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SPECIFIC CALCULATIONS AND EXAMPLES OF TECHNOLOGICAL SIZING

Appendix 1.

HEATING OR COOLING THERMAL AGENTS

In this paragraph, will be present some generalities regarding heating or cooling agents and intermediate heating agents. There will be briefly discussed the principles of obtaining low temperatures and will provide more specific data on the physical properties of fluids.

A. 1.1. GENERAL INFORMATION ON THERMAL AGENTS

The classic ***heating agents*** are hot water, steam and flue gases. Hot water is usually condensate, obtained from steam at pressures slightly higher than atmospheric pressure and temperatures slightly higher than 100°C. This is generally used for heating heavy products, to avoid freezing and reduce the viscosity (ex. preheating of liquid raw material for carbon black plants). Heating with hot water is realized at temperatures below 100°C.

The steam used as a heating agent is always saturated steam at low or medium pressure. As opposed, the steam used as an energetic agent (by expansion in a turbine, where mechanical work occurs), is superheated steam at medium or high pressure. For heating is preferred saturated steam because this is condensed practically isothermal, the heat transfer coefficient being higher and the required transfer area reduced. Steam heaters are common at fractional column boilers, the temperatures achieved being generally below 200°C, and the thermal loads relatively low.

For heating at high temperatures and in general, at large thermal loads, the flue gases obtained by combustion of fuel are used as thermal agents. Electric heating, being uneconomical, is very rare in the petrochemical industry and used at low thermal loads (examples: initial melting of salts used as an intermediate thermal agent in some petrochemical plants; avoid freezing of substances transported by pipes; avoid freezing of the soil under the cryogenic storage tanks use for light hydrocarbons).

The economic efficiency of a technological installation increases with the increase of the degree of heat regeneration; it is good to achieve a heat exchange as intense as possible between the effluents and the raw material that feed the installation. In such cases, the effluents are heating thermal agents in relation to the raw material. Similar is the case when heat is recovered from effluents, for steam generation, etc.

If an intermediate thermal agent is used in a technological installation (for example, oil), in a closed circuit, carrying heat from a hot stream to a cold stream, the intermediate thermal agent is also a partial heating agent. As a curiosity, it can be mention as a heating agent, helium. In a petrochemical plant in Japan, served by a nuclear power plant, the reactor is cooled with helium, which is heated to 1000°C. The heat obtained from atomic energy is transported by helium, and used for district heating (technological steam generation and electricity), and high-temperature heating (heating at the syngas reactor), replacing the combustion of fuel.

The classic thermal ***cooling agents*** are water, air and refrigerants. The water used as a coolant is, in most cases, recirculation water (hot water is cooled in cooling towers by direct contact with atmospheric air and pumped to coolers and condensers), Recirculation water has the disadvantage that it has a variable, dependent temperature of atmospheric temperature. Water coolers and condensers of recirculation are designed for the unfavourable case, taking the temperature initial flow of water 28. . . 30°C. Water heating is only allowed 10 ... 15°C, so that water losses by evaporation in the cooling tower not to be very large and for the deposits to be lower. It compensates permanently for these losses, adding to the circuit water, preferably softened or demineralized.

Well water, extracted from groundwater is richer and of relatively large depths, is more expensive and high flows cannot be secured. It has the advantage of a practically constant temperature, independent from atmospheric temperature, of the order of 14 ... 18 ° C. Direct cooling with river water or seawater is also less common. Seawater does not form layers of significant deposits, only in the case providing: a tube wall temperature below 70°C, heating, with only a few degrees and high speed of water circulation.

Air is use as a coolant, especially in coolers and condensers with air, with finned tubes, and at the water cooling towers. It has the disadvantage that its temperature is variable and also that forced circulation is expensive for coolers and condensers because of fans. In the design, for the air, an unfavorable temperature is taken (30... 32°C), allowing cooling in chillers and surface condensers up to about 50 ... 60°C.

The pressure at which a fractionation column works is dependent on the temperature provided in the peak capacitor, and thus the temperature of the coolant used in the condenser (with recirculation water can ensure in the condenser a temperature of about 40 ° C, and with water of well at a temperature of 30°C).

