally, some relatively small buildings can be seen to incorporate substantial timbers and excellent craftsmanship, reflecting the relative wealth and status of their original owners. Important resources for the study of historic building methods in the U. K. are open-air museums.

16.6.6 French tradition

Coupesarte Manor (Normandy, France)

Elaborately half-timbered houses of the 13th through 18th centuries still remain in Bourges, Troyes, Rouen, Thiers, Dinan, Rennes, and many other cities, except in Provence and Corsica. Timber framing in French is known colloquially as *pan de bois* and half-timbering as *colombage*.

The *Normandy tradition* features two techniques: frameworks were built of four evenly spaced regularly hewn timbers set into the ground (*poteau en terre*) or into a continuous wooden sill (*poteau du sole*) and mortised at the top into the plate. The openings were filled with many materials including mud and straw, wattle and daub, or horsehair and gypsum.[35]

- Old houses in Troyes (Champagne, France)
- Church of Drosnay (Champagne, France)
- 14th-century early corbelled house, Rouen (Normandy, France)
- 15th-century manor, Saint-Sulpice-de-Grimbouville, (Normandy, France)
- Framing of the roof, Notre Dame, Paris. Illustration by Eugène Viollet-le-Duc
- Trinity Church of Langonnet, Langonnet, France

16.6.7 Basque tradition

- Inharri baserri in Ibarron (Lapurdi)
- Aranguren dorretxea (Orozko, Bizkaia)
- Half-timbered houses from Uztarritz (Lapurdi)

Most traditional Basque buildings with half-timbering elements are detached farm houses (in Basque: baserriak). Their upper floors were built with jettied box frames in close studding. In the oldest farmsteads and, if existing, in the third floor the walls were sometimes covered with vertical weatherboards. Big holes were left in the gable of the main façade for ventilation. The wooden beams were painted over, mostly in dark red. The vacancies were filled in with wattle and daub or rubble laid in a clay mortar and then plastered over with white chalk or nogged with bricks. Although the entire supporting structure is made of wood, the timbering is only visible on the main façade, which is generally oriented to the southeast.

Although the typical Basque house is now mostly associated with half-timbering, the outer walls and the firewalls were built in masonry (rubble stone, bricks or, ideally, ashlars) whenever it could be afforded. Timber was a sign of poverty. Oak-wood was cheaper than masonry: that is why, when the money was running out, the upper floor walls were mostly built timbered. Extant baserriak with half-timbered upper-floor façades were built from the 15th to 19th centuries and are found in all Basque regions with oceanic climate, except in Zuberoa (Soule), but are concentrated in Lapurdi (Labourd).

Some medieval Basque tower houses (dorretxeak) feature an overhanged upper floor in half-timbering.[36]

To a lesser extent timbered houses are also found in villages and towns as row houses, as the photo from the Uztaritz village shows.

Currently, it has again become popular to build houses resembling old Basque farmsteads, with more or less respect for the principles of traditional half-timbered building.[37]

16.6.8 German tradition (*Fachwerkhäuser*)

Germany has several styles of timber framing, but probably the greatest number of half-timbered buildings in the world are to be found in Germany and in Alsace (France). There are many small towns which escaped both war damage and modernisation and consist mainly, or even entirely, of half-timbered houses.

Idstein, Hesse, on the German Timber-Frame Road.

The German Timber-Frame Road (*Deutsche Fachwerkstraße*) is a tourist route that connects towns with remarkable fachwerk. It is more than 2,000 km (1,200 mi) long, crossing Germany through the states of Lower Saxony, Saxony-Anhalt, Hesse, Thuringia, Bavaria, and Baden-Württemberg.[11][38]

Some of the more prominent towns (among many) include: Quedlinburg, a UNESCO listed town, which has over 1200 half-timbered houses spanning five centuries; Goslar, another UNESCO listed town; Hanau-Steinheim (home of the Brothers Grimm); Bad Urach; Eppingen ("Romance city" with a half-timbered church dating from 1320); Mosbach; Vaihingen an der Enz and nearby UNESCO-listed Maulbronn Abbey; Schorndorf (birthplace of Gottlieb Daimler); Calw; Celle; and Biberach an der Riß with both the largest medieval complex, the *Holy Spirit Hospital* and one of Southern Germany's oldest buildings, now the Braith-Mali-Museum, dated to 1318.

A very narrow timber frame house in Bernkastel at the river Moselle

German *fachwerk* building styles are extremely varied with a huge number of carpentry techniques which are highly regionalised. German planning laws for the preservation of buildings and regional architecture preservation dictate that a half-timbered house must be authentic to regional or even city-specific designs before being accepted.[39][40]

A brief overview of styles follows, as a full inclusion of all styles is impossible.

In general the northern states have *fachwerk* very similar to that of the nearby Netherlands and England while the more southerly states (most notably Bavaria and Switzerland) have more decoration using timber because of greater forest reserves in those areas.

The German fachwerkhaus usually has a foundation of stone, or sometimes brick, perhaps up to several feet (a couple of metres) high, which the timber framework is mortised into or, more rarely, supports an irregular wooden sill.

The three main forms may be divided geographically:

- West Central Germany and Franconia:
  - In West Central German and Franconian timber-

work houses (particularly in the Central Rhine and Moselle): the windows most commonly lie between the rails of the sills and lintels.

- Northern Germany, Central Germany and East German(which belongs since the last war to Poland):
  - In Saxony and around the Harz foothills, angle braces often form fully extended triangles.
  - Lower Saxon houses have a joist for every post.
  - Holstein fachwerk houses are famed for their massive 12-inch (30 cm) beams.
- Southern Germany including the Black and Bohemian Forests
  - In Swabia, Württemberg, Alsace, and Switzerland, the use of the lap-joint is thought to be the earliest method of connecting the wall plates and tie beams and is particularly identified with Swabia. A later innovation (also pioneered in Swabia) was the use of tenons — builders left timbers to season which were held in place by wooden pegs (*i.e.,* tenons). The timbers were initially placed with the tenons left an inch or two out of intended position and later driven home after becoming fully seasoned.

The most characteristic feature is the spacing between the posts and the high placement of windows. Panels are enclosed by a sill, posts, and a [[wall plate|plate],] and are crossed by two rails between which the windows are placed—like "two eyes peering out".[39][40]

In addition there is a myriad of regional scrollwork and fretwork designs of the non-loadbearing large timbers (braces) peculiar to particularly wealthy towns or cities.

A unique timber frame house type can be found in the region where the borders of Germany, the Czech Republic, and Poland(former East Germany) meet - it is called the Upper Lusatian house (Umgebindehaus, translates as *round-framed house*). This type has a timber frame surrounding a log structure on part of the ground floor.[41]

- Ständerbau in Quedlinburg (Germany), about 1350
- Timber frame town hall of Wernigerode
- House in Rothenburg (Bavaria)
- Timber frame ensemble in Rothenburg
- Buildings in Hornburg
- Buildings in Braubach
- House in Schwerin, built in 1698
- Gelbensande Castle, a hunting lodge built in 1887 near Rostock
- The half-timbered houses in Dinkelsbühl mostly have plastered and painted facades.
- An Umgebindehaus in Oybin (Saxony). The timber frame is outside a log wall on the ground floor.
- 20th-century timber framing in Ribnitz (Mecklenburg)
- Fachwerk (timber framing) under construction in 2013, Tirschenreuth

16.6.9 Italy

You can find some examples of half-timbered houses in Northern Italy, especially in Piedmont, Lombardy, and in the city of Bologna.

