

Modern technology of dry distillation of wood

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Nowadays the process of dry (destructive) distillation of wood is carried out in a periodical (batch) or continuous manner. In the former case steel (mobile) retort furnaces are used, while in the latter case, retorts included in automated plants. In both cases temperature during the process is gradually increased from 200°C to 600°C, with limited admission of air. The products of the processes taking place include, in addition to charcoal, a distillate comprising gases and vapours. The gaseous components include carbon dioxide, carbon monoxide, hydrogen, methane and ethylene. Vapours contain mainly methanol, acetic acid, acetone, formic acid, propionic aldehyde and acid. They also contain components that condense to form wood tar. These are phenol derivatives, such as: cresols, guaiacol, catechol, pyrogallol, xilenol, turpentine ingredients: carene, pinene, camphene, terpineol, limonene, bornyl acetate.

Products of dry distillation of wood

Process variables, particularly temperature, temperature increase rate, type and composition of wood, moisture content, have an effect on the yield of individual products. Rapid temperature increase in the 220-300°C range increases the proportion of gases generated. Debarked wood of trees such as: beech, oak, birch, lime, hornbeam, spruce, pine yield more methanol and acetic acid than non-debarked wood. On the other hand, dry distillation of wood with bark provides more charcoal, tar and gases.

The yield of products of dry distillation of wood varies in a wide range [1, 2] (Tab. 1).

Table 1

Yield of products of dry distillation of wood [1, 2]

Product	Yield* % wt
Charcoal	31.8-37.9
Water	22.3-28.0
Wood gas	
CO ₂	9.9-11.0
CO	3.3-4.2
CH ₄	0.2-0.5
C ₂ H ₄ and higher hydrocarbons	0.2-0.6
Vapours	
acetic acid	3.2-7.1
methanol	0.8-2.1
acetone	0.2
methyl acetate	0.0-0.1
Tar, total	15.0-19.1
soluble	6.5-9.1

*beech, hornbeam, oak, birch, lime, pine, spruce

Wood gas from dry distillation contains (%wt.): CO₂ 40-55, CO 26-35, CH₄ 3-10, C₂H₄ 2, H₂ 1-4. It is often used for steam generation for captive use at the distillation plant or in nearby facilities, or directly as fuel for heating the retort. The mean heating value of the gas is 8.4-12.6 MJ/m³. This gas under war conditions was used for driving internal combustion engines.

Liquid distillates, upon collection and settling in tanks, separate and form a settled tar layer and a water solution called pyroigneous acid, the latter containing acetic acid, methanol, acetone, methyl acetate and tar components. After vacuum distillation in multiple-effect evaporators a water distillate is obtained, the main components of which are acetic acid, methanol, acetone. The tail fraction is tar, which can be further processed together with the settled tar. The acidic distillate is usually separated by extraction, neutralising acetic acid with milk of lime or by esterification. In the case of the neutralisation-based method, methanol and acetone are distilled off (wood spirit), and the solution of calcium acetate is concentrated, crystallized, dried and treated with sulphuric acid after comminution. The liberated acidic acid is purified using rectification methods. Similarly, the wood spirit is fractionated by rectification.

The largest amounts of **settled tar** are separated as a layer from liquid distillates. Some of its components are present in pyroigneous acid in the form of dissolved tar. It is isolated during the separation of the main components of pyroigneous acid: acetic acid, methanol and acetone and it can be processed together with the main fraction of tar. The dissolved tar is also used unprocessed in the manufacture of charcoal briquettes. Usually the settled tar is distilled into light oil, with boiling point up to 120°C, heavy oil, collected at 120-270°C, and the residue is pitch. The light oil is used as a floatation agent in metal ore processing. Heavy oil is used for wood impregnation. Components isolated from heavy oil include guaiacol and creosote (mixture of cresols, dihydric phenols, methyl ethers thereof, xlenols).