More advanced cooling, required in many cases, is provided with agent refrigerators. The refrigerants are individual substances (ammonia, propane, propylene, ethylene, Freon 12, Freon 22 etc.) in the liquid phase, which by heat absorption is vaporized isothermally at a pressure close to atmospheric pressure, so at a temperature close to normal boiling temperature (with propane a temperature can be achieved of about -35 ° C, and with ethylene of -95 ° C).

Intermediate thermal agents are sometimes also cooling thermal agents. Intermediate thermal agents are used in closed circuits or the field high temperatures, or the range of low temperatures. Also, and the raw materials are coolants relative to the effluents heat with which it exchanges heat or the water from which steam is generated through heat recovery.

There are two special examples of thermal cooling agents. Steam is used as a coolant in some pyrolysis plants, by injecting into reaction products with a temperature of 800 ... 850°C, evacuated from the oven; water is used as a coolant in carbon black installations, being injected and vaporized in the reaction products at a temperature of above 1000°C, to freeze reaction.

Intermediate thermal agents are used in closed circuits, transporting heat from a warmer flow to a colder flow and working in the field hot or refrigerated. In some refrigeration systems, vaporizing the refrigerant is cooling an intermediate thermal agent, used in the liquid phase, which is then use for various cooling or condensing at low temperatures. They are more common as intermediate heating agents, refrigerants, methanol (cooled with ethylene and used to separate paraxylene by crystallization), calcium chloride sole (cooled with ammonia and used in May many petrochemical plants and the manufacture of paraffin), oil, soles sodium chloride, diethylene glycol solution, etc.

Among the most commonly used intermediate thermal agents (agents that shows thermal stability at high working temperatures) are worth mentioning following: a eutectic mixture of biphenyl oxide and biphenyl (trade names: difil, dowthermA, thermex), the mixture of molten salts and, more recently, dibenzylbenzene mixture (usable between -15 and + 350°C).

Difil contains 73.5% mass of biphenyl oxide and 26.5% mass of biphenyl, has a solidification temperature 12°C and a normal boiling point 257°C and is used especially in the liquid phase up to 350°C. It is encountered as an intermediate agent in heat regeneration systems (air preheating in flue gas ovens), or in heat recovery systems (generation of steam with pyrolysis gases discharged from the furnace).

The commonly used eutectic mixture of molten salts consists of $KN0_3$ 53%, $NaN0_2$ 40% and $NaN0_3$ 7% mass and has a melting temperature 142°C. It is meets as an intermediate agent, for example, in the plant of maleic anhydride, for transporting the reaction heat from the reactor (reactor thermostat at 385°C) to a steam generator.

When heating and vaporizing liquid ethylene with a very low temperature, steam is used as a heating agent and as an intermediate agent, butane (it gives off heat at a relatively low temperature).

A.1.2. PRINCIPLES OF OBTAINING COLD AGENTS

In industry, through installations specific refrigerators that, consuming energy from the outside, make a heat transport from a cold source to a hot source, low temperatures are obtained. Installations refrigerators are of several types (with mechanical vapours compression, with absorption, ejection and gas), but in the majority of cases, refrigeration systems with mechanical vapours compression are used.

Energy management at the level of a petroleum refinery must also have an integrative vision on all the consumers of thermal energy within the processing plants and the available energy resources.

From the point of view of petroleum fuels, refineries are very advantageous because a large part of the necessary even in the technological installations is produced.

Throughout the refinery, the non-condensable gases resulting from the fractionation columns, are collected and managed.
If the refinery has an individual component separation plant in the processing scheme, with uses mainly as feedstocks for petrochemicals, then the use of refinery gases as fuels is limited and the refinery is forced to supplement its fuel needs by natural gas resources from the national network.
If refinery gases are not separated into components or mixtures with the required composition of certain users, then they are used as fuel in refinery furnaces, and the natural gas required to be taken from the national grid is much lower.
The composition of refinery gases consists of gaseous hydrocarbons in the normal state (C1 - C5), to which are added molecular hydrogen, hydrogen sulphide and some non-combustible components such as nitrogen, carbon dioxide and others, in varying amounts depending on the nature of crude oil processed in the refinery and the type of installations operating at a given time.
Liquid fuels are managed, also throughout the refinery, which is partially used in furnaces in technological installations, and the rest is sold to users, such as power and district heating plants (DHP), district heating plants (DH) and other industrial consumers, social or domestic.
Liquid fuels come from residues resulting from the processing of heavy liquid oil fractions. They are collected centrally and conditioned until the standardized qualities are obtained in terms of calorific value, viscosity at 50 and 100°C and freezing temperature.
The need and availability of liquid petroleum fuels are very variable depending on the season, the technologies available in the refinery and the type of crude oil processed.
Regarding the steam demand at the level of an oil refinery, its quantitative and qualitative assurance is made from two sources.
One, it is represented by external suppliers and the second is represented by the possibilities of internal production.
External suppliers are in most cases DHPs, which are usually located in the proximity of petroleum refineries. The refineries ensure the necessary steam of different qualities before processing from DHPs, 2, 3 qualities of extraction steam at high parameters, which subsequently, depending on the needs, transforms them to the necessary parameters in their laminated and cooling stations.
At the refinery, the second source of the steam is the own sources of generation. In the technological installations, there are two thermal resources from which steam can be obtained, in advantageous conditions, from a technical-economic point of view. One, it is represented by the flue gases from the furnaces and the second is represented by the oil fractions, usually liquid, with high temperatures. The process of obtaining steam from these resources with high thermal potential is defined heat recovery.
The qualities and flow rates of steam obtained from these resources depend on the temperatures and flow rates from which heat is recovered.

The decision to recover heat at the technological installations in the refineries is decided only if a feasibility study highlights the profitability of steam production in this sector, taking into account the technical and economic aspects related to investment and operating costs, including the cost of water treatment. steam is generated.
Because all refineries in Romania were built or upgrade until 1990, the principles that formed the basis of the design of the energy management system were not based on the laws of the market economy (competitive) but the laws of the socialist economy, with centralized coordination.
In the current conditions, when the law of supply and demand makes its presence felt, the price of energy is no longer managed by state bodies and has a marked upward trend.
In this situation, oil refineries, which consume a lot of energy, especially heat, tend to become energy independent, so that they no longer depend to the extent that they currently depend on steam and electricity generators.
Once the refineries achieve their energy independence, operating expenses will be reduced, by reducing the costs of thermal and electrical energy.

The road that a refinery has to go through to achieve a high degree of energy independence contains a series of stages that involve making investments, not infrequently very large, for making its own boilers to produce the steam needed for consumption.
Another aspect that consider into account, by the technical-economic management of the refineries, is the upgrading of the installations, which also involves the optimization of the heat transfer schemes.
The higher degree of heat regeneration between the hot and cold flows in a refinery, the lower need for externally purchased energy.
Currently, the global trend to increase energy independence in industrial units, which consume large amounts of heat and electricity, is the construction of cogeneration plants, which ensure the production of heat and electricity by burning petroleum fuel.
Along with changes in technological schemes, to achieve optimal degrees of regeneration and heat recovery, the construction of cogeneration plants in petroleum refineries are the most efficient solutions, corresponding to current technologies, to achieve a high degree of energy independence.

Pătraşcu , C., Termoenergetica prelucrării petrolului, Editura UPG – Ploieşti 2003. (Cap. I, Cap. II pâna la pag. 25)

Pătraşcu , C., Thermoenergetics of petroleum processing, Editura UPG, Ploieşti 2003. (Cap. I, Cap. II up to pg. 25)

STEAM

The most widely used thermal energy agent in the industry is steam. It has established itself in competition with other thermal agents due to the large number and importance of the advantages it has compared to the disadvantages.
Table 1 summarizes the main advantages and disadvantages of steam, used as a thermal agent in various industrial processes.

Table 1. Advantages and disadvantages of using steam

Advantages	1	Low cost due to the low cost of the water from which it is produced and due to the relatively accessible technologies.
	2	It does not present the danger of corrosion due to its inert character up to temperatures of the order of 500°C, above which the rate of decomposition reactions with oxygen formation becomes significant.
	3	No fuel.
	4	Not toxic.
	5	High-energy absorption capacity due to latent vaporization heat and high specific heat.
	6	High convection heat transfer coefficients due to high thermo physical properties compared to hydrocarbons from petroleum fractions or other thermal agents.
	7	Pipeline transport is done by lowering its own pressure. No pumping systems required.
Disadva ntages	8	Cannot be stored. The production and use of steam must be technologically coupled..
	9	High vapour pressure requires high temperatures to obtain.

	10	During transport, due the heat loss to the environment, the quality of steam degrade, so superheated steam turns in to dry saturated steam, and dry saturated steam to wet steam

The qualities of steam have made it usable in a very wide range of situations.
The classification of the uses of steam in the chemical industry, respectively in the field of crude oil processing and the energy field can be synthesized according to the scheme presented in figure 1.
Due to the very diverse conditions in which it can be found and due to the large number of uses, over time a large number of terms specific to different qualities of steam have been imposed.

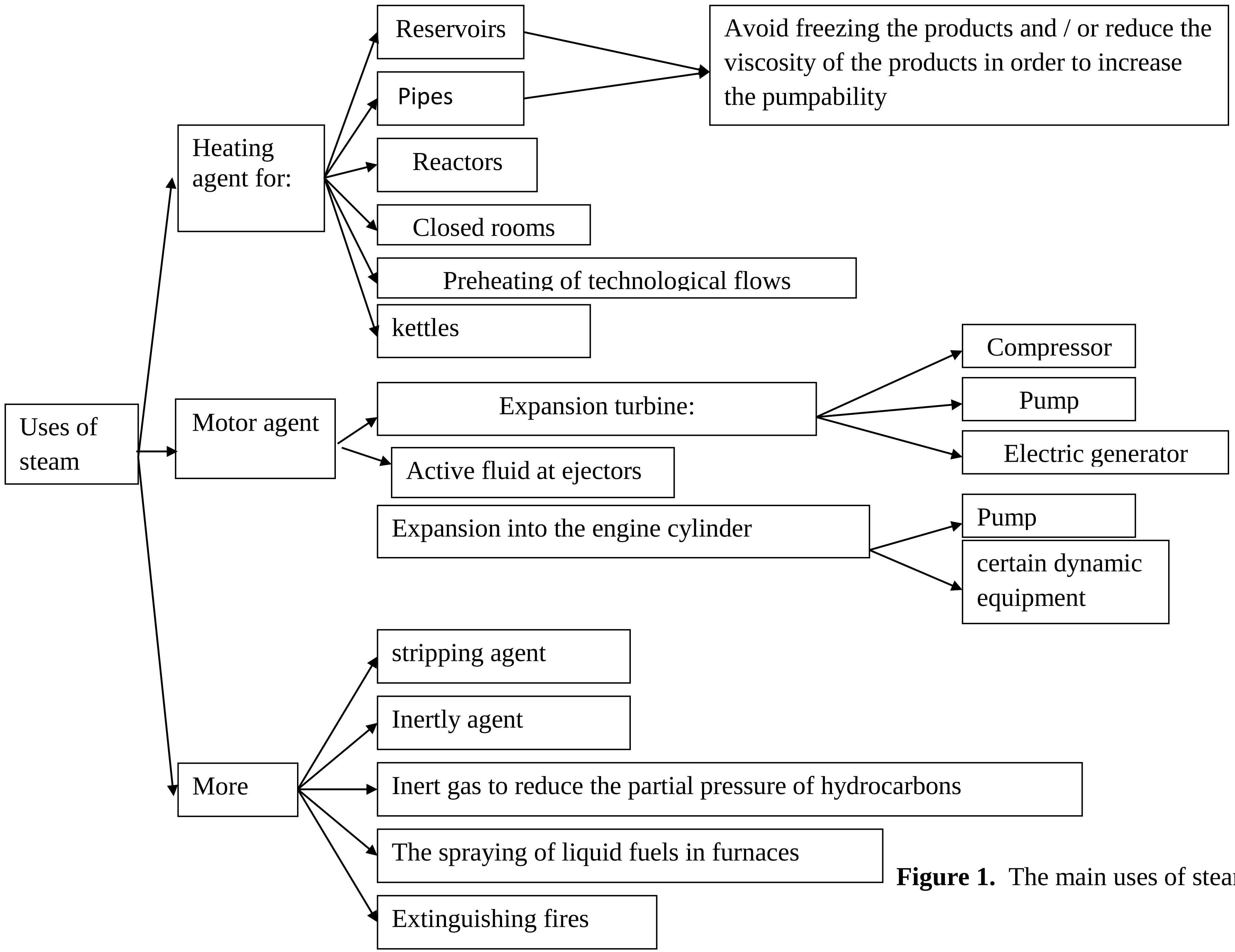


Figure 1. The main uses of steam

Listing these terms and defining them is useful in imposing an engineering rigor in communicating the correct information.
Table 2 presents the classifications established for the main types of steam used in industrial practice.

Table 2. Types of steam

<table>
<tr><th>Classification criterion</th><th colspan="2">Type of steam</th><th>The main state parameters</th></tr>
<tr><td rowspan="3">Temperature</td><td rowspan="2">Saturated steam</td><td>wet</td><td>$t = t_s$, $x \in (0,1)$</td></tr>
<tr><td>dry</td><td>$t = t_s$, $x=1$</td></tr>
<tr><td colspan="2">Superheated steam</td><td>$t > t_s$</td></tr>
<tr><td rowspan="3">Pressure</td><td colspan="2">Low pressure steam</td><td>P_s=1-12 bar; $t=t_s$-300°C</td></tr>
<tr><td colspan="2">Medium pressure steam</td><td>P_s=12-50 bar; $t=t_s$-450°C</td></tr>
<tr><td colspan="2">High pressure steam</td><td>P_s=50-370 bar; $t=t_s$-650°C</td></tr>
<tr><td rowspan="5">How to get</td><td colspan="3">Fresh steam (live or power generation steam)</td></tr>
<tr><td colspan="3">Used steam (dead, evacuated)</td></tr>
<tr><td colspan="3">Sampling steam (extraction steam)</td></tr>
<tr><td colspan="3">Laminated steam</td></tr>
<tr><td colspan="3">Waste steam</td></tr>
</table>

In Table 2 the different types of steam are characterized by the values of the state parameters:
- Temperature t compared to saturation temperature, ts,
- Dryness fraction, x, (mass fraction of vapours mixed with liquid water under steady state)
- Ps - saturation pressure.

Steam is obtained industrially by heating and vaporizing water at a certain pressure.
At higher pressure, the boiling temperature of the water is higher.

The steam at the temperature and pressure corresponding to vaporization is called SATURATED STEAM. If it is found in the presence of saturated liquid water, the system is called WET SATURATED STEAM.

The liquid water in the wet saturated steam can be evenly distributed throughout the mass of the steam in the form of larger and smaller droplets, or it can form a distinct phase of liquid mass in the presence of the saturated steam.

DRY SATURATED STEAM is the steam in equilibrium conditions (saturation temperature and pressure) in the absence of liquid water.

Dry saturated steam corresponds to a state on the dew point curve in the thermodynamic diagrams and can be obtained from wet saturated steam by mechanical separation of liquid water or by a heat input in the system, which represents the latent heat of vaporization of liquid water. .

Dry saturated steam can also be obtained from superheated steam by cooling to the condensing temperature corresponding to the pressure at which the thermodynamic system is located.

Dry saturated steam is in an unstable state because any change in temperature or pressure in the system moves it to the area of wet saturated steam or the area of overheated steam.

In industrial practice, another notion not used for dry saturated steam is used. It is called DRY SUPERSATURETED STEAM, considered as the limit state of transition from wet saturated steam with the title x=1 and superheated steam.

OVERHEATED or SUPERHEATED STEAM is steam that has a temperature higher than the saturation temperature corresponding to the pressure at which it is located.
The degree of overheating is defined as the difference between the temperature at which it is located and the saturation temperature corresponding to the pressure in the system.

$$\varphi_s = t - t_s \text{ , °C}$$

If the temperature of the superheated steam is lower than the critical temperature, t<374,15°C, the steam is considered in the vapour phase, and if the temperature is higher than the critical temperature, t > 374,15°C, the steam is considered in the gaseous phase and its behaviour tends to of ideal gas.

In table 2 is presented the classification of steam in terms of pressure is defined by three ranges of values, adopted by convention. Each of the three categories can be classified in terms of temperature into saturated steam and superheated steam.

Superheated low-pressure steam can be used for expansion in low-power turbines and in the engine cylinders of piston engines, which are still common in pumping heavy petroleum products.

From the point of view of energy efficiency, the use of this type of steam for expansion is not recommended, as medium and high-pressure steam is much more efficient.

Low pressure saturated steam is used mainly for heating, in virtually all variants shown in Figure 1.

Medium and high-pressure steam is used mainly to working high capacity turbines (tens to hundreds of MW) that working high capacity compressors or electric generators in district heating (DHP) power plants.

According to the way of obtaining, in Table 2 are presented five types of steam:

- FRESH STEAM (LIVE or POWER GENERATION STEAM), is the steam obtained from a generator and is not yet used in a technological process;
- USED STEAM (dead, evacuated) is the steam resulting from a process of expansion or heating;
- EXTRACTION STEAM (outlet steam) is generally the steam intended for use as a heating agent or other various uses and comes from engine steam that expands in a turbine. The system is founding especially in district heating plants (DHP) equipped with turbines in which steam with very high parameters expands at low pressures.

To obtain steam at certain values of the status parameters, place between the input and output parameters, the turbines equipped with adjustable sockets (equipped with pressure controllers) or change with the change of the turbine load to those with non-adjustable sockets.

The sampled steam pressure can be kept constant in turbines with adjustable outlets (equipped with pressure controllers) or changes with the turbine load to those with adjustable outlets.

The possibility of sampling steam from the turbines is very advantageous in terms of the flexibility of using steam as heating agent and as motor agent, with the possibility to change the weight of the two uses depending on demand.

Figure 2 shows the schematic diagram for a turbine that produces mechanical work at the shaft, Lt and from which two categories of extraction (outlet) steam are sampling.

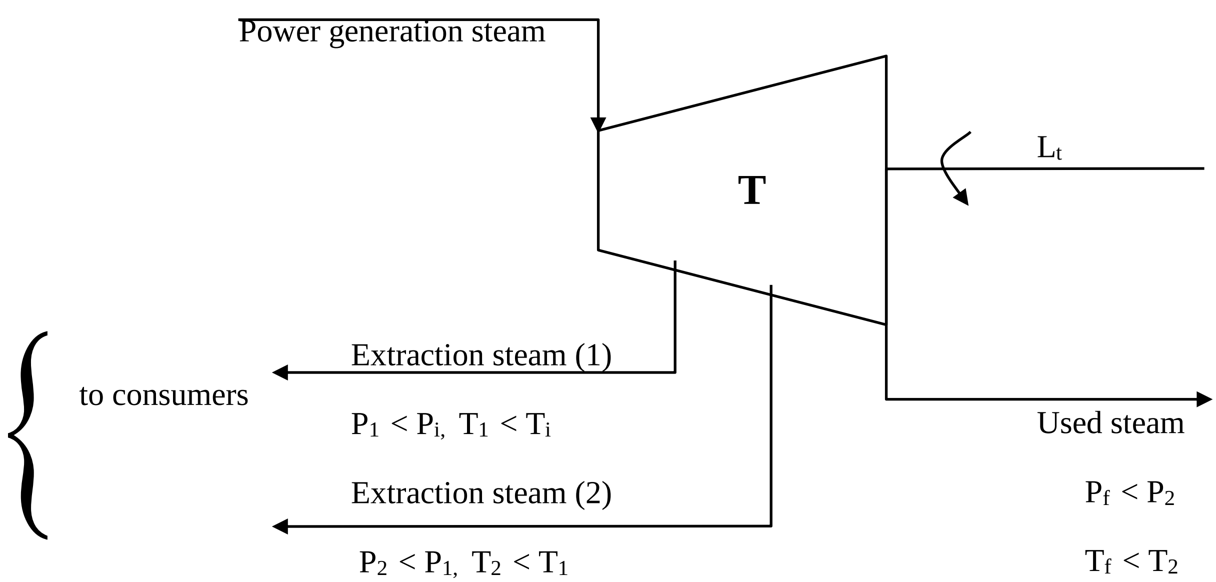


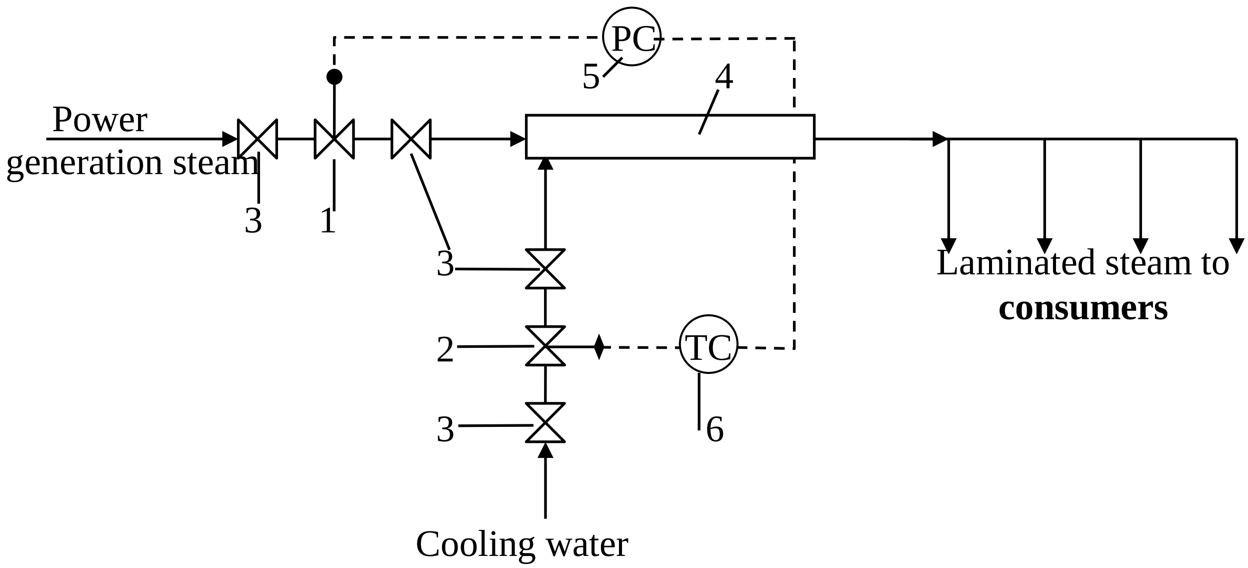
Figure 2. Schematic diagram of a turbine with two outlets of extraction steam

- LAMINATED STEAM is the steam obtained at a certain pressure from a steam with higher pressure by theoretically isenthalpic and adiabatic lamination.

From an energy point of view, the production of laminated steam is recommended because it does not produce a degradation of a steam with high parameters.

The justification for the use of laminated steam is given by the existence of certain consumers with strict requirements related to steam quality and the disposal of only steam with higher parameters than those required for consumption.

Figure 3 contains the principle diagram of a reduction - cooling station destined to obtain laminated steam, with certain imposed parameters, from a living steam with higher parameters.



1. Laminated Steam tap;
2. Flow control valve to cooling water;
3. Mechanical isolation valves;
4. Mixing chamber;
5. Pressure controller;
6. Temperature controller.

Figure 3. Diagram of a reduction - cooling installation

Valves for laminating are in various construction variants that allow the pressure to be reduced in steps.

If it is desired to obtain several qualities of laminated steam in parallel or if the steam flow to be laminated exceeds the maximum amount of a reducer (approximately 3 t/h) several valves can be mounted in parallel.

If the inlet-outlet pressure ratio exceeds values of the order of 15-20, it is necessary to install several valves in series.

- Table 2 also shows the WASTE STEAM category, which results in numerous technological processes as an unusable by-product, which poses problems based on removal from the installation and avoidance of environmental pollution.
In the delayed coking plant, significant amounts of waste steam are obtained when cooling the coke mass in the chambers, before drilling and hydraulic cutting.
Also in installations where there are still water coolers, such as submerged coil tubs, there are significant amounts of waste steam by surface vaporization.
In general, if the losses are economically significant, systems for recovering condensate from waste steam can be designed.

Characterization of water-steam systems

Due to the multiple applications in different fields, the water-steam system is the most studied and rigorously concretized thermal energy agent.
The values of the state parameters and the process parameters must be known exactly to be able to design and operate the thermal energy systems in conditions of optimization from a technical-economic point of view.
The thermo-energetic properties of the water-steam system are accessible in three variants, partially overlapping, being partially specific and highlighting certain particular aspects.
The first variant is that of CALCULATION RELATIONS for thermos physical properties.
The main advantage of this variant is that it allows easy use in computer programs. The accuracy of the calculations using analytical relations is that of the accuracy of the recurrence relations deduced based on the experimental values.
The second variant through which the values of the state parameters can be obtained is that of the TEMRODYNAMIC TABLES, accessible in numerous specialized works. The advantage of tables is that they can include experimental values or values obtained from the primary processing of experimental data.
The third way of obtaining the parameters is the state and highlighting the transformations that the water-steam system goes through is that of THERMODYNAMIC DIAGRAMS.
Disadvantageous by the inaccuracy of objective readings on graphs, thermodynamic diagrams have the great advantage of capturing the behaviour of the water-steam system during thermodynamic transformations.