- Half-timbered house in Ozzano Monferrato, Piedmont.
- Half-timbered house in Biella, Piedmont.
- Half-timbered house in Arquata Scrivia, Piedmont.
- Half-timbered house in Monza, Lombardy.
- half-timbered house in Susa, Piedmont.

16.6.10 Poland

Slavic traditional house in Wdzydze Kashubian museum

The Slavic tradition of vernacular architecture is rather log building. Most half-timbered houses have been built in

Slavic traditional house near Koło on Warta

regions that before World War II used to belong to Germany or had had a lot of German immigrants. As these regions were parts of Prussia, half-timbered walls are called "mur pruski". The Slovincians, an autochthone Slavic group in the Prussian province of Pomorania also built half-timbered houses. A distinctive type of house associated with mostly Mennonite immigrant groups from Frisia and the Netherlands, known as the Olędrzy, is called an arcade house (dom podcieniowy).

The Umgebindehaus rural housing tradition of south Saxony (Germany) is also found in the neighboring areas of Poland (the Silesian region) and the north of Czech Republic.

Another world-class type of wooden building Poland shares with some neighboring countries are its wooden church buildings.

- Timber frame architecture, Mill Island, Bydgoszcz
- Wheelwright croft in Zgorzelec
- Antoniów, Lower Silesian Voivodeship
- Granary in Bydgoszcz, built in 1795 upon 15th-century gothic cellar
- Sts. Peter & Paul Church in Sułów
- Trutnowy Mennonite arcade house
- 19th-century timber frame manor house in Toruń

16.6.11 Spain

The Spanish follow the Mediterranean forms of architecture with stone walls and shallow roof pitch. Timber framing is often of the post and lintel style. Castile and León have the most representative examples of the use of timber framing in the Iberian Peninsula, as in the old town of Frías, Province of Burgos.

16.6.12 Switzerland

An exceptional fachwerk house called Eglihaus in Hombrechtikon, Switzerland

Switzerland has many styles of timber framing which overlap with its neighboring countries.

16.6.13 Belgium

Nowadays, timber framing mostly subsists in the provinces of Limburg, Liège, and Luxemburg. In urban areas, one used to build the ground floor in stone and the upper floors in timber framing. Also, as timber framing was seen as a cheaper way of building, often the visible structures of noble houses were in stone and bricks, and the invisible or lateral walls in timber framing. The open air museums of Bokrijk and Saint-Hubert (Fourneau Saint-Michel) show many examples of Belgian timber framing. Many post and beam houses subsists in cities and villages, but, unlike France, the United Kingdom, and Germany, there are few fully timber framed cityscapes.

- The house where André Grétry was born in Liège
- The Sugny House (18th century), in the Fourneau Saint-Michel Museum
- a House in Theux (17th century)

- The former water mill of Lierneux
- Small “chapel” (shrine) at the Bokrijk Open Air Museum
- Unskilled worker’s thatched cottage (Hingeon 19th century) transplanted and reconstituted in the open air museum Fourneau Saint-Michel

16.6.14 Sweden

The Swedish mostly built log houses but they do have traditions of several types of timber framing: Some of the following links are written in Swedish. Most of the half-timbered houses in Sweden were built during the Danish time and are located in what until 1658 used to be Danish territory in southern Sweden, primarily in the province Skåne. In Swedish half-timber is known as “korsvirke”.

- Stave construction is called “stavverk”. Scandinavia is famous for its ancient stave churches. Stave construction is a traditional timber frame with walls of vertical planks, the posts and planks landing in a sill on a foundation. Similar construction with earthfast posts is called “stolpteknik”. and Palisade construction where many vertical wall timbers or planks have their feet buried in the ground called post in ground or earthfast construction is called “palissadteknik”. (see also Palisade church)
- Swedish plank-frame construction is called skiftesverk. This is a traditional timber frame with walls of horizontal planks.

16.6.15 Norway

Norway has at least two significant types of timber framed structures: 1) The stave church and 2) grindverk. The term stave church essentially means a framed church, a distinction made in a region where log building is common. All but one surviving stave church buildings are in Norway. Replicas of stave churches and other Norwegian building types have been reproduced such as at the Scandinavian Heritage Park in North Dakota, U.S.A.

Grindverk translates as bent construction but what makes the Norwegian type of bent construction important is this type of framing uses no mortise and tenon joints. Archaeological excavations have uncovered similar wooden joints from over 3,000 years ago, suggesting that this type of framing is an ancient, unbroken tradition. Grindverk buildings are only found on part of the western coast of Norway and is mostly found in boathouses and barns. There is not currently an article in English about grindverk framing but in Norwegian Wikipedia is here.[42]

- Borgund stave church in Lærdal, Sogn og Fjordane country, Norway.
- Garmo stave church detail. Note how the sills lap and the post fits around the sills. The post is the stave from which these buildings are named.
- Kaupanger stave church interior, Kaupanger, Norway.
- An example of gridnverk framing. The tie beams are captured in slots in the post tops.

16.6.16 Netherlands

A half timbered building without the infill in Limburg, Netherlands.

The Netherlands is often overlooked for its timbered houses, yet many exist, including windmills. It was in North Holland where the import of cheaper timber, combined with the Dutch innovation of windmill-powered sawmills, allowed economically viable widespread use of protective wood covering over framework. In the late 17th century the Dutch introduced vertical cladding also known in Eastern England as clasp board and in western England as weatherboard, then as more wood was available more cheaply, horizontal cladding in the 17th century. Perhaps owing to economic considerations, vertical cladding returned to fashion.[43] Dutch wall framing is virtually always built in bents and the three basic types of roof framing are the rafter roof, purlin roof, and ridge-post roof.[44]

16.6.17 Americas

Main article: American historic carpentry

Most “haft-timbered” houses existing in Missouri, Pennsylvania, and Texas were built by German settlers.[35] Old Salem North Carolina has fine examples of German

fachwerk buildings.[45] Many are still present in Colonia Tovar, (Venezuela), Santa Catarina, and Rio Grande do Sul,(Brazil), where Germans settled. Later, they chose more suitable building materials for local conditions (most likely because of the great problem of tropical termites.)

New France

In the historical region of North America known as New France, **colombage pierroté**, also called *maçonnerie entre poteaux*,[46] half-timbered construction with the infill between the posts and studs of stone rubble and lime plaster or bousillage[46] and simply called *colombage* in France. Colombage was used from the earliest settlement until the 18th century but was known as *bousillage entre poteaus sur solle* in Lower Louisiana. The style had its origins in Normandy, and was brought to Canada by very early Norman settlers. The Men's House at Lower Fort Garry is a good example. The exterior walls of such buildings were often covered over with clapboards to protect the infill from erosion. Naturally, this required frequent maintenance, and the style was abandoned as a building method in the 18th century in Québec. For the same reasons, half-timbering in New England, which was originally employed by the English settlers, fell out of favour soon after the colonies had become established.

Other variations of half-timbering are *colombage à teurques* (torchis), straw coated with mud and hung over horizontal staves (or otherwise held in place), colombage an eclisses, and colombage a lattes.[46]

Poteaux-en-terre (posts in ground) is a type of timber framing with the many vertical posts or studs buried in the ground called post in ground or "earthfast" construction. The tops of the posts are joined to a beam and the spaces between are filled in with natural materials called bousillage or pierrotage.

Poteaux-sur-sol (posts on a sill) is a general term for any kind of framing on a sill however sometimes specifically refers to "vertical log construction" like poteaux-en-terre placed on sills with the spaces between the timbers infilled.

Piece-sur-piece also known as Post-and-plank style or "corner post construction" (and many other names) in which wood is used both for the frame and horizontal infill; for this reason it may be incorrect to call it "half-timbering". It is sometimes a blend of framing and log building with two styles: the horizontal pieces fit into groves in the posts and can slide up and down or the horizontal pieces fit into individual mortises in the posts and are pegged and the gaps between the pieces chinked (filled in with stones or chips of wood covered with mud or moss briefly discussed in Log cabin.)

This technique of a timber frame walls filled in with horizontal planks or logs proved better suited to the harsh climates of Québec and Acadia, which at the same time had abundant wood. It became very popular throughout New France, as far afield as southern Louisiana. The Hudson's Bay Company used this technique for many of its trading posts, and this style of framing becoming known as Hudson Bay style or Hudson Bay corners. Also used by the Red River Colony this style also became known as "Red River Framing". "The support of horizontal timbers by corner posts is an old form of construction in Europe. It was apparently carried across much of the continent from Silesia by the Lausitz urnfield culture in the late Bronze Age."[47] Similar building techniques are apparently not found in France[48] but exist in Germany and Switzerland known as Bohlenstanderbau when planks are used or blockstanderbau when beams are used as the infill. In Sweden known as sleppvegg or skiftesverk and in Denmark as bulhus.

A particularly interesting example in the U.S. is the Golden Plough Tavern (c. 1741), York, York County, PA, which has the ground level of corner-post construction with the second floor of fachwerk (half timbered) and was built for a German with other Germanic features.[49]

Settlers in New France also built horizontal log, brick, and stone buildings.

New Netherland

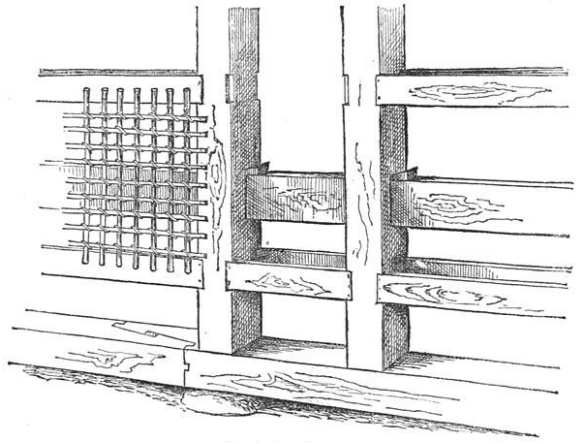
Characteristics of traditional timber framing in the parts of the U.S. formerly known as New Netherland are H-framing also known as dropped-tie framing in the U.S. and the similar anchor beam framing as found in the New World Dutch barn.

New England

Some time periods/regions within New England contain certain framing elements such as common purlin roofs, five sided ridge beams, plank-frame construction and plank-wall construction. The English barn always contains an "English tying joint" and the later New England style barn were built using bents.

16.6.18 Japanese

Japanese timber framing is believed to be descended from Chinese framing (see Ancient Chinese wooden architecture). Asian framing is significantly different from western framing, with its predominant use of post and lintel framing and an almost complete lack of diagonal bracing.



Wall framing of a Japanese house under construction

16.6.19 Revival styles in later centuries

The Saitta House, Dyker Heights, Brooklyn, New York built in 1899 has half-timber decoration.[50]

When half-timbering regained popularity in Britain after 1860 in the various revival styles, such as the Queen Anne style houses by Richard Norman Shaw and others, it was often used to evoke a "Tudor" atmosphere (*see Tudorbethan*), though in Tudor times half-timbering had begun to look rustic and was increasingly limited to village houses (*illustration, above left*).

In 1912, Allen W. Jackson published *The Half-Timber House: Its Origin, Design, Modern Plan, and Construction,* and rambling half-timbered beach houses appeared on dune-front properties in Rhode Island or under palm-lined drives of Beverly Hills. During the 1920s increasingly minimal gestures towards some half-timbering in commercial speculative house-building saw the fashion diminish.

In the revival styles, such as Tudorbethan (Mock Tudor), the half-timbered appearance is superimposed on the brickwork or other material as an outside decorative façade rather than forming the main frame that supports the structure.

The style was used in many of the homes built in Lake Mohawk, New Jersey as well as all of the clubhouse, shops, and marina.

For information about "roundwood framing" see the book Roundwood Timber Framing:Building Naturally Using Local Resources by Ben Law (East Meon, Hampshire: Permanent Publications; 2010. ISBN 1856230414)

16.7 Advantages

The use of timber framing in buildings offers various aesthetic and structural benefits, as the timber frame lends itself to open plan designs and allows for complete enclosure in effective insulation for energy efficiency.

In modern construction timber-frame structure offers many benefits:

- it is rapidly erected
- it lends itself well to prefabrication, modular construction, and mass-production
- lends well to pre-fitting the frame usually in bent or wall-sections that are aligned with a jig. This allows faster erection on site and more precise alignments. Such pre-fitting in the shop is independent of a machine or hand-cut production line. Valley and hip timbers are not typically pre-fitted.
- an "average"-sized timber-frame home can be erected within 2 to 3 days.
- the frame can be encased with SIPs for the *drying in*: that is, ready for windows, mechanical systems, and roofing.
- it can be tailored to suit customer tastes and creativity such as carvings or incorporation of heirloom structures such as barns etc.

- it can use recycled or otherwise discarded timbers
- it offers some structural benefits as the timber frame, if properly engineered, lends itself to better *seismic survivability* [51] Consequently, there are many half-timbered houses which still stand despite the foundation having partially caved in over the centuries.
- The generally larger spaces between the frames enable greater flexibility in the placement, at construction or afterwards, of windows and doors with less resulting weakening of the structural integrity and the need for heavy lintels.

In North America, heavy timber construction is classified Building Code Type IV: a special class reserved for timber framing which recognizes the inherent fire resistance of large timber and its ability to retain structural capacity in fire situations. In many cases this classification can eliminate the need and expense of fire sprinklers in public buildings.[52]

16.8 Disadvantages

16.8.1 Traditional or historic structures

In terms of the traditional half-timber or *fachwerkhaus* there are maybe more disadvantages than advantages today. Such houses are notoriously expensive to maintain let alone renovate and restore, most commonly owing to local regulations that do not allow divergence from the original, modification or incorporation of modern materials. Additionally, in such nations as Germany, where energy efficiency is highly regulated, the renovated building may be required to meet modern energy efficiencies, if it is to be used as a residential or commercial structure (museums and significant historic buildings have no semi-permanent habitade exempt). Many framework houses of significance are treated merely to preserve, rather than render inhabitable — most especially as the required heavy insecticidal fumigation is highly poisonous.

In some cases, it is more economical to build anew using authentic techniques and correct period materials than restore. One major problem with older structures is the phenomenon known as *mechano-sorptive creep* or slanting: where wood beams absorb moisture whilst under compression or tension strains and deform, shift position or both. This is a major structural issue as the house may deviate several degrees from perpendicular to its foundations (in the x-axis, y-axis, and even z-axis) and thus be unsafe and unstable or so out of square it is extremely costly to remedy.[53]

A summary of problems with *Fachwerkhäuser* or half-timbered houses includes the following, though many can be avoided by intelligent design and application of suitable paints and surface treatments and routine maintenance. Often, though when dealing with a structure of a century or more old, it is too late.[43]

- “slanting"- *thermo-mechanical* (weather-seasonally induced) and mechano-sorptive (moisture induced) creep of wood in tension and compression.[53]
- poor prevention of capillary movement of water within any exposed timber, leading to afore-described creep, or rot
- eaves that are too narrow or non-existent (thus allowing total exposure to rain and snow)
- too much exterior detailing that does not allow adequate rainwater run-off
- timber ends, joints, and corners poorly protected through coatings, shape or position
- non-bevelled vertical beams (posts and clapboards) allow water absorption and retention through capillary action.
- surface point or coatings allowed to deteriorate
- traditional gypsum, or wattle and daub containing organic materials (animal hair, straw, manure) which then decompose.
- in both *porteaux en terre* and *porteaux du sole* insect, fungus or bacterial decomposition.
- rot including dry rot.
- infestation of xylophagous pest organisms such as (very common in Europe) the *Anobiidae* family particularly the common furniture beetle, termites, cockroaches, powderpost beetles, mice, and rats (quite famously so in many children’s stories).
- Noise from footsteps in adjacent rooms above, below, and on the same floor in such buildings can be quite audible. This is often resolved with built-up floor systems involving clever sound-isolation and absorption techniques, and at the same time providing passage space for plumbing, wiring, and even heating and cooling equipment.
- Other fungi that are non-destructive to the wood, but are harmful to humans such as black mold. These fungi may also thrive on many “modern” building materials.

- Wood burns more readily than some other materials, making timber-frame buildings somewhat more susceptible to fire damage, although this idea is not universally accepted: Since the cross-sectional dimensions of many structural members exceed 15 cm × 15 cm (6” × 6”), timber-frame structures benefit from the unique properties of large timbers, which char on the outside forming an insulated layer that protects the rest of the beam from burning.[54][55]
- prior flood or soil subsidence damage

16.9 See also

- American historic carpentry
- Carpentry
- Framing (construction)
  - Balloon framing
  - Platform framing
- German Timber-Frame Road
- Norman architecture
- Weatherboarding
- Open-air museum
- Boat building
- Berg house

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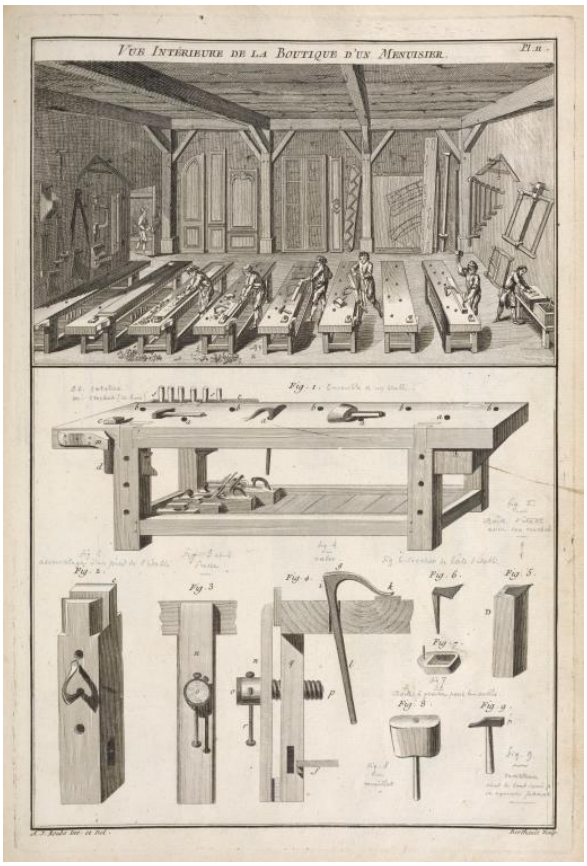
Chapter 17

Workbench (woodworking)

A basic bench

A **workbench** is a table used by woodworkers to hold workpieces while they are worked by other tools. There are many styles of woodworking benches, each reflecting the type of work to be done or the craftsman's way of working. Most benches have two features in common: they are heavy and rigid enough to keep still while the wood is being worked, and there is some method for holding the work in place at a comfortable position and height so that the worker is free to use both hands on the tools. The main thing that distinguishes benches is the way in which the work is held in place. Most benches have more than one way to do this, depending on the operation being performed.



Original Roubo workbench plans, circa 1769

17.1 Holding the work

17.1.1 Planing stop

Probably the oldest and most basic method of holding the work is a **planing stop** or dog ear, which is simply a peg or small piece of wood or metal that stands just above the surface at the end of the bench top. The work is placed on the bench with the end pushed against the stop. The force of the planing keeps the board in place, so long as the force is always toward the stop. Planing against a stop gives the woodworker good feedback - he can tell a lot about what is going on just by the pressure, force and balance required. A stop can take the form of a batten attached to the end of the bench, or it can be adjustable, able to be moved up and down according to the size of the work - or pushed down below the surface when not needed. A simple bench dog can serve as a planing stop.

17.1.2 Hold fast

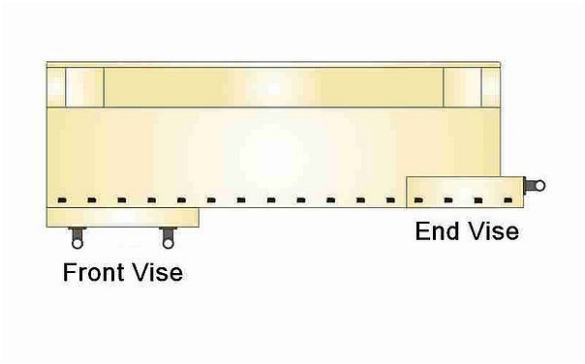
Another ancient method of holding the work is the **hold fast** or **holdfast**. A holdfast looks like a shepherd's crook. The shank goes into a hole in the bench top and the tip of the hook is pressed against the work from above. The holdfast is set by rapping the top with a mallet, and released by hitting the back side. A good holdfast works remarkably well, and is inexpensive and easy to install.

The holdfast can also be used for clamping work to the side of the bench for jointing. If the legs on your base are not too far under the top, simply bore a hole in the side of the leg and use the holdfast horizontally. A woodworker can do just about anything he needs on a bench with only a planing stop and a holdfast or two.

17.1.3 Hardpoints

It is common to have holes in the benchtop that tools or jigs can be bolted to. In applications where repeated removal and reinstallation of the tool or jig is desirable, screwing into the wood of the benchtop with woodscrews or lag bolts is not an ideal solution, because the wooden threads don't lend themselves to repeated disassembly and reassembly. In such cases, it is useful to create **hardpoints**, which are metal threads embedded in the wood. These hardpoints make repeated disassembly and reassembly trouble-free. They are essentially nuts that are embedded into the wood in one way or another. T-nuts (aka tee nuts) are an easy way to create a hardpoint. Custom nuts similar to T-nuts but with holes for woodscrews in place of the spikes are sometimes machined for the purpose.

17.1.4 Vises



Overhead view of the typical vise positions for a right-handed woodworker. Left-handers sometimes find a reversed layout more comfortable.

Long ago, just as today, woodworkers required a more helpful way to keep the wood in place while it was being worked. A device was needed that could be used effectively on different sizes of wood. Probably the first such device used two stops - at least one of which was adjustable for position - and wedges between them and the work to fix it in place. This is still a cheap and effective method for holding the work.

A screw is really just a wedge in the round. Today, most vises use a big screw to apply the clamping force. The vise is often used to hold objects in place when working on a piece.

There are two main categories of vises: vises on the end of the bench and vises on the front of the bench. End vises (also called 'tail vises') are usually mounted on the right side of the bench for right-handed workers. They can typically hold work in two ways: between the jaws and along the top of the bench using moveable 'dogs' in place of jaws. Not all benches have tail vises. A front vise (also called 'face vise' or 'shoulder vise') is typically mounted on the left front side of the bench. They may be used for holding a board to be edge jointed, or sometimes for sawing out dovetails and the like.

Front vises

Leg vise Probably the oldest front vise design is the leg vise. It's called a leg vise because one of the bench's legs is an integral part of it - usually forming the inside jaw. The outside jaw also goes all the way to the floor - or nearly so. There is a single screw mounted between a quarter and a third of the way down that goes through both jaws with the nut on the back of the leg. Finally, there is some sort of horizontal beam at the bottom to act as a fulcrum. This beam may take the form of a board that can be adjusted by means of holes and pegs, or it can even be another screw. The leg vise is probably the simplest and least expensive of the front vises, and it is very strong.

Shoulder vise Another old design is the shoulder vise. The best thing about this design is that it allows clamping directly behind the screw. This yields unobstructed vertical clamping for cutting dovetails and similar operations. There is also typically a little play in the screw/jaw attachment that provides for clamping of tapered work. This is one vise that should be designed into the bench from the beginning, as it is difficult to retrofit into an existing bench. The primary drawback of the shoulder vise is its fragility, unless the "arm" is attached to the "end cap" using a dovetail or finger joint, usually glued or "pinned"

to eliminate rotative movement about the joint, otherwise it is fairly easy to break it with a big steel bench screw. But one should never really have to put *that* much force on it. Some woodworkers say that the big vise gets in the way of some jobs, others find it unobtrusive. Implicit in a shoulder vise is an integral planing stop, formed by the intersection of the jaw and the jaw spacer, and which allows the shoulder vise to perform multiple duties, such as jointing long boards with a "bench slave" to hold the opposite end. In earlier times, a *crochet* and a holdfast would perform the same function.

Hybrid vise Many of the commercial European benches have a front vise that uses a wooden jaw with a metal screw and built-in anti-racking hardware. These vises are also available as inexpensive kits that can be mounted on almost any bench.

Quick-action vise Perhaps the easiest face vise to install is the self-contained iron vise, sometimes called the 'quick-action' vise (except they are not all quick-action). This tool comes already assembled and only has to be mounted to the bench. Usually, auxiliary wooden jaws are added. The quick-action feature makes setting it much quicker and is quickly taken for granted. Not only are these vises easy to install and use, they are also robust. Their main drawback is the relatively high cost.

Patternmaker's vise

Patternmaker's vise The patternmaker's vise is sometimes used as a front vise. This style was originally designed for patternmakers, the folks who make the forms used in metal casting. Pattern making is exacting work using shapes not normally encountered by a cabinetmaker. The patternmaker's vise can hold odd shapes at various angles, and it can certainly hold simple shapes at regular angles. The drawbacks of this vise are the expense, the moderately complicated mounting, and a tendency to fragility. The most sought-after is an antique Emmert, but there are several clones on the market today, including one by Lee Valley Tools that is made of an aluminum alloy—which should be less likely to break—and several from Taiwan and which are clones of the smaller Emmert. A possible disadvantage of the patternmaker's vise is it usually requires installation on a bench which is at least 1-3/4" thick

Twin-screw vise This is another old design making a comeback thanks to Lee Valley's Veritas Toolworks. The twin-screw vise was popular during the late eighteenth and early nineteenth centuries, particularly with chair makers. The updated Veritas design uses a chain to connect the two screws, keeping them slaved to each other. There is also a provision for decoupling the screws so that tapered work can be held. This design has many of the advantages of the classic shoulder vise and single screw face vise, with few of the disadvantages. It can also be used effectively as an end vise. The main drawbacks of the twin-screw vise are the expense and the relatively difficult installation.

Front vise comparison

End vises

Traditional tail vise The traditional tail vise uses one large screw, either wooden or metal. It is made in the form of a frame, with the back part of the frame fitting under the bench, and the movement of that frame located and restrained by a complex system of sliding tongues and grooves, and runners, such that smooth left and right movements of the frame are possible, but forward and backward movements, or rotative movements of the frame are impossible. The jaw has a face that contacts the bench top, and it has one or more dog holes on the top—often 3 to 4, each spaced 5 inches apart—that are in line with the dog holes located on the front face (apron) of the bench—numerous holes, each also spaced 5 inches apart. This is the least expensive option for a tail vise, but it is by far the most complex to design, construct and maintain. Tage Frid and Frank Klausz popularized this type of tail vise in North America, although its origin dates back to northern Europe (most probably Germany) in the 18th century.

Wagon or Enclosed Tail vise This traditional tail vise also uses one large screw, either wooden or metal. It consists of a movable block with one or more dog holes in it, the movable block rides in a large mortise in the workbench. The jaw has a face that contacts the bench top, and the dog holes are in line with the dog holes on the bench top. The two main varieties of this vise depend on whether the screw nut is mounted in the bench or on the dog hole block. When the screw nut is mounted on the dog hole block the installation is more complicated and expensive, but the screw does not move in and out as the vise is used.

Modern tail vise A newer form of tail vise does away with the need of a frame. It uses steel plates for its structure - one steel plate with the nut is mounted on the side of the bench, two others are built into a sliding jaw along with the bench screw. This is a robust design and it's easier to install and adjust than the older style. However, only a few sizes are commercially available (although larger sizes have been custom made).

Face vises as end vises Some bench designers have adapted face vises for use as tail vises - with differing levels of success. Unfortunately, we are most likely to find the continental style vise used this way, and it's really least suited to the task. When used as a tail vise it has a strong tendency to "wrack" (twist or distort) because of the side forces. It isn't long before the hardware begins to show wear.

The steel quick-action vise doesn't suffer so much from this problem. With one exception, it functions well on the end of the bench. Its main drawback as a tail vise is the distance of the dog from the edge of the vise. Ideally, the dog hole strip should be fairly close to the edge of the bench. This puts your weight more directly over the work and behind the plane, enabling you to put more power and control into the operation with less strain. It is also important to keep the dog holes near the edge so that fenced planes can easily be used. With even a small quick-action vise the dog hole strip is still pretty far from the edge. So if you decide to use a quick-action vise as a tail vise, get the smallest good one you can find.

The twin-screw vise marketed by Lee Valley works well as a tail vise - that's really what it's designed for. The old wooden twin-screw design isn't suited for this task because there is no facility for holding the offside jaw open.

End vise comparison

- A planing stop
- A hold fast being used to affix a board to the benchtop for chiseling dovetails
- A simple vise using dogs and wedges (the wedges are colored for clarity)
- A leg vise
- A board clamped in a shoulder vise
- A hybrid vise
- An easy to install self-contained iron vise
- A patternmaker's vise
- The Veritas twin-screw vise
- A traditional tail vise
- A modern tail vise
- A quick-action vise used as an end vise

17.2 Construction materials

Most workbenches are made from solid wood; the most expensive and desirable are made of solid hardwood. Benches may also be made from plywood and Masonite or hardboard, and bases of treated pine and even steel. There are trade offs with the choice of construction material. Solid wood has many advantages including strength, workability, appearance. A plywood or hardboard bench top has the advantage of being stable, relatively inexpensive, and in some ways it's easier to work with - particularly for a woodworker who doesn't yet have hand tools. The practical drawbacks of a plywood or composite bench top are that they don't hold their corners and edges well, and they can't be resurfaced with a plane - something that is needed from time to time.

Workbenches are fairly forgiving in the choice of wood. Maple, cherry, mahogany, or pine rarely give problems. Beech, oak, walnut, and fir make good benches. Benches are occasionally made using more exotic woods like purpleheart and teak - though the expense is high. The choice of wood is not as important as the integrity of the design - cross grain construction and inadequate joinery typically have a more destructive effect than the use of a less-than-ideal wood.

One popular and cheap source for bench top material is old bowling alley lanes. These are usually made from thick,

high-quality laminated maple. Two problems present themselves with bowling alley wood: first, the waxes used on the surface for bowling frequently contain silicone and other substances that can play havoc with work pieces at finishing time - a little silicone on a project will cause trouble with many finishes, and won't manifest it until it's too late. The other problem with bowling alley wood is nails. Most pieces have loads of nails buried in them, which do not mix well with woodworking tools.

Many benches use different species of woods together. Small business woodworkers who work in a store-front sometimes use various species so that their clients can see examples of the different woods in a finished state. If this is done, it is important to use woods that are compatible with each other - particularly in the area of relative movement. Otherwise changes in temperature and humidity will stress the structure out of shape or it may even break.

The most common use for exotic woods in bench construction is for auxiliary parts such as oil cups, bench dogs, vise handles, sawing stops and the parts of wooden vises.

17.3 Size and positioning

The optimum size of a bench depends on the work to be done, space considerations, and budget. In general, bigger is better - though most woodworkers find that most work is done on the front few inches of the top, and then mostly in the front vise or right around the tail vise. So a smaller, narrow bench isn't as much of a drawback as might be expected - and it is far better than no bench at all. Tage Frid's classic bench is relatively small and it is one of the most copied designs. A big disadvantage of a smaller bench is that they are usually too light to resist heavy work without skidding around - but this problem can be overcome by attaching the bench to the floor.

Woodworkers seem to be evenly divided on the subject of bench positioning. Some like to be able to access their benches from all sides, while others like their bench against a wall. The advantage of wall placement - besides the saved space - is that tools can be stored on the wall over the bench, within easy reach. This keeps the tool storage out of the way, and the tools can still be reached without turning around or bending down.

17.4 The base

A workbench base should support the top so that it doesn't move, while at the same time keeping clear of the work. There are two main types: open bases and bases with built in storage. Open bases are easier to build and there is less chance of the base hindering the work - plus, it is usually necessary to compromise the strength and rigidity of a base in order to accommodate storage.

Probably the most popular style is the sled-foot trestle base. With this design, each pair of legs is put together in the form of an 'I' with two vertical bars. The leg pairs are connected by a pair of stretchers. These stretchers can be permanently fixed to the leg-pairs, or they can be made removable with tusk tenons or a bed-bolt arrangement. One of the advantages of this style is that there is no end-grain resting on the floor, so the legs are not as prone to wick-up moisture and rot.

Another popular style is a simple post and rail table structure. This is probably best implemented in heavy gauge steel, as wood doesn't really give enough resistance to the side forces that develop during heavy work. Most woodworkers who use this style with wood end up making another base before very long.

A hybrid design of the sled-foot trestle and the post and rail styles can work well. Instead of an 'I' structure, the sled foot is moved up to become a rail - sort of an 'H' with a bar across the top. This puts end-grain on the floor, but it is otherwise a strong design and somewhat easier to build. Plus, the feet don't get in the way of the work as sled-feet sometimes do.

Cast iron leg kits are available for woodworkers who do not want to design and build their own base.

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Chapter 18

Glossary of woodworking

Main article: Woodworking

A number of **specialized terms are used in woodworking**.

18.1 Contents

18.2 A

- **Applied carving** - background which is worked separately and then applied, rather than being worked in place.
- **Architrave** - ornamental mouldings around a door or window frame, covering the joint between the frame and plaster.

18.3 B

- **Bead** - a semicircular piece of moulding.
- **Bench dog** or **Bench stop** - a peg standing proud of the bench surface.
- **Blind** - joinery with mating surfaces not protruding through the face or end grain of the pieces being joined. Example - *blind* mortise and tenon joint
- **Billet** - 1. a short piece of log particularly used for fuel; 2. a split out piece of a *bolt* of wood.
- **Bolster** (pillow, cross head) - 1. shoulder; 2. a timber between a post and a beam to increase the bearing or shorten the span.
- **Bolt** - a piece of log cut to specific length, usually a short length from which products such as shingles are split or cut. Sometimes also called a billet or round.
- **Brace** - a hand tool used to drill holes, having a knobbed handle on the top to which pressure is applied, and a U-shaped grip in the middle which is used to rotate the drill bit.
- **Burl** - a knotty growth from a tree with a convoluted, complex grain.

18.4 C

- **Cannel, channel** - the concavity of a gouge blade.
- **Card scraper** - a flat blade with a burred edge used for smoothing.
- **Caul** - A strip or block of wood used to distribute or direct clamping force
- **Chatoyance** - the effect seen in dramatic wood grain direction changes as seen in flame figured maple.
- **Chip carving** - incised surface decoration, usually geometric.
- **Chops** - a type of vise.
- **Climb cut** - On a table saw or router, cutting against the normal feed direction at the end of the cut to prevent tearout.
- **Close grain** - woods with very fine fibers of cells (wood grain) that are not visibly porous.
- **Conversion** - reduction of a whole log into pieces suitable for working. Conversion can be done in three basic ways, sawn, hewn, or split.
- **Crook** - longitudinal bending to one side, caused by uneven seasoning or grain. (See Wood warping)

- **Crotch** - the section of a tree where a branch divides from the trunk, or the trunk divides in two; typically an area of convoluted grain.
- **Crossgrain** - working perpendicular to the grain.
- **Crosscut** - a cut made perpendicular to the grain.
- **Crown of thorns** - a system of self-supporting and interlocking pieces.
- **Cruck** - a pair of crooked, structural timbers in a timber frame building. Crucks act as both posts and rafters like an A-frame.
- **Cup** - transverse bending, convex or concave, usually predictable, considering grain orientation. (see Wood warping)

18.5 D

- **Dado** - a slot made across the grain.
- **Dovetail joint** - a joint technique most commonly used in woodworking joinery. Noted for its resistance to being pulled apart (tensile strength), the dovetail joint is commonly used to join the sides of a drawer to the front.
- **Drill** - (verb) the process of making holes in a material or (noun) a tool for drilling holes.

18.6 F

- **Face** - when a board has one side that is wider than the other, the wider side is referred to as the face (as opposed to the edge). May also refer to the face that is to be visible in the finished item.
- **Fence** - a flat and straight length of some material, usually wood, steel or aluminium, which provides a reference for tools to work against, or which prevents the work from sliding.
- **Fiber/fibre** - the fine tube-like structure of wood which is hollow and determines the grain direction.
- **Figure** - naturally occurring decorative patterns in wood, caused by either growth increments or tissue orientation.
- **Firmer** - a strong chisel for general work or mortising, may have square sides or bevels on both sides.
- **Fishtail chisel** or **gouge** - a chisel or gouge with a splayed end.
- **Flat gouge** - a gouge with minimal curvature, used for finishing and smoothing.
- **Flitch** - a board in which the round of the trunk is still visible, a rough-cut board.
- **Flute** - a deep channel cut in wood* occasionally denotes the cannel of a gouge.
- **Foxing** - a yellow-brown discoloration of wood due to fungal infection.
- **French cleat** - a molding used to hang cabinets
- **Fret saw** - a saw with a very fine toothed blade used for delicate cuts in thin material.
- **Frosting** - regular indented patterns created with a special-purpose punch called a froster.

18.7 G

- **Grain** - the longitudinal fibers in wood.
- **Gouge** - a chisel-like tool with a curved cutting edge.
- **Green wood** - unseasoned wood; freshly harvested timber, usually with a high moisture content.
- **Grit** - the grade of particles in sandpaper or sharpening stones which determines the aggressiveness of the cut.
- **Groove** - a slot or channel made with the grain, usually on the end-grain in preparation for a tongue and groove joint.
- **Grooving**- a rectangular sinking in the surface of any material.

18.8 H

- **Hand plane** - see **Plane**.
- **Hardwood** - wood from an angiosperm tree, i.e. a tree in the division Magnoliophyta. Despite the name, not necessarily very hard or dense wood (e.g. balsa is a hardwood), although generally harder than **softwoods**.
- **Heart shake** - a shake (i.e. crack or split) radiating out from the heartwood.
- **Heel** - the corner of a chisel, knife, or gouge bevel which meets the back of the blade and polishes the cut.

- **Hold down or hold fast** - a hold-down iron, fitting into a hole in a bench, tightened or loosened by hammer taps.
- **Hollow grinding** - a concave bevel on a chisel, gouge, or knife.

18.9 I

- **Incannel** - the concave surface of a gouge; a gouge sharpened on the concave surface.
- **Interlocked grain** - wood grain which has multiple longitudinal directions in alternating layers, typical of many tropical hardwoods, and very difficult to work and to produce smooth surfaces.

18.10 J

- **Jig saw** - a tool that can form circular cuts by moving the work piece past a blade rapidly moving up and down.
- **Joiner** - a woodworker who does finer work than a framing carpenter.
- **Jointer** - 1. a power plane used to straighten boards and square edges, sometimes called a joiner; 2. an intermediate length hand plane, a jointer plane.

18.11 K

- **Kerf** - the gap left when material is removed by a saw. The width of the kerf is equal to the set of the saw.
- **Knot** - A circular pattern in timber, caused by a dead branch that was not fully integrated into the tree before it was cut down. A loose knot is one that cannot be relied upon to remain in place in the piece. A tight knot, on the other hand, is fixed by growth or position in the wood structure so that it firmly retains its place in the surrounding wood.

18.12 L

- **Lead** - the tendency for wood that is being cut to direct the saw parallel to its grain.
- **LathArt** - a type of folk art that uses lath from old plaster and lath walls

18.13 M

- **Molding** - a strip of material with various profiles used to cover transitions between surfaces or for decoration.
- **Mortise** or **Mortice** - a cavity or hole (generally rectangular) in a piece of wood, meant to receive a tenon or a hinge
- **Mitre** (UK, Cda) or **Miter** (US) - a joint made by fastening together pieces with the ends cut at an angle.
- **Mitre box** (UK, Cda) or **Miter box** (US) - a box used for making mitre joints by having slots to guide a saw at the desired angle for the joint.

18.14 O

- **Off fall** - Scrap created by making a cut. Abbreviated as fall.
- **Outcannel** - the convex surface of a gouge; a gouge sharpened on the convex surface.

18.15 P

- **Plane (tool)** - (verb) the process of removing material in thin shavings in order to make it flat, or (noun) a tool for planing.
- **Plane iron** - cutting part of a hand plane.
- **Planer** - or thicknesser. a machine which reduces the thickness of boards.

18.16 Q

- **Quarter-sawn** - a plank with growth rings perpendicular to the wider face. (See Wood grain)

18.17 R

- **Rabbet** - A 'groove' cut parallel to, and at the edge of, a board.
- **Rail** - Horizontal member of a frame on a door, window or panel.
- **Rasp** - a long and flat steel tool with raised teeth for shaping wood.
- **Reed** - a series of beads in a row.

- **Relief cut** - short straight cuts made at right angles to a curved layout so sharper than normal curves can be cut with a jig saw or band saw.
- **Riffler** - a paddle-shaped rasp.
- **Rift sawn** - rip sawing of lumber (timber) perpendicular to the grain, often confused with *quarter sawn*.
- **Ring shake** - a natural type of split (shake) occurring between the annual rings.
- **Rip** - a cut made parallel to the grain.
- **Route** - to cut a channel or groove. See router (woodworking).

18.18 S

- **S2S** - lumber, usually furniture grade hardwood, with two sides planed. (S4S - four sides)
- **Saw rasp** - a rasp with saw teeth.
- **Scorp** - a drawknife with a curved, sometimes completely circular blade, often used for hollowing out objects such as bowls.
- **Scratch awl** - a sharp-pointed hand tool used to mark wood for cutting, usually used in joinery or when a more precise mark is need beyond that provided by a pencil or other method of marking out the cut.
- **Scribe** - the woodworking technique of shaping the end of a moulding or frame component to neatly fit the contours of an abutting member.
- **Scroll saw** - a motorized fretsaw.
- **Seasoning** - reducing the moisture content of wood before working to prevent cracking, splitting, and other damage due to drying.
- **Shake** - 1. a crack or split in wood, caused by damage or drying; 2. a split (as opposed to sawn) shingle.
- **Shoot** - planing an edge straight or square. See Shooting board.
- **Slab** - 1. a partially round cut from a log; 2. In Australian English a slab is a plank.
- **Slab-cut** - a plank with growth rings roughly parallel to the wider face.
- **Slick** - a giant chisel used in framing and traditional building construction.
- **Slip** - a shaped stone used for sharpening non-flat blades such as gouges.
- **Snib** - a wooden toggle used to hold the work on a table.
- **Softwood** - wood from a gymnosperm tree, i.e. trees in the divisions Pinophyta and Ginkgophyta Despite the name, not necessarily very soft or light wood (e.g. douglas-fir is a softwood).
- **Spalting** - a change in the texture, strength and color of wood caused by colonies of fungus growing within the dead wood. Where colonies of fungus meet, fine black lines - often considered a desirable feature, can be seen.
- **Split** - to longitudinally separate wood along grain layers.
- **Spokeshave** - a tool used to shape and smooth wooden rods and shafts - often for use as wheel spokes and chair legs.
- **Square** - 1. a tool such as a steel square, try square, combination square; 2. a right angle; 3. an area of 100 sq. ft.
- **Stickers** - a small block of wood used to separate boards that are in the process of drying.
- **Sticking** - a moulding that is part of a larger piece of wood such as a frame (as opposed to being applied).
- **Stile** (or sometimes *style*) - vertical member of a frame on a door, window or panel.
- **Stringer** - in stairs, a is a timber (usually 2"x12") that supports the treads and rises in a staircase.
- **Sweep** - 1. the curvature of a gouge, ranging from flat (little curvature, but not actually flat else it would be a chisel) to deep or quick; a warping defect in a piece of wood.

18.19 T

- **Tear out** - broken or torn fibres resulting from damage as the blade of a tool exits the cut.
- **Tenon** - is a projection on the end of a piece of wood for insertion into a **mortise**.
- **Tread** - in stairs the part that is stepped on.
- **True** - something which is accurately placed, shaped, or sized. To true up two pieces of wood is to make them align. The correct size or shape.

- **Twist** - longitudinal twisting of wood due to uneven seasoning or grain. (See Wood warping)

18.20 U

- **Undercutting** - cutting away from an edge to increase the sense of relief or thinness.

18.21 V

- **Veiner** - a small deep gouge.
- **Veneer (wood)** - very thin slices of wood used for inlay or to cover surfaces.
- **Veneer saw** - specialty tool for trimming veneer.

18.22 W

- **Wane** - an edge of a sawn board where the bark or surface of the trunk remains.
- **Warp** - distorted lumber, such as a twist, cup or a bow. (See Wood warping)
- **Wasting** - quickly removing wood during carving, usually with an adze, knife, or rasp.
- **Waste** - wood that will be removed in the finished work, often retained during working as a handle.
- **Wood** - an organic material, a natural composite of cellulose fibers (which are strong in tension) embedded in a matrix of lignin which resists compression.

18.23 External links

- Woodworking glossary

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- **Mortise and tenon** *Source:* http://en.wikipedia.org/wiki/Mortise%20and%20tenon?oldid=661887740 *Contributors:* Heron, Zippy, Infrogmation, JohnOwens, Minesweeper, Glenn, Technopilgrim, Charles Matthews, DJ Clayworth, Carnildo, Etune, Tangerine Cossack, JoJan, Mzajac, Sam Hocevar, Rich Farmbrough, Number 0, Aaronbrick, Bobo192, Nigelj, Ahruman, Aquelajames, Dave.Dunford, Luigizanasi, MONGO, Mandarax, Graham87, FlaBot, GreyCat, Haroldarmitage, Kymacpherson, NawlinWiki, BOT-Superzerocool, Enneagon, Nathparkling, SmackBot, Eskimbot, Gilliam, Jerome Charles Potts, Can't sleep, clown will eat me, Kelvin Case, OrphanBot, Onorem, Madman2001, Just plain Bill, Jim Derby, Iepeulas, CmdrObot, Basawala, Mattisse, Thijs!bot, Davefoc, James086, Yettie0711, Dekker, AntiVandalBot, Widefox, Ling.Nut, 28421u2232nfenfcenc, Mschel, Nwbeeson, Hanacy, MarkAnthonyBoyle, Martin2Reid, Qha, Philip Trueman, Uodnelome, WikiCantona, Malick78, Andy Dingley, Logan, PericlesofAthens, Tpb, SieBot, ClueBot, The Thing That Should Not Be, Der Golem, Mild Bill Hiccup, Parkwells, Rockfang, Aaaronsmith, MystBot, Addbot, Captain-tucker, KaiKemmann, Luckas-bot, Yobot, Cuss, Citation bot, Xqbot, Capricorn42, Anna Frodesiak, Almabot, GrouchoBot, Jhbdel, RibotBOT, FrescoBot, Mfwitten, Pinethicket, Vrenator, DARTH SIDIOUS 2, Stevenliuyi, WittyMan1986, ZéroBot, Paul a sellers, ClueBot NG, Spencer greg, Suestein1960, Mifter Public, Einav.Zamir, Scootaboyz1, YiFeiBot, Noyster, Epicyoloswagtrollface, SPIKE SPIKE BAD and Anonymous: 85
- **Frame and panel** *Source:* http://en.wikipedia.org/wiki/Frame%20and%20panel?oldid=609456872 *Contributors:* Bobblewik, Joyous!, Nabla, Luigizanasi, ScottDavis, Dinosaurdarrell, Carrionluggage, SilentC, Zerodamage, Arniebuteft, Dogears, Langhorner, ScottW, Odie5533, Nono64, Naples, Slysplace, Saddhiyama, Thingg, WikHead, Anna Frodesiak, ClueBot NG, Lily5ruiz, KapitanCookie and Anonymous: 14
- **Turning** *Source:* http://en.wikipedia.org/wiki/Turning?oldid=649815414 *Contributors:* Robbot, Chris 73, Altenmann, MPF, Gtrmp, FrozenUmbrella, Rich Farmbrough, Vsmith, MeltBanana, Smalljim, Daniel Case, Graibeard, Sumanch, Carbonferum, Waaaazzzzaaaa, Akamad, Boinger, Reyk, SmackBot, KocjoBot~enwiki, Keanu, Colonies Chris, Darth Panda, Pegua, John, Evenios, Makyen, Wizard191, Iepeulas, Rifleman 82, Kozuch, Daniel Olsen, Tortillovsky, Thijs!bot, Begs, VoABot II, Entropy, VolkovBot, Kyle the bot, TXiKiBoT, Xcrissx, CarVac, Andy Dingley, AlleborgoBot, SieBot, Lightmouse, Sunrise, Werldwayd, Ariadacapo, Pakaraki, VQuakr, Excirial, Three-quarter-ten, PixelBot, Razorflame, Warrior4321, 1ForTheMoney, Lx 121, SilvonenBot, LizGere, Addbot, CanadianLinuxUser, Imeite, Chamal N, LinkFABot, Numbo3-bot, Jarble, Krenakarore, Luckas-bot, WikiDan61, Ptbotgourou, Aboalbiss, Materialscientist, Ieuan Sant, Kgartner, GrouchoBot, Milmmann, Asleepstanding, Scottstephens101, Anto2002, PrincessofLlyr, Bryancpark, Vrenator, Onel5969, EmausBot, Oliverlyc, Wilhkar, Polisher of Cobwebs, ClueBot NG, Satellizer, Rezabot, Mmarre, Buhl1946, Dexbot, Pptx, Writers Bond and Anonymous: 78
- **Woodturning** *Source:* http://en.wikipedia.org/wiki/Woodturning?oldid=662015176 *Contributors:* Bryan Derksen, Schneelocke, RodC, Charles Matthews, Fredrik, Ludraman, Alan Liefting, Niteowlneils, Yekrats, MarkSweep, Máirtín, Lankiveil, Causa sui, Tjic, Cmdrjameson, Mpenacho, Versageek, Woohookitty, Spettro9, Pacobob, BD2412, RxS, Angusmclellan, NeonMerlin, Graibeard, Avocado, Loggie, Lightamplification, Jared Preston, Wavelength, RussBot, Irishguy, Ravedave, HereToHelp, NeilN, Kingboyk, Veinor, Prodego, Jpvinall, OrphanBot, KaiserbBot, Seadragon, Gohst, Cybercobra, Deiz, SilkTork, Anjow, Skapur, RememberSammyJankis, Viridae, Mombas, Epbr123, Mojo Hand, Nemti, I already forgot, Kamocat, N7bsn, M256, Rwexelblat, VoABot II, Biggedink, Jllm06, Csydude, Jennf, R'n'B, J.delanoy, Pharaoh of the Wizards, Numbo3, Damien Shiest, Mcewan, Slysplace, Jackfork, Purple Aubergine, DesmondW, Bernhard Hofmann, Andy Dingley, Ppatel43026, Steve.davidpotter, Turmennan, Nelsondh, ClueBot, DottoreD, Eadthem, Apparition11, SilvonenBot, ScotKersten, Addbot, Kvedros, Seacin, Pietrow, Fraggle81, AnomieBOT, Seacin1120, KYSean, Byrneskin, Elmmapleoakpine, Frankenpuppy, Mattgeldard, Anna Frodesiak, Thewoodworker0077, TheTurningGallery, Hamamelis, GliderMaven, Voxii, Kkj11210, Aerolin55, Detrickm, Mattpearson, JohnFEdwards, Ddaudelin, ClueBot NG, Dominikmatus, Williamseibert57, Imediadesigns, Xjumper65, Jglefler, Sanbecr, Klilidiplomus, Zakmanbear, Pratyya Ghosh, Iamnofool4, Gityerkix, Trumpcard777, Xrak1, Gingergus, Rlcallum and Anonymous: 91
- **Segmented turning** *Source:* http://en.wikipedia.org/wiki/Segmented%20turning?oldid=631676471 *Contributors:* Luigizanasi, RHaworth, Chris the speller, Bluebot, Lambiam, Nagle, Five40, ThuranX, CmdrObot, Marleyturned, MarshBot, Magioladitis, Newracer, Slysplace, Chzz, Lloyd32552, Bermicourt, Yobot, Woodtrekker, AnomieBOT, Anna Frodesiak, Grantmidnight, Turnerbpritchard, Khazar2 and Anonymous: 10

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