Flow sheet of plant for continuous dry distillation of wood

A flow sheet of plant for dry distillation of wood operating in a continuous manner, is shown in Figure 1. Vapours and gases are not separated in this plant, they are used for heating the plant and for steam generation [3]. Wood in the form of round billets or slivers up to 20 cm in diameter is arranged on a bench and transferred onto a trough conveyor. The round billets are moved on rotating cylinders to the cutting disk of the conveyor. The billets are cut to blocks ca. 25 cm long. These blocks are transferred to the storage silo 10. A charging bin is positioned under the silo and is filled and then moved to dryers 9. When the level of wood in the dryer falls to a defined height, the loading chamber of the dryer is opened and the charge of wood is complemented. This wood is exposed to the action of drying gas the temperature of which is 160-180°C. The water contained in the wood is evaporated and the gas is cooled to 50-80°C. Gas flow is forced by fans installed downstream of drying gas expansion chambers 8. The expansion chambers receive small pieces of wood formed during drying. Vibration chutes installed at the bottom of each dryer transfer the dried wood to a container-car which moves over the retort 1 and drops wood into it when the level falls to a defined height. The retort accommodates the full contents

of the container. The retort is closed and the water remaining in the wood is evaporated, after which the thermal decomposition of wood commences. This is initiated by hot gases of the temperature of 250-300°C which flow from the central part of the retort (tempering zone). The process is exothermic. The organic substance of wood is carbonized. The process also results in the liberation of acetic acid, acetone, methanol, wood tar, oils, gases: carbon dioxide and monoxide, methane, ethane and higher hydrocarbons, hydrogen and water. The partly carbonized wood shrinks and moves down the retort to the tempering zone. Here, at the temperature of 500-550°C, charcoal in its final form is formed. However, the amount of heat generated is too small to maintain this temperature and to complete degasification. For this reason hot flue gas at a temperature of 500-600°C is fed to the tempering zone. Charcoal descends under its weight to the cooling zone in the lower part of the retort. The cooling medium here is cold flue gas at a temperature of 35-40°C. It is fed by a fan which draws in flue gas cooled in water cooler 5.

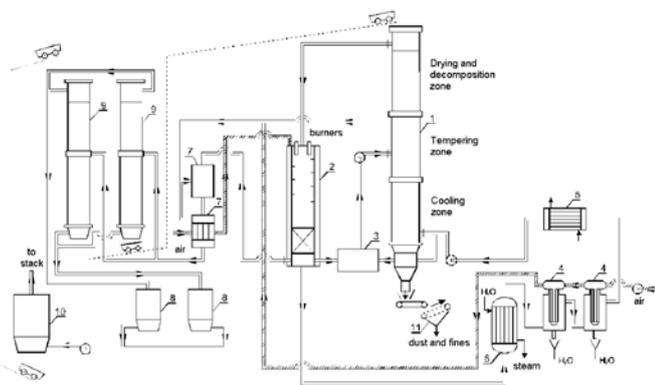


Fig. 1. Simplified flow sheet of plant for continuous dry distillation of wood.

1 - retort, 2 - vapour and gas combustion furnace, 3 - heating gas mixing chamber, 4 - air cooler, 5 - water cooler, 6 - steam boiler, 7 - gas mixing chamber, 8 - gas expansion chamber, 9 - wood drier, 10 - storage silo for wood blocks

The level of charcoal and wood in the retort drops because of shrinkage, but mainly because of the operation of a screw installed in the bottom part of the retort. Intermittent screw operation causes the charcoal to be moved to the discharge chamber. As the tightness of the retort needs to be maintained, its bottom doors are shut, the screw is stopped and the charcoal is transferred from the discharge chamber to a closed chute, and there from to sorting conveyor 11. Here the charcoal dust and fines and the proper charcoal fractions are received. Charcoal is seasoned for a few days in storage bunkers and then transferred to packing unit. Charcoal dust and fines are used in the manufacture of briquettes.

Vapours and gases generated mainly in the decomposition and tempering zones are discharged through the top of the retort, along with that portion of cooling gas which was not carried away via the side manifold. The mixture of vapours and gases at a temperature of 200°C is conveyed with air to burners installed in separate furnace 2. It is forced through an external cooling jacket of the combustion chamber, which protects the internal wall of the combustion chamber against overheating. A portion of the heated air is used for the drying of wood. Flue gas from furnace 2, at a temperature of ca. 1000°C, are after-burned while flowing over a catalyst in the lower part of the combustion chamber of furnace 2. In case of insufficient amount of vapours and gases from the retort, or during the start up of the plant or in the case of main burners being put off, an emergency (start up) burner is ignited. That burner is supplied independently with natural gas or other hydrocarbon gas. A portion of flue gas from the vapour and gas combustion furnace 2 is conveyed to the heating gas mixing chamber 3 and is used for carbonization. Flue gas is cooled here

to 500-600°C and forced by a fan to the tempering zone of the retort. Gas of this temperature is obtained by mixing in chamber 3 of flue gas from the vapour and gas combustion furnace 2 with flue gas from steam boiler 6, upon the cooling of the latter flue gas in cooler 4 with air and in cooler 5 with water. The remainder of flue gas from the vapour and gas combustion furnace 2 is used to cool charcoal to ca. 40°C in the cooling zone of the retort. To this end, a portion of flue gas at an initial temperature of ca. 1000°C is used to heat the steam boiler 6. In this process of steam generation the temperature of that flue gas is lowered to ca. 200°C. Further indirect cooling of gases is effected in heat exchangers cooled with air, the temperature of which is increased to 60-70°C. The flue gas is cooled to below the dew point of water vapour contained therein, causing the condensation of water, which is discharged to sewers. Further cooling of gases to 30-40°C is effected in water cooler 5.

Air from indirect heat exchangers 4, at a temperature of 70-80°C, is mixed with flue gas from the tempering zone of the retort. Air is mixed with flue gas in dedicated chambers 7. As a result, the flue gas from the tempering zone is cooled from 500-600°C to 160-180°C. This gas is used for wood drying in dryers 9. If flue gas temperature decrease is insufficient, additional air is introduced into the chambers.

In the Austrian town of Güssing there is a heat and power generation plant where wooden chips are gasified directly with steam, with no air admission and under a slightly increased pressure [4]. The plant produces gas of low nitrogen content and of relatively high heating value. This gas is used directly as fuel in a gas engine, which is coupled with a power generator. The hot exhaust gases from the engine additionally heat water in the district heating system. The charcoal, which is a by-product, is used as fuel for the process.

Charcoal applications

The mean elementary composition of charcoal is as follows (%wt.): 80-85 C, 14-16 O, 3-4 H and N and few percent ash. The principal application of charcoal is associated with its good adsorptive properties, acquired as a result of activation [5]. Its high specific surface area (400-1500 m²/g) ranks it among materials of the highest adsorptive capacity. It is therefore used in industrial adsorbers for the removal and recovery of organic compounds, particularly from vapours and gases to be discharged into air, and in gas masks and in extractor hoods. It is also used for removing undesired compounds from liquids, particularly from water and wastewater.

Charcoal is also used a fuel, also in the form of briquettes. In pyrotechnics it is used as an ingredient of many gun propellants, the best known of which is black powder. It is also used for making drawings.

Activated charcoal, used in a variety of adsorbing apparatus and devices, is obtained after additional expansion of the surface area of charcoal derived from wood or other material (coconut shells, bones, peat, lignite or petroleum refining residue). The raw material for charcoal manufacture is subjected to destructive distillation in retorts, without air admission, upon saturation with water solutions of such compounds as chlorides (preferably of zinc(II)), phosphates or phosphoric acid, sulphides of alkali metals, potassium thiocyanate. Distillation is performed at 300°C to 600°C. The product is washed with water to remove the compounds added, charcoal is dried and activated with steam.

Activated charcoal is also formed as a result of selective oxidation of charcoal with steam or carbon dioxide at a temperature of ca. 200°C. This process is carried out in cylindrical steel retorts several metres in length.

Commercial activated charcoal is in the form of fine powder, pellets, beads and cylinders. Powdery charcoal is mixed with a suspension of a binder in water and then suitable shape is given to it. The beads or other shapes are activated at elevated temperature in an oven.

Adsorptive capacity is increased by forming new pores and creating openings in existing pores. Finally the material is washed with an acid to lower ash content.

For adsorption of gases the best results are obtained with activated charcoals with pores 1.2 - 20 nm in diameter, whereas for adsorption from aqueous solutions the best results are provided with pores from a few to 100 nm in diameter.

Activated charcoal is used for refining sugar, vegetable oils, alcohols, for decolorizing citric acid, lactic acid and other acids, and for improving the flavour of soft drinks, eliminating odours and removing colloids.

It is also used as a catalyst or a carrier for proper catalyst.

Activated charcoal (best grades manufactured from wood of lime trees) in the form of tablets is used in pharmacy; it absorbs bacteria, toxins, gases in the digestive tract and regulates peristalsis in the intestines. It is also added to animal feed, e.g. for broilers [6]. It may also be used as a reducer in metallurgy.

Summary

The main commercial product obtained from a modern plant for continuous dry distillation of wood is charcoal. Gaseous and liquid products are used as fuel for carrying out the process of wood decomposition, and the excess heat is used for steam generation for captive use at the site or in nearby facilities.

In plants for dry distillation of wood operating in batch mode there is also the possibility of using liquid distillates and wood tar. Acetic acid and wood spirit are isolated from liquid distillates. Wood tar is distilled into light oil and heavy oil. The former is used as a floatation agent in metal ore processing, the latter is used for wood impregnation.

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