BEST PRACTICE NO. 61

INVENO ENGINEERING LLC

# » THE DIFFERENT NAMES AND TERMINOLOGY FOR STEAM

Today, many different terms or names are used to describe steam in different applications and industries. This different nomenclature can be confusing, and sometimes the steam is not being described correctly or being used in the correct applications.

Any steam application outside the utility steam applications should follow your company's policies and the rules and regulations of any governing agency or organization.

## 1. UTILITY STEAM (LIVE STEAM, PLANT STEAM)

There are several reasons that plants vent steam to the atmosphere. However, with modifications using today's technology, steam and condensate systems do not need to vent steam.

Utility steam is sometimes called "live steam" or "plant steam." It is steam produced from the boiler operation using softened water, reverse osmosis, or water that has had some type of preparation for the boiler.
Utility steam is the majority of the steam consumed by industrial process applications. Utility steam is a dry and invisible fluid that contains both sensible and latent energy that can be provided to the process as saturated or superheated steam.

*Figure 1: Standard Utility Boiler*

The latent and sensible energy component of the steam will vary depending on steam pressure and temperature. The only chemical transported with the steam is a corrosion inhibit (amine), which is injected in the steam line. Otherwise, utility steam is a clean, invisible vapor that contains a tremendous amount of energy.

"Live steam" and "plant steam" are other terms often used for utility steam depending on the facility, industry, or region, but they all mean the same thing: water that is heated in a boiler to produce steam by using water that has been prepared for an industrial boiler.

## 2. SATURATED STEAM (DRY STEAM)

Saturated steam is a state that steam can achieve with certain heating parameters. This saturated steam results from water being heated to a boiling point; more heat is then added until the steam vaporizes (latent heat of vaporization). Saturated steam occurs when both the liquid and the gas phases are present at the temperature and pressure.

Saturated heat has properties that give saturated steam many advantages over superheated steam: rapid, even heating throughout the heat transfer; the ability to control temperature through pressure; and a high heat transfer coefficient. In particular, this high coefficient is why heat exchangers primarily use saturated steam instead of superheated steam.

## 3. SUPERHEATED STEAM

Superheated steam is created by the process of continually heating the saturated steam until it is heated beyond the saturated steam point, thus increasing the steam temperature without increasing the temperature. This is called superheated steam.

The properties of superheated steam include having a higher temperature and lower density than saturated steam at the same pressure.

Superheated steam is used in a variety of ways due to its ability to cool and still retain the same state and not produce condensate. These properties make superheated steam crucial in the ability to power devices such as turbines. Steam turbines take the superheated steam and use it to flow through nozzles and spin the internal components of a turbine, which power a shaft that can be used to generate electricity or power process equipment. However, the turbine process lowers the pressure of the steam and reduces its temperature slightly. Then, the advantage of using superheated steam in this application is that it will remain ultra-dry steam through the steam turbine without forming condensate, which could cause premature failures in the turbine.

Superheated steam does have disadvantages: a low heat transfer coefficient, variable steam temperatures at constant pressures, and more expensive steam components due to the higher temperatures. Also, the vast amount of latent energy cannot be released until the steam achieves saturated conditions. Therefore, there is no superheat in the steam.

## 4. FLASH STEAM

Flash steam is the production of steam when high-pressure and high-temperature condensate is discharged to a lower-pressure system. The condensate is at the same pressure and temperature as the steam in the process; therefore, when the condensate is exposed to a lower pressure, it has more energy than it can contain at the lower pressure. The additional energy of the higher temperature condensate is energy released into the vapor or flash steam (latent heat of vaporization). The flash steam is no different from utility steam (energy or quality). The name "flash steam" just describes how the steam is formed. Flash steam is always reused in different processes to use the energy.

*Figure 2: . Flash Steam and Condensate Discharging From a Steam Trap Test Station*

## 5. STEAM QUALITY (WET STEAM)

Steam quality is the proportion of saturated steam (vapor) in a saturated condensate (liquid)/steam (vapor) mixture. A steam quality of 0 indicates 100 % liquid, (condensate) while a steam quality of 100 indicates 100% steam. One (1) lb of steam with 95 % steam and 5 % percent of liquid entrainment has a steam quality of 0.95.

The measurements needed to obtain a steam quality measurement are temperature, pressure, and entrained liquid content. A high percentage (88 % or more) of industrial steam systems use saturated steam for process applications. Saturated steam (meaning steam that is saturated with energy) is completely gaseous and contains no liquid.

When steam is less than 100%, plants do refer to this as wet steam. However, the true terminology is low steam quality and understanding the steam quality measurement.

## 6. CULINARY STEAM

Culinary steam is steam directly injected into products to clean or sterilize product contact surfaces in the food industry. The steam must follow 3-A Sanitary Standards, Inc. (SSI) Accepted Practice 3A-609-03, corporate policies, or the regulations or rules of any other governing organization.

Culinary steam typically contains additives that prevent corrosion within the steam system. The steam is filtered to ensure that no corrosion or other contaminants enter the process. After any filtration is installed, all steam components and piping/tubing need to be stainless steel. Coalescing steam filters that are used before the process or contact with product can remove excess condensate, particles of rust, pipe scale, and other contaminants as small

as 0.1 µm to an efficiency of 98%.
Any chemical additives injected into the steam line for corrosion inhibitors must meet all applicable FDA and USDA requirements. The benefit of culinary steam over pure steam or clean steam is that it is more economical to produce and provide to the process. Culinary steam does require yearly or semiyearly maintenance on the filtration system.

*Figure 3: Culinary Steam Filter: Donaldson Filtration Solutions*

## 7. FILTERED STEAM

Filtered steam is used for applications, such as sterilization, where any contamination can negatively affect the final product or process. Utility steam has to be delivered through a strainer and then filtered to remove impurities, such as rust, corrosion materials, and condensate, that could be in the steam piping and become entrained in the steam flow. The steam filter must be capable of removing particle sizes as dictated by the company standards or governing rules or regulations. For example, hospital sterilizers must comply with ANSI/AAMI–ST 8: 2013.

After the steam is filtered, all downstream steam components and piping/tubing should be stainless steel.

## 8. PURE STEAM/CLEAN STEAM

In the world of steam systems, the expressions "pure steam" and "clean steam" are used repeatedly, but it is seldom clear

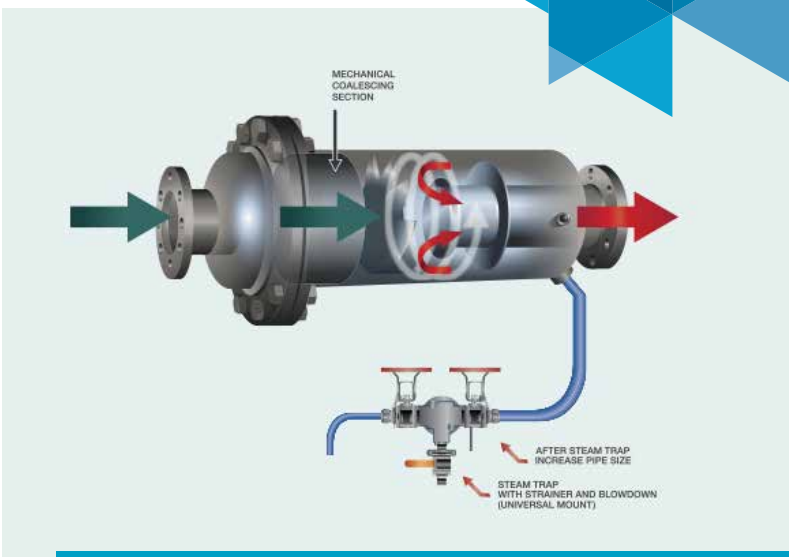


*Figure 4: Mechanical Coalescing Filtration*

whether these two expressions mean the same thing. Indeed, it is not simple to answer this question. Good manufacturing practices (GMPs) often use the term "clean steam" without any further explanation. The steam's quality is defined by its use, and its quality is regulated in standards and pharmacopoeias (see the next section).

For now, here is a general definition: pure or clean steam does not contain any additives and is created by heating specific purified water through a specific steam generator (pure/clean steam generator) to produce a high-quality steam that is free of any chemicals or additives. The water source can be one of the following:

- purified water (PW),
- highly purified water (HPW), or
- water for injection (WFI).

The most common steam specification requires the condensate to satisfy WFI requirements for conductivity, total organic carbon (TOC), and endotoxin and is referred to as "pure steam." (The microbial limit is normally excluded, as viable microorganisms cannot survive in steam systems.) When to use clean and pure steam is determined by GMPs. These are general rules applicable to pharmaceutical manufacture and are detailed in the Code of Federal Regulations (CFR Title 21, Part 211). They do not provide any specific recommendations regarding steam, but they do present general requirements for facility systems, equipment, and operation needed to prevent contamination of pharmaceutical products during manufacturing.

The quality of this steam is defined by its condensate, which must have WFI quality. The steam quality is applied for the sterilization of primary packaging material for sterile dosage forms or for the sterilization of equipment parts in contact with the product during sterile production, for example.

### 8.1. Applicable Standards

The qualities at the point of use are regulated in the different international pharmacopeias. The United States Pharmacopoeia (USP) is the organization that first published the requirements for pure steam back in 2006[1]. Another publication, the European Pharmacopoeia, maintains that distillation is the only acceptable way to produce WFI. Although some pharmacopeias allow alternative production technologies, distillation is the technology of choice and the industry standard for generating WFI. Additionally, ANSI/AAMI defines a steam quality that is used for the sterilization of goods that are not in direct contact with the product or for the sterilization of parenterals in closed containers. The steam is called "sterilization steam."

In contrast to the steam described in the pharmacopoeia, the maximum for the conductivity of the condensate in the ANSI/AAMI standards is 10 µm/cm, above the limit of WFI.

The ANSI/AAMI standards also indicate a limit for noncondensable gases. The USP similarly mentions noncondensable gases but without any specifications. Noncondensable gases can cause the occurrence of gas bubbles in areas that are difficult to access, where they prevent the steam from heating to the temperature required for sterilization. The presence of each gas means that you have to calculate pressures differently: the total pressure of mixed gases consists of the partial pressures that each gas or vapor exerts.

### 8.2. How Pure/Clean Steam Is Used

Clean steam and pure steam are used in the pharmaceutical and healthcare industries in processes where the steam or its condensate can come into contact with the pharmaceutical or medical product and cause contamination.

Keep the following points in mind:

- Steam from a conventual boiler (utility steam) is unsuitable for pharmaceutical and medical applications because it contains boiler additives, rust, or other undesirable materials.

- Pure steam is often used to produce organic products, including food, that restrict usage of chemicals and additives; it is also required for most pharmaceutical products and healthcare industries that require the usage of steam. Other uses of pure steam include autoclaves, sterilizers, and humidification of air conditioners for ventilation of clean rooms.

- Pure steam is used in products that have strict endotoxin limitations and is required for end products, such as injectables and intravenous products.

- A specification for clean steam may be based on the PW specification insofar as the chemical composition (TOC and conductivity). This would be appropriate in facilities producing products that must be sterile but where endotoxin in the final product is not a concern. An example of this would be noninjectables.

- For biopharmaceutical companies that are not operating within FDA standards, these guidelines do not apply, and many installations use clean steam applications where pure steam should be used. An FDA-approved site should use pure steam for the humidification of critical areas and either pure or clean steam for noncritical applications. Non-FDA sites may use clean steam for humidification.

[1] The USP is a nonprofit scientific organization that develops and disseminates public compendiums of quality standards for medicines and other products. The USP has no role in enforcement; that is left to the FDA and other government authorities in the U.S. and elsewhere.