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Food and beverage

best practice guide to managing steam quality

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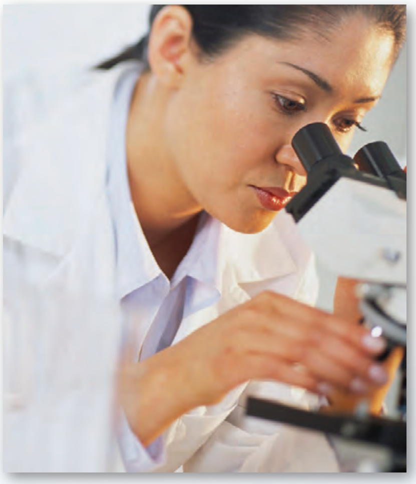

Foreword

By John Holah, Campden BRI

Campden BRI, with offices in the UK and Hungary, is the worlds largest independent membership-based organisation carrying out research and development for the food and drinks industry worldwide. It is committed to providing industry with the research, technical and advisory services needed to ensure product safety and quality, process efficiency and product and process innovation.

With respect to this guidance document, Campden BRI has a long history of providing services in which the use of steam is paramount. These include heat transfer processes (e.g. blanching, canning, aseptic) and their validation and hygienic factory and equipment design and their hygienic maintenance including cleaning and disinfection.

Steam is an essential service in many parts of the food industry, primarily as a source of heat for food product or equipment decontamination. The hygienic quality of the steam, particularly if it comes into direct contact with food product or food contact surfaces, is critical. Consequently all necessary measures should be undertaken in the specification, design, installation, control and maintenance of steam production systems to ensure that the steam used is of the appropriate hygienic quality.

The principles outlined in this document, which are supported by Campden BRI, will - if followed correctly - help food manufacturers to minimise the risk of product contamination from this source.

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1. Executive summary

Steam is the most energy efficient, reliable and flexible way to transfer heat for many food and beverage operations. Steam is routinely used in direct contact with food products, but this can raise quality or even food safety issues if the correct standard of steam is not used. Food and beverage manufacturers should therefore take pains to identify and control the quality/purity of their steam systems to avoid any potential risk of product contamination.

There is little current legislation focusing on the quality of steam in direct contact with food products/processes. However, the same Hazard Analysis Critical Control Points (HACCP) that manufacturers use to manage their processes can equally be applied to steam systems, to ensure the correct standard of steam is used.

There are several grades of steam that are commonly in use, in food processing, each offering very different levels of contamination risk:

Plant steam is the lowest grade of steam and therefore has the highest risk of potential contamination. The levels of contamination arising from using plant steam are determined by the following factors:

- The quality of raw water entering the boiler.
- The level of chemicals being dosed into the system and adherence to a water treatment management programme.
- The correct operation of the boiler, i.e. boiler loading, level controls, TDS control and operating pressure, etc.
- Cross contamination from other processes.

Filtered steam, also known as culinary steam, is plant steam that has passed through a fine stainless steel filter, typically of five microns pore size. The potential risk of contamination from boiler water treatment chemicals and cross contamination still remains when using a culinary filter. The amount of contamination that finds its way past the filter will depend upon the severity of the problem, the nature of the maintenance regime and the velocity of the steam.

Clean steam is the highest grade of steam for food and beverage applications and is typically raised from purified water in a dedicated clean steam generator. Clean steam should be considered for quality-critical processes.

Pure steam is the pharmaceutical industry's development of clean steam. The quality and purity of pure steam is in excess of that required for the food and beverage industry today.

This guide looks at the differences between plant, filtered and clean steam and the various issues that affect their quality and purity. It summarises the best practices in steam system design, operation and maintenance that will help keep any steam system running at optimum efficiency and more importantly prevent contamination problems from occurring in the future.

2. Introduction

Steam's flexible characteristics provide endless possibilities to cook, sterilise, humidify, dry and generally heat thousands of applications within the food and beverage process industry.

Steam is used extensively throughout the production, processing, handling and packaging of many food and beverage products and is very often in direct contact with the product. See Appendix 1 for a list of some typical applications where steam is used in direct contact with the product / process.

Steam is often seen as an ideal sterile and contaminant-free source of energy. As is the case with any medium that is in contact with the process, precautions should be taken to minimise the potential risk of contamination occurring, which could be a hazard to human consumption or potentially affect the taint or colour of the product.

Food and beverage manufacturers are legally bound to ensure the quality of the final product by identifying potential hazards and controlling them, typically by using a HACCP approach. The current lack of legislation or guidance governing the quality and purity of steam, therefore means manufacturers should be vigilant in ensuring suitable controls are established and adhered to. Within a HACCP context, steam quality and safety could be described as a HACCP prerequisite or, if the steam is added directly into the product, as a stage in the food production process.

This best practice guide sets out to offer guidance in the following areas relating to steam quality / purity within the food and beverage sector:

- The various grades of steam quality available to users and how these are achieved.
- Potential sources of contamination arising from the use of an inappropriate grade of steam.
- Best practice in the design, maintenance and testing of steam systems to ensure the correct quality / purity of steam reaches the process.

2.1 Scope

This publication does not cover the use of pure steam, since this is not used within the food and beverage industry.

Recommendations are given on the type and operation of equipment to be used within the complete steam and condensate system.

Maintenance activities required to maintain the performance of the steam system are identified.

Measurement and testing procedures to verify the quality/purity of the steam system are identified.

2.2 Commonly referred to regulations

There are many standards, guidelines and legislations in place to ensure the safe production of food. However, little regulation currently exists (particularly within Europe), that provides specific guidelines on the quality and purity of steam when in direct contact with the process or the product. The regulations that are commonly referred to are detailed below:

- UK:
  - S.I. 2006 No. 14 - The Food Hygiene (England) Regulation.
  - Guidelines for the Safe Production of Heat Preserved Food – Department of Health.
- Europe:
  - Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. (Chapter VII, Section 5).
  - Codex Alimentarious.
  - European Hygienic Engineering and Design Guidelines (EHEDG).
  - Regulation (EC) No 1935/2004 of the European Parliament and the Council of 27 October 2004 on materials and articles intended to come in contact with food and repeating Directives 80/590/EEC and 89/109/EEC.
- USA:
  - 3-A Accepted Practices for A Method of Producing Culinary Steam, Number 609-03.
  - FDA Code of Federal Regulations, 173.310, Title 21, Volume 3, Revised as of April 1, 2005.
  - National Organic Standards Board (NOSB), Steam Generation in Organic Food Processing Systems TAP Review.
- International:
  - PAS 220 Prerequisite programmes in food safety for food manufacturing.

3. Steam grade definitions

When using steam it is important for any organisation to ask itself "do we really understand the quality and purity of steam entering the process?". To answer this, it is first necessary to understand the four grades of steam commonly used in industry today, and how they are ranked in their purity:

1. Plant steam 2. Filtered steam (culinary steam) 3. Clean steam 4. Pure steam

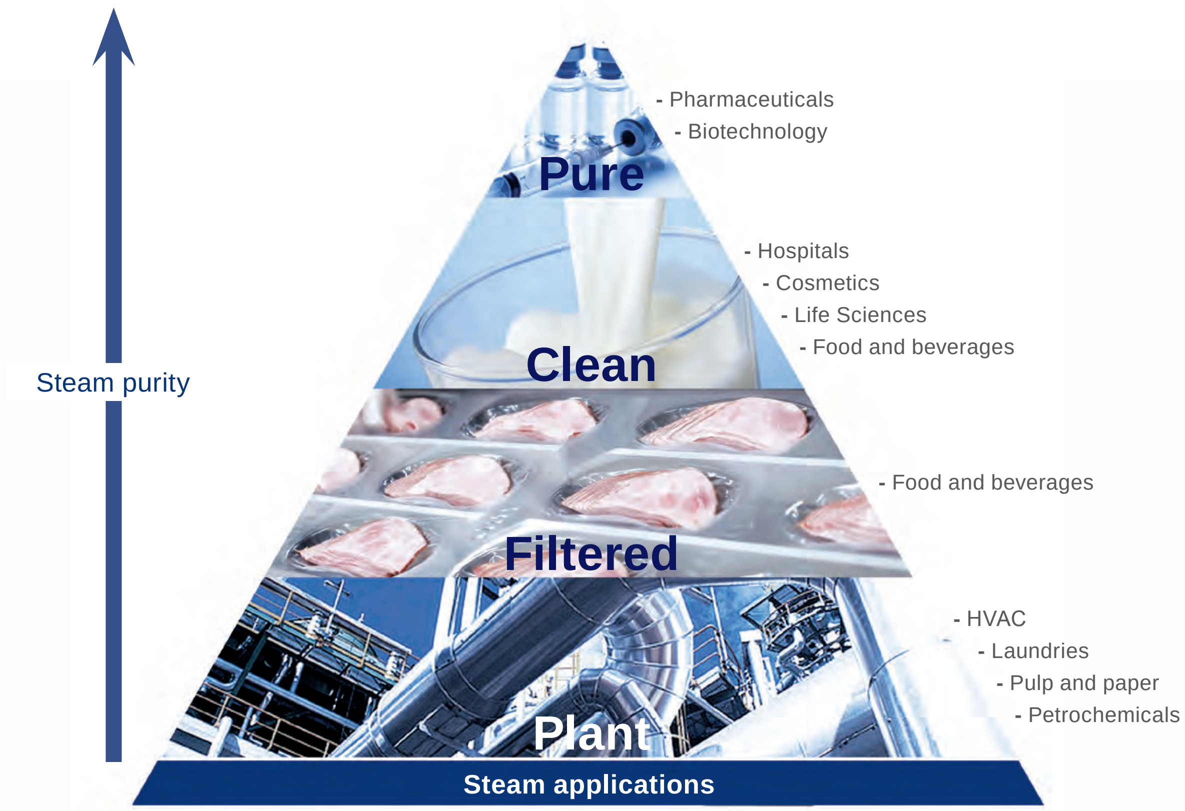


Figure 1: Steam grades and their market applications

Details of how the above grades of steam are generated, and the potential issues with each are covered in the following Sections of this guide. The following definitions may help in clarifying some of the terminology used in relation to steam.

3.1 Steam quality

Steam quality is a term used regarding steam systems. In this context the word quality commonly refers only to the amount of water in the steam and not any other contaminants. A more correct term is dryness fraction.

The dryness fraction of steam is defined using the following ratio:

$$\text{Dryness fraction} = \frac{\text{Mass of steam}}{\text{Mass of steam + Entrained water}}$$

3.2 Steam purity

Steam purity is a quantitative measure of the dissolved solids, volatiles or other particles in the vapour that may remain in the steam following primary separation in the boiler.

The following Sections provide further details on the characteristics of each grade of steam, and which critical points should be controlled to minimise the risk of contamination.

4. Plant steam

Plant steam, or industrial steam as it is sometimes known, is the starting point for all grades of steam used within food and beverage processing. Plant steam is certainly fit for purpose for all applications where it is not in direct contact with the process or the food/drink product, e.g. when used within heat exchangers, boiling pans or for hot water generation, etc. When used in direct contact with the process, consideration should be given to the quality/purity of the steam entering the process.

Plant steam is typically produced using either softened water, de-alkalisation or reverse osmosis (RO) water, which is then pre-heated and chemically treated to prevent corrosion and scale occurring within the system. Plant steam should be available at the point of use in the correct quantity, at the correct pressure, clean, dry and free from air and other incondensable gases.

Where possible the condensate (produced as a result of the steam giving up its latent heat), should always be returned to the boiler for re-use, since this allows valuable energy, water and chemicals to be re-used.

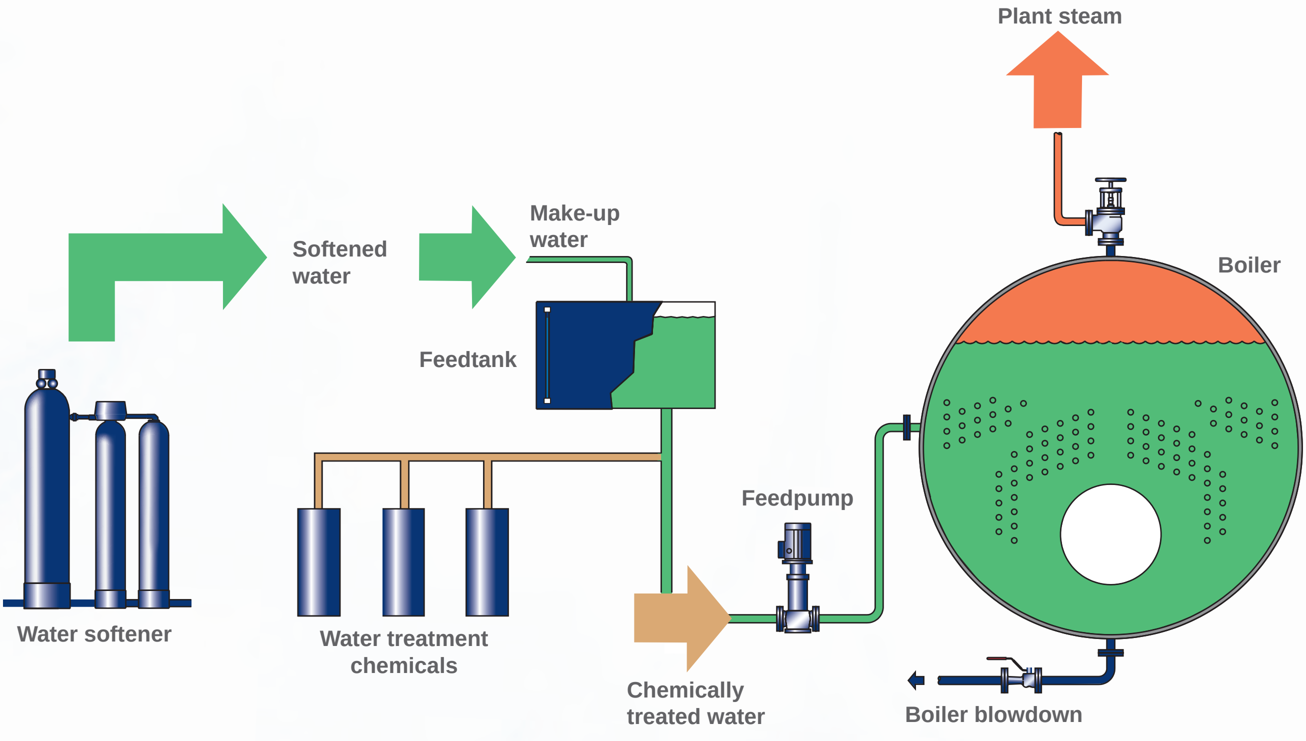


Figure 2: Plant steam generation

4.1 Plant steam contaminants

When plant steam is produced there are many factors that potentially affect the quality and purity of steam up until its point of use at the process. The following Sections detail the critical points that should be controlled to minimise the potential risks of contamination.

4.1.1 Chemical

The quality of the water used to produce plant steam will have a profound effect on the efficiency and safe operation of the boiler and steam distribution system. In addition to the elements that are present in the raw water as it enters the steam cycle, various chemicals are added to the boiler feedwater in order to reduce the effect of scale, corrosion and chemical attack within the system.

Appendix 2 details a typical list of chemicals, which are generally added to the feedwater as part of a water treatment programme.

Appendix 3 details a list of chemicals that are approved (by the FDA - USA) for use with food and beverage products and the acceptable levels of concentrations for each chemical.

4.1.1.1 Guidelines and Legislation

The chemicals that are added to the boiler water should adhere to a strict chemical treatment programme. BS 2486: 1997 and BS EN 12953 –10 2003 are examples of UK and European Practices providing guidance on water treatment. Deviation from such practices can result in excessive chemicals entering the steam system, which in turn can result in severe fluctuations in the quality / purity of steam entering the process. Conversely, insufficient chemical dosing can result in excessive corrosion and scale within the steam and condensate system.

UK / Europe: There are no standards currently in place that control both the type of chemicals (e.g. food approved or not), or the quantity of boiler chemicals that have the potential to enter the food process through the steam system. Since steam quality checks are often not put in place, the types of chemicals (food approved or not) and their concentration levels within the steam often remain unknown.

When using plant steam in direct contact with the process, boiler treatment chemicals that are not food approved (e.g. non-FDA approved) should not be used! Non-approved chemicals used and found within the steam can potentially contaminate any foodstuff in contact with the steam. The residual compounds of these chemicals may be long lasting. Regular steam quality checks (detailed in Section 4.2.2) should be carried out to ensure both the quality and purity is maintained at an acceptable level for the process.

Whilst FDA regulations are not recognised in Europe, chemicals approved to FDA standard are widely used in the food and beverage industry throughout Europe.

Some food / beverage manufacturers are now stipulating that any 'steam products' (e.g. pressure regulation valves) that are supplying steam, which is either in direct contact with the food / beverage product, should be certified to EC 1935 / 2004 (materials in contact with food). The principle underlying this Regulation is that any material or article intended to come in contact directly or indirectly with food must be sufficiently inert to preclude contamination of the food.

Although the implementation of EC 1935 / 2004 will prevent any material or article within the steam system from contaminating the process, there is possibly a much higher risk of contamination occurring in the steam itself, if quality control measures are not correctly implemented and controlled.

USA: In the event that FDA approved chemicals are used, the levels of chemicals in contact with the product / process should be controlled, in line with FDA, Code of Federal Regulation, Title 21, Volume 3, Section 173.310, boiler water additives. Note that this regulation details specific limits for the amount of boiler chemicals in the 'steam' (as a vapour) in contact with the product / process. It is important to note that zero limits are set for boiler water (carryover), which will contain considerable concentration levels of chemicals. Although the FDA set down clear limits relating to the concentrations of chemicals that should be present, the frequency and testing method for checking these levels needs to be considered.

The following paragraph is an extract from the FDA regulation controlling feedwater chemicals: 'Boiler water additives may be safely used in the preparation of steam that will contact food, under the following conditions: (a) The amount of additive is not in excess of that required for its functional purpose, and the amount of steam in contact with food does not exceed that required to produce the intended effect in or on the food…….' (see Appendix 3 for further detail).

International: PAS 220, 'Prerequisite programmes in food safety for food manufacturing' is intended to be used in conjunction with ISO 22000, the internationally recognised standard for food safety management systems. Section 6.3 within PAS 220 states that boiler chemicals, if used, shall be either:

a) Approved food additives which meet relevant additive specifications.

b) Additives which have been approved by the relevant regulatory authority as safe for use in water intended for human consumption.

4.1.2 Boiler carryover

It is **important to note that boiler carryover is not steam** and contains potentially high levels of boiler water treatment chemicals in the form of foam and entrained water that are drawn into the steam system. To see video footage of carryover taking place in a boiler please refer to the following web link:

http://www.spiraxsarco.com/industries/food-and-beverage/how-clean-is-your-steam.asp

Carryover can be caused by two factors:

- Priming - This is the sudden draw off of boiler water into the steam off-take and is generally due to one or more of the following:
  - Incorrect selection, installation, maintenance of raw water pre-treatment plant e.g: water softener
  - Operating the boiler with an excessively high water level.
  - Operating the boiler below its design pressure, increasing the volume and the velocity of the steam released from the water surface.
  - Sudden, excessive steam demand.
- Foaming - This is the formation of foam in the space between the water surface and the steam off-take. To see video footage of foaming taking place in a boiler please refer to the following web link:
  http://www.spiraxsarco.com/industries/food-and-beverage/how-clean-is-your-steam.asp

  The greater the amount of foaming, the greater the problems experienced. Foaming is generally due to one or more of the following:
  - High levels of Total Dissolved Solids (TDS) in the boiler.
  - Excess water treatment chemicals, i.e. non adherence to a water treatment programme.
  - Contamination of boiler water from other areas of the process.
  - High alkalinity (>1000 ppm).

4.1.3 Cross contamination

Most food and beverage manufacturers will return condensate from as many areas of the plant as possible, in order to reduce energy, water and chemical consumption. As the steam / condensate travels around the system it may well be subject to cross-contamination from other potential sources:

- **Clean-In-Place (CIP)**: Steam is often used in the generation of hot water for CIP. If pin holes or cracking occur within the CIP heat exchanger, this can potentially lead to contamination of the condensate system, (i.e. caustic, detergent, etc.) which in turn will contaminate the steam used in direct contact with the product or process.

- **Process**: The list of potential sources of contamination from various process applications is extensive. Attention should therefore be focussed toward areas where steam or condensate could potentially be contaminated from the process itself, e.g: plate heat exchangers.

4.1.3.1 Guidelines and Legislation

Neither EU nor US legislation deal with the potential risks associated with cross contamination from other sources. This is a real issue that can occur and if not checked for, can remain undetected for considerable lengths of time. Contamination detection equipment fitted in the condensate return system will provide an early warning of any potential problems (see Section 4.2.2).

4.1.4 Particulates

Adherence to an approved water treatment programme will minimise the potential effects of scale and corrosion around the steam and condensate system. Carbon dioxide and oxygen in particular can cause severe corrosion of steam / condensate pipework and boilers. Resultant corrosion products can precipitate forming deposits that can contaminate steam supplies and any area where steam may be used.

Scale deposits

Boiler tube scale, showing calcium carbonate, layered calcium carbonate and precipitation on the surface of a shell and tube boiler.

Corrosion

Oxygen corrosion shown in a steam condensate pipe. This can occur in a relatively short period of time.

4.1.5 Non-condensable gases

Oxygen, ammonia, carbon dioxide and other gases dissolved in feedwater or introduced by other means, may produce undesirable effects in the steam system (i.e. corrosion, reduced heat transfer, etc). These gases should be controlled within acceptable limits with a water treatment programme and correctly positioned air / gas venting devices around the steam system.

Carbon dioxide and oxygen in particular can cause severe corrosion of steam / condensate pipework and boilers. Resultant corrosion products can precipitate forming deposits that can contaminate steam supplies and any area that steam may be used.

4.2 Corrective action

4.2.1 Corrective action against boiler carryover and poor water treatment

The following are preventative measures to minimise the potential risk of boiler carryover:

- Operation - Smooth boiler operation is important. With a boiler operating under constant load and within its design parameters, the amount of entrained moisture carried over within steam should be less than 2%.

  If load changes are rapid and of large magnitude, the pressure in the boiler can drop considerably, initiating extremely turbulent conditions as the contents of the boiler flashes to steam. To make matters worse, the reduction in pressure also means that the specific volume of the steam is increased, and the foam bubbles are proportionally larger. This can result in significant amounts of water being drawn off into the steam system. In addition to potential process contamination issues, the dryness fraction of the steam will have a considerable impact on heat transfer.

  Low boiler feedwater temperature (<80°C) will exacerbate the problem by suppressing the boiling rate, leading to a further drop in pressure. It will also increase the levels of oxygen entering the steam and condensate system.

  If the plant conditions are such that substantial changes in load are normal, it may be prudent to consider the following:

  - Modulating boiler water level controls if on / off boiler controls are currently fitted.
  - Further enhancements to modulating controls can be made by linking them directly to a steam flowmeter, enabling the boiler to react directly to the steam demand, rather than wait for a resultant drop in boiler water level.
  - 'Surplussing controls' will limit the level to which the boiler pressure is allowed to drop.
  - A steam accumulator.
  - 'Slow-opening' controls that will bring plant on-line over a pre-determined period.
  - Steam 'banking', where steam is held in boilers operating on stand-by.
  - Boiler sequencing.

- Chemical control - The control of chemical dosage into the boiler should be in line with a boiler water treatment programme and should 'not be in excess of that required for its functional purpose,..........'
  (as detailed in FDA Regulations Appendix 3).

- Control of TDS - TDS control limits should be kept in line with water treatment guideline recommendations and at levels that minimise the effect of foaming. Automatic TDS control systems should be used to maintain the boiler at its optimum guideline limit.

- Condensate testing - Condensate and steam sampling should be carried out regularly and the sample tested to ensure the water treatment programme is running correctly. Samples should be taken from the condensate outlet of the steam separator fitted immediately before the process application where the steam is being used. Steam samples should be taken through a sample cooler, fitted immediately prior to the process application (Figure 4, page 14, illustrates a typical sample cooler layout, fitted after a culinary steam filter). Since boiler carryover is dependant upon many different factors, intermittent testing may not always identify if / when carryover is taking place.

4.2.2 Corrective action against cross contamination

Cross contamination of the steam system from other sources can take place at any time and therefore should be monitored on a constant basis. Condensate Contamination Detection (CCD) Systems can be installed to monitor the condition of the condensate being returned to the boiler. The schematic (Figure 3) illustrates a typical example of a CCD system, which should be installed on the main condensate return line.

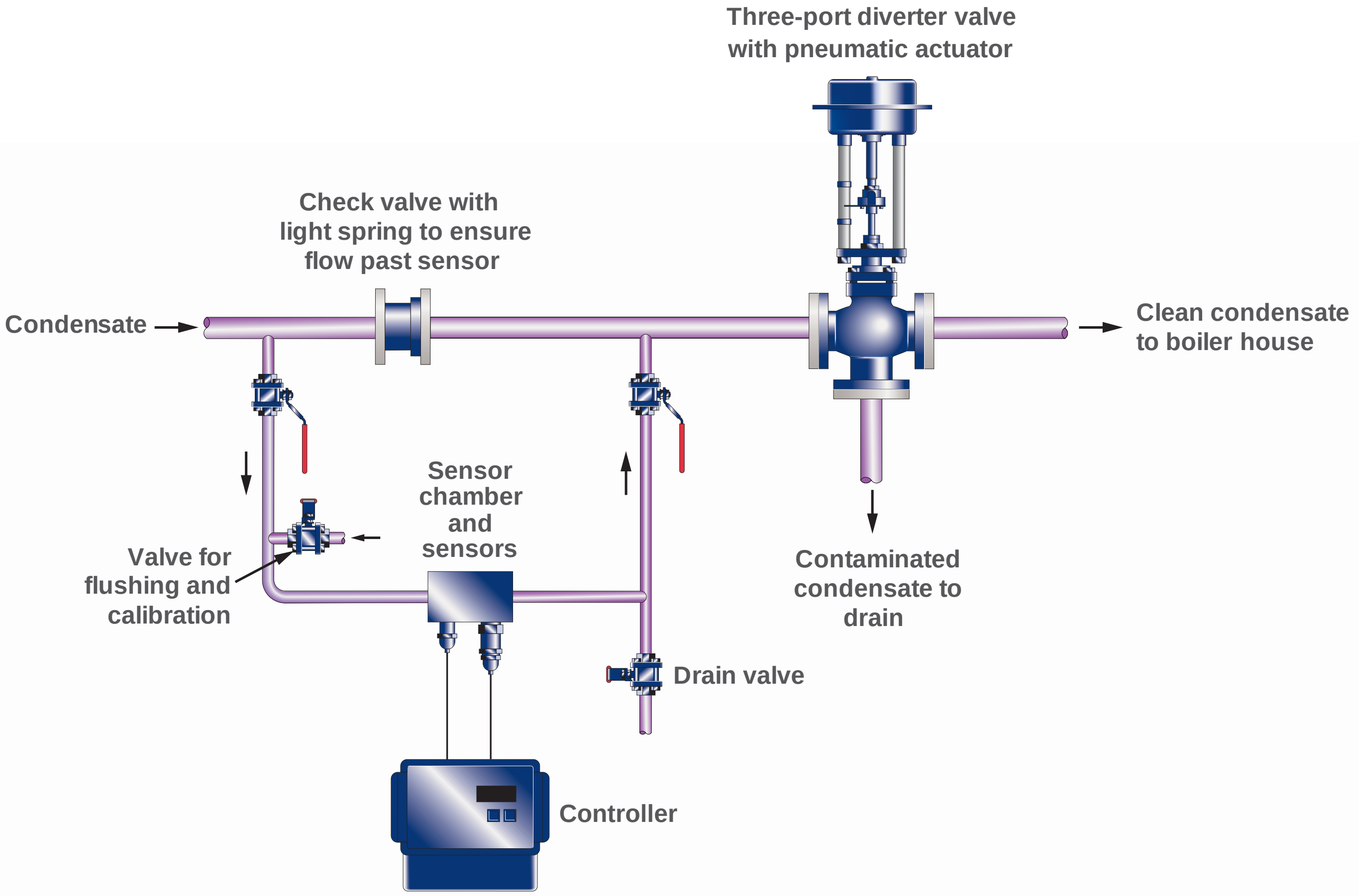


Figure 3: Condensate contamination detection system

The type of sensors fitted as part of the CCD system, will vary depending upon what types of contamination are to be detected, e.g. turbidity meter (oil / fats), conductivity (some process contamination), pH (acids).

Steam used in contact with the product should be regularly checked and analysed. The analysis of the samples will vary depending upon the potential risk of contamination from other processes / sources (see Figure 4, page 14).

4.3 Plant steam summary

The quality / purity of plant steam is determined by the following factors:

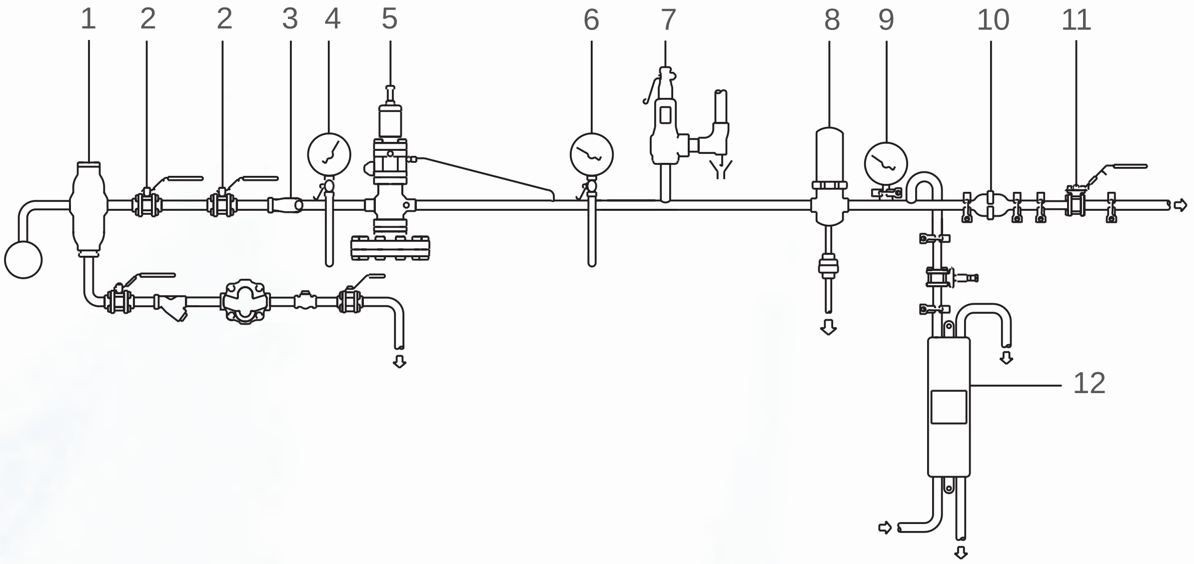
- The quality of raw water entering the boiler.
- The level of chemicals being dosed into the system and adherence to a water treatment management programme.
- The correct operation of the boiler, i.e. boiler loading, level controls, TDS control and operating pressure.
- Cross contamination from other processes.

5. Filtered steam

The term 'filtered steam', often referred to as 'culinary' steam, is plant steam that has passed through a fine stainless steel filter, typically 5 microns.

A 5 micron filter element is designed to remove 95% of all particles larger than 2 microns and is acknowledged in the USA as being acceptable for culinary steam.

If a 5 micron filter is used, a pre-filter (typically 100 mesh) should be installed upstream of the culinary steam filter, in order to prevent it from blocking (blinding) too quickly. The diagram below, illustrates the recommended components for a culinary steam installation complete with a sample cooler station.



1	Steam separator	7	Safety valve
2	Ball valve (x2) double isolation	8	Culinary steam filter
3	Strainer	9	Sanitary pressure gauge
4	Pressure gauge	10	Sanitary check valve
5	Pressure reducing valve	11	Sanitary ball valve
6	Pressure gauge	12	Sample cooler

Figure 4: Typical filtered steam station

Figure 5 illustrates the particle separation levels that can be achieved through varying levels of filtration. The 5 micron filtration level recommended for culinary steam, is highlighted on Figure 5.

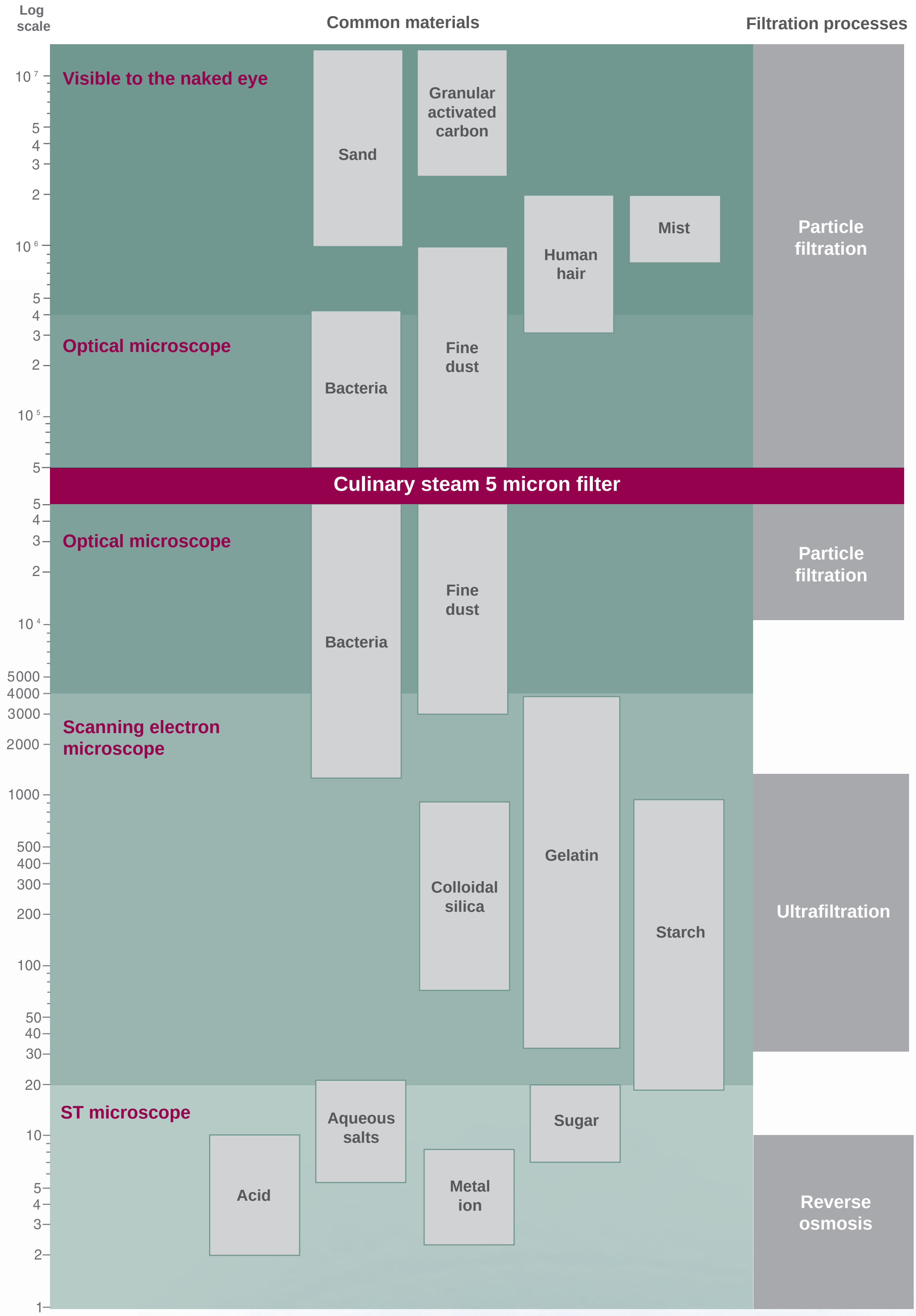


Figure 5: Filtration spectrum

5.1 Guidelines and Legislation

5.1.1 UK/Europe

Regulation (EC) No. 852/2004 of the European Parliament and of the council of 29th April 2004 on the hygiene of foodstuffs (Chapter VII, Section 5), states: 'Steam used directly in contact with food is not to contain any substance that presents a hazard to health or is likely to contaminate the food'.

Whilst the above statement stipulates that contamination is not permissible, it does not give specific guidance as to the acceptable quality or purity of steam when in direct contact with the process.

In practice many operators within Europe often refer to the US 3-A practices for producing filtered (culinary) steam, referred to in Section 5.1.2.

5.1.2 USA

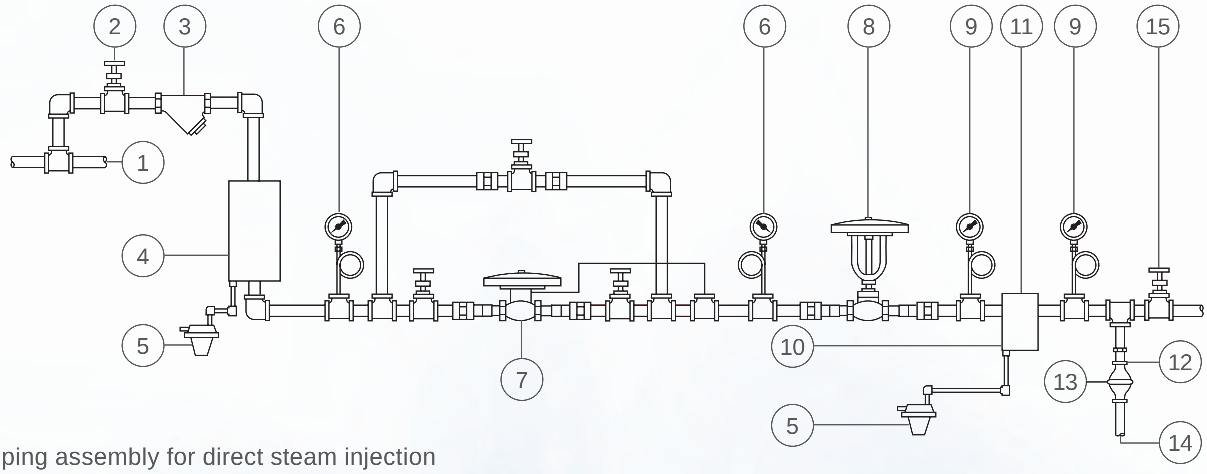
3-A Accepted Practices for a Method of Producing Culinary Steam, Number 609 - 3, is a standard developed in the US that establishes the 'minimum' sanitary (hygienic) requirements for the method of producing culinary steam.

This practice stipulates the requirements in terms of materials used, surface finishes, installation and boiler operation with regard to the use of culinary steam.

It is important to note that the Section on boiler operation within the 3-A Practice, stipulates that boilers should be 'operated in such a manner as to prevent foaming, priming, carryover, and excessive entrainment of boiler water into the steam'.

Refer to Section 4.2.1 on corrective action to prevent boiler carryover.

Figure 6 is an extract from the standard detailing the system components required for culinary steam, according to 3-A Accepted Practices:



Piping assembly for direct steam injection

1 Steam main
2 Stop valve
3 Strainer
4* Entrainment separator
5* Condensate trap
6 Pressure gauge
7 Steam pressure regulating (reducing) valve
8 Steam throttling valve (automatic or manual) or orifice
9* Differential pressure measuring device
10* Filtering device
11* Stainless steel from this point
12* Sanitary piping and fittings from this point
13* Spring-loaded sanitary check valve
14* Sanitary piping to process equipment
15* Sampling means

* Required equipment

Figure 6: Extract from 3-A culinary steam standard Number 609-03

5.2 Factors affecting filtered steam quality and purity

5.2.1 Water treatment, boiler carryover and cross contamination

The filtration spectrum shown in Figure 5 clearly illustrates that a 5 micron filter is not capable of removing 'Aqueous Salts'. Although a 'culinary' steam filter will act as a potential barrier they are not designed to remove suspended water within the steam (in the form of boiler carryover). If the filters are unable to remove 'Aqueous Salts', boiler water carryover containing chemical additives can still acquiesce through filter media. This could therefore lead to process or product contamination.

The use of an entrainment separator will help with the separation of water droplets from the steam. However, the efficiency of separation will be dependant upon the following factors:

- Velocity of steam (dependant on pipe size and steam load).
- Type of separator being used, i.e. cyclone, baffle, etc.
- Level of entrained water / boiler carryover.

5.3 Corrective action

The potential risk of contamination from boiler carryover and cross contamination still remains when using a culinary filter. The amount of contamination that potentially finds its way past the filter will depend upon the severity of the problem. Corrective action for both boiler carryover and cross contamination is covered in Sections 4.2.1 and 4.2.2, respectively.

6. Clean steam

Clean steam is a means of overcoming the potential contamination risks highlighted in the previous sections.

To create clean steam, a secondary generator with a controlled feedwater quality is used to ensure steam quality and purity is kept at the appropriate levels. The design of the steam distribution network, material selection and installation practices are all critical factors for minimising steam degradation, thus ensuring acceptable purity and quality at the point of use. The Figure 7 illustrates how clean steam is produced through a secondary generator.

Clean steam generators should only be operated if the feedwater is of appropriate quality. Raw water is not adequate and will require some pre-treatment which is governed by the nature and concentration of raw water contaminants. Reverse osmosis (RO), deionised/demineralised (DI) and continuous electrodeionised (CEDI) water are possible feedwater treatment alternatives. The feedwater used for generating clean steam will not be chemically treated since most of the particulates, inorganics, dissolved solids, etc, are taken out at the pre-treatment stage. The risk of water treatment chemical contamination is therefore eliminated when using clean steam.

Although clean steam generators often use plant steam as a heat source, the quality (dryness) of the plant steam is still important to maintain good heat transfer, hence maximising efficiencies.

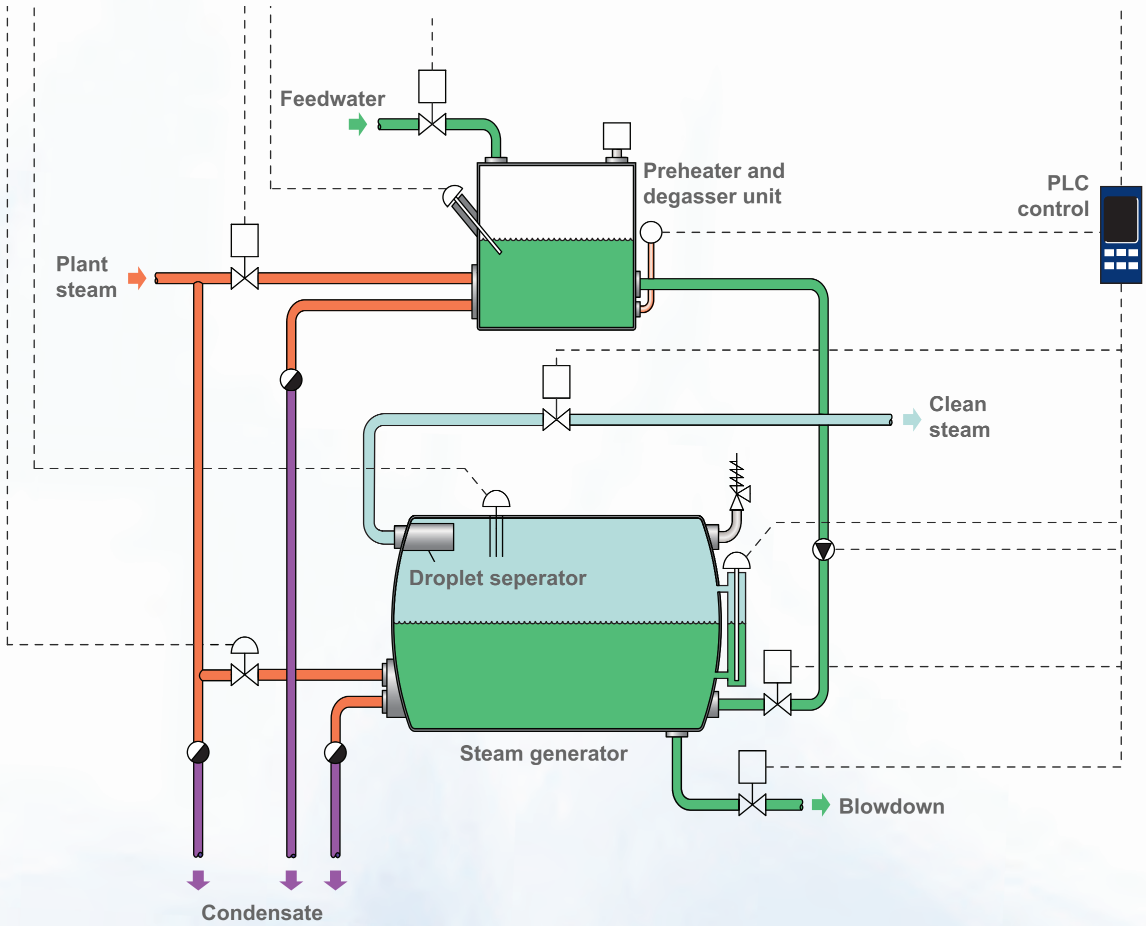


Figure 7: Schematic of a clean steam generator

In addition to the quality / purity of the clean steam leaving the generator, there are other factors that should be considered when installing a clean steam system. These include:

- **Materials of construction:** Clean steam is typically very aggressive, as many of the elements have been removed. Grade 304, 316 or 316L stainless steel is typically used throughout the system to ensure corrosion does not occur.
- **Surface finish:** The requirement for improved surface finish is predominantly to maintain sterility in the system by reducing the risk of microbial growth in crevices. Due to the high temperature of the steam, the majority of bacteria will be killed off.
- **System design:** Similar to surface finish, this relates to microbial growth. The clean steam system should be designed to be crevice-free with self-draining products fitted throughout. Guidance can be sought from 3-A Sanitary Standards.
- **Connections:** Whilst sanitary clamp (Tri-clamp) connections are often the preferred standard for clean steam systems (due to ease of cleaning), screwed and butt weld connections can also be considered. Guidance can be sought from 3-A Sanitary Standards.

6.1 Guidelines and Legislation

The pharmaceutical industry has strict guidelines in place for the generation and distribution of both clean steam and pure steam. Whilst these standards are not applicable to the food and beverage industry, they can provide guidance on the quality, purity and design of a clean steam system. Typical standards include EN 285 and HTM2031.

Certain process industries and food manufacturers are starting to see the benefits of using clean steam to minimise contaminants that could affect taste or contaminate the final product.

6.2 Factors affecting clean steam quality and purity

The potential risk of contamination from particulates, boiler chemicals and cross-contamination is eliminated with the use of clean steam, due to:

- The high quality of feedwater used.
- Removal of water treatment chemicals.
- Production of steam in a secondary generator.

6.3 Corrective action

The use of water separators is advised when using clean steam, as water droplets can still potentially enter the steam system, as a result of sudden and excessive demand on the clean steam generator. Heat loss from pipework will also cause condensate to form.

7. Pure steam

The subject of pure steam is not covered in any depth within this guide, since its use is generally restricted to the pharmaceutical sector. This Section is merely to inform that a fourth level of steam purity is available.

As with clean steam, pure steam is created within a dedicated generator, but one designed, built and operated in accordance with Pharmaceutical Good Manufacturing Practices (GMP) and associated regulations. The purity of the steam produced is such that its condensate matches the regulatory specifications governing Water For Injection. In other words, it is pure enough to be injected into the human body without any adverse effect.

8. Installation, operation and maintenance

The following table summarises the various elements of a plant / filtered steam system, highlighting some of the potential issues that could affect steam quality / purity and identifies the corrective action to resolve these issues. Should your food / drink process require minimal risk of potential contamination, consideration should be given to the use of clean steam (see identification number 7 on Figure 8).

Steam system elements	Factors affecting steam quality / purity
Water pre-treatment	Boiler carryover: If the pre-treatment plant make-up water is chlorinated at source, chlorine (CL2) and its associated and reacted products could enter the feedwater system and the boiler. The boiler will begin to break down such products, transferring them either as gaseous products into the steam circuit or as a reacted contaminant in the form of carryover.
	High raw water alkalinity will result in high boiler alkalinity and carbonic acid corrosion of the condensate circuit.
Feedwater	Boiler carryover from excessive chemical treatment: Some chemical reagents can be added to the feedtank, but most chemicals are added to the boiler feedline. The feed system may supply an economiser and this is a third area of potential chemical reagent injection. The economisers will feed the boiler, which is a fourth area where chemical injection can be found.
	Incorrect boiler water treatment chemicals resulting in potential process contamination.
Boiler operation	High boiler water level, resulting in carryover.
	Low boiler operating pressure resulting in lower steam capacity storage and higher risk of carryover.
	Boiler foaming, as a result of high boiler TDS levels.
	Boiler carryover resulting from sudden boiler loading.
Steam distribution	Wet steam occurring from poor steam distribution installation.
	Waterhammer / wet steam from poor steam trap maintenance.
	Process contamination from particulates.
	Regular blocking of culinary steam filter.
Condensate return system	Contamination of condensate system from process or other sources, e.g. CIP.

Ident. no in Fig. 8	Corrective action
1	Incorrect selection / installation of pre-treatment equipment. The quality of the raw water supply will determine the most appropriate and economical selection of water pre-treatment equipment. Expert advice should be sought to understand the variation in raw water quality and correct selection of equipment.
	Water softener slippage. Water softener may require maintenance.
1	Ensure pre-treatment plant is correctly selected and installed.
2	Poor water treatment programme. BS 2486 and EN 12953 – 10 2003 are UK and European Practices, that provide guidance on water treatment programmes. Deviation from these practices can result in excessive chemicals entering the steam system, resulting in boiler carryover and product contamination.
	Regular sampling and monitoring of steam quality / purity.
2	Food approved water treatment chemicals should always be used, where steam is in direct contact with the process / product.
	Regular sampling and monitoring of steam quality / purity.
3	Annual boiler maintenance to ensure level controls are set correctly.
3	Ensure boiler is operated and maintained at the correct design pressure.
3	Installation of automatic TDS control system to ensure TDS levels are maintained at appropriate levels.
	Regular sampling and monitoring of steam quality / purity.
3	Installation of steam meters to monitor peak demands.
	If multiple boilers are installed, ensure boilers are correctly sequenced.
	'Steam banking' where boiler standby is available.
	Installation of two / three element level control system to react more rapidly to steam demand.
	Installation of steam accumulator.
	Installation of steam surplussing valves.
4	Ensure steam traps and separators are installed in the appropriate positions around the steam distribution system. Undertake steam system audit to evaluate current steam system installation.
	Regular sampling and monitoring of steam quality / purity.
4	Regular (minimum annually) steam trap survey and maintenance.
5	Ensure culinary steam filter and ancillaries are installed prior to process application (see section 5).
5	Could be a combination of a poor water treatment programme, boiler carryover, boiler loading, etc. Steam system audit to evaluate source of problem.
6	Installation of Condensate Contamination Detection (CCD) system to detect increase in conductivity, turbidity or pH.
	Regular sampling and monitoring of steam quality / purity.

Factors affecting steam quality and purity

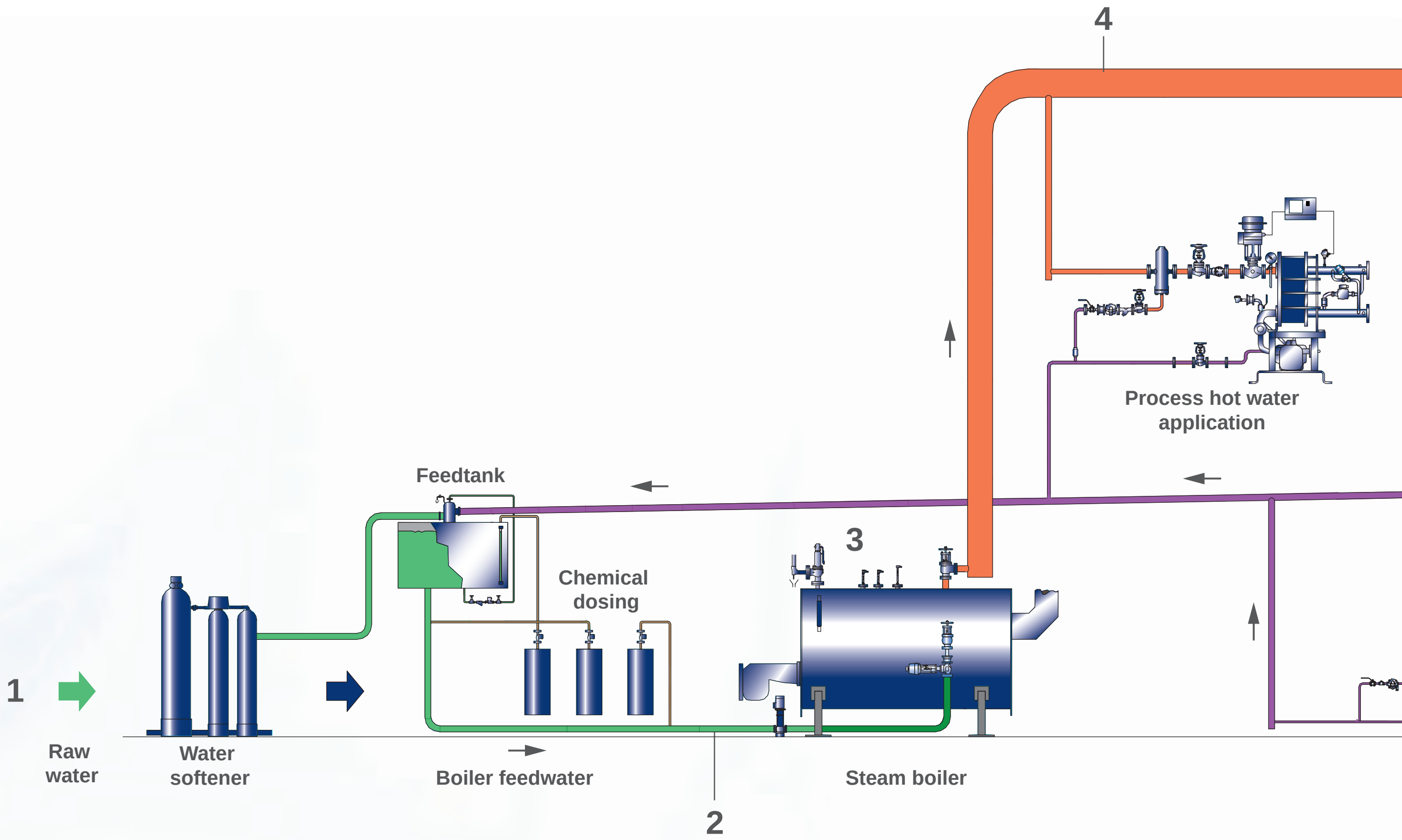
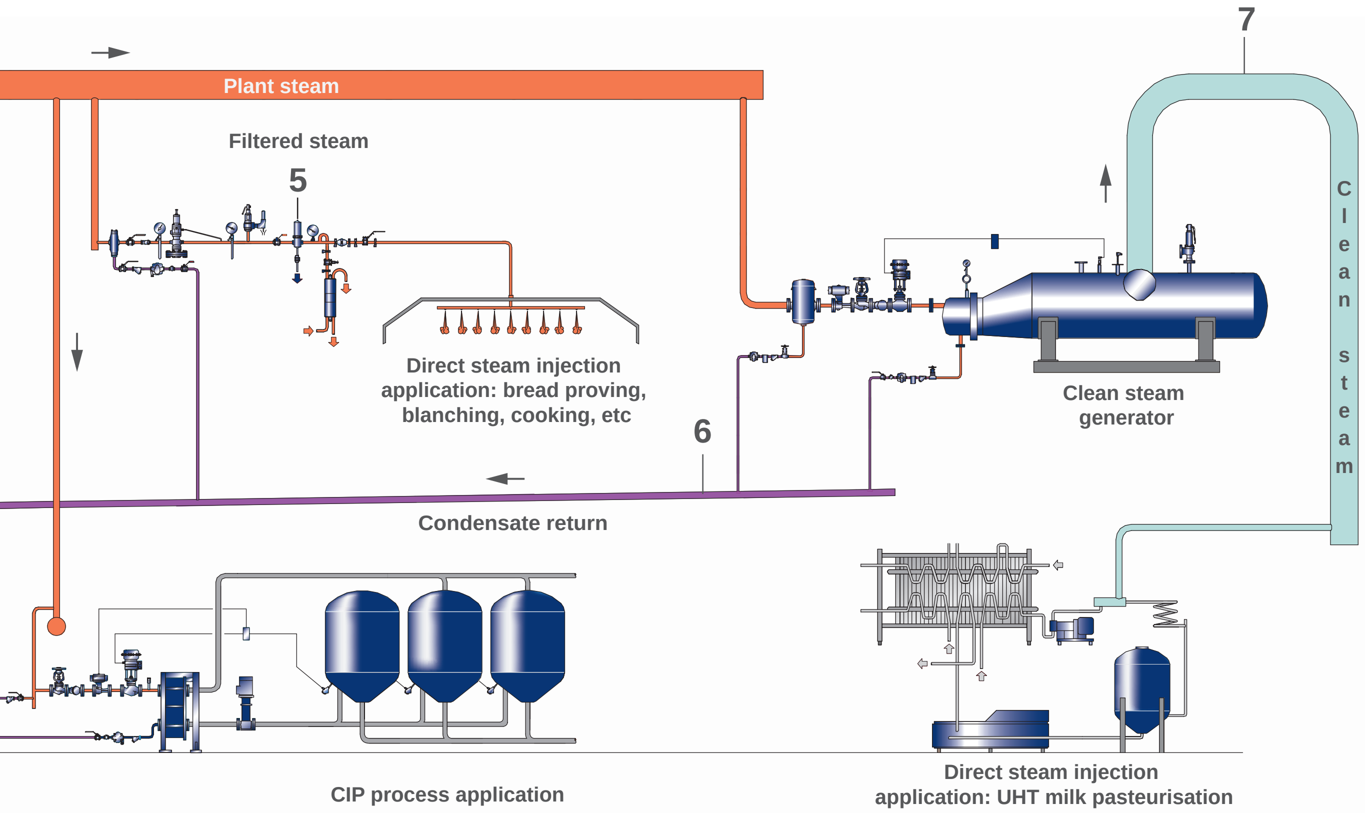


Figure 8: Factors affecting steam quality and purity


7
Plant steam
Filtered steam
5
Direct steam injection application: bread proving, blanching, cooking, etc
6
Clean steam generator
Clean steam
Condensate return
CIP process application
Direct steam injection application: UHT milk pasteurisation

Appendix 1

Process application list

Some typical applications where steam is in direct contact with process or products.

Steam application	Industry	Direct contact
Steam cooking tunnels	Food	✓
Steam injection for cooking sauces, soups, ready meals, etc.	Food	✓
Superheated steam for browning food	Food	✓
Steam used for pulling vacuum in jars, cans, bottles, etc.	Food	✓
Bread proving	Food	✓
Meat vapour condenser	Food	✓
Superheaters to 'puff' wheat.	Food	✓
Meat cooking, smoking & curing	Food	✓
Pig scald tanks	Food	✓
Chicken de-feather and pre-cooking	Food	✓
Steam barrier for aseptic filling	Dairy	✓
Milk sterilisation (UHT)	Dairy	✓
Sterilising in place (SIP)	Food	✓
Sterilisation of beer barrels	Beverage	✓
Direct injection on Wort boiler (brewing)	Brewing	✓
Steam bed for producing sweets	Food	✓
Flash peeling of vegetables	Food	✓
Steaming pasta in preparation for frying	Food	✓
Pasta extrusion process	Food	✓
Steam for sterilisation of bottles	Beverage	✓
Blanching foodstuffs	Food	✓
Distilling (whisky industry)	Beverage	✓
Cooking shellfish	Food	✓
Steam to soften frozen fish	Food	✓
Animal rendering	Food	✓
Steam tunnels for oven chips	Food	✓
Coffee extraction	Food	✓
Noodle cooking	Food	✓

Appendix 2

Typical water treatment chemicals

These chemicals are usually supplied under proprietary names. Detailed information on the chemical make-up can usually be found on the Safety Data Sheets (SDS). This is **not** a list of food approved chemicals:

Chemical	Purpose
Sodium hexametaphosphate	Antiscalant and sludge conditioner
Sodium hydroxide	Corrosion inhibitor
Sodium metabisulfite	Oxygen scavenger
Sodium metasilicate	Sludge dispersant
Sodium phosphate (mono-, di-, tri-)	Antiscalant and sludge conditioner
Sodium polyacrylate	Sludge dispersant
Sodium polymethacrylate	Sludge dispersant
NN-diethylhydroxylamine	Condensate corrosion inhibition
Tannin powder	Oxygen scavenger
Sulphonated copolymer	Sludge dispersant
PBTC	Sludge dispersant
Methylene phosphoric acid	Sludge dispersant
Diphosphoric acid	Sludge conditioner
NTA (4Na)	Sludge dispersant
Cobalt sulphate	Oxygen scavenger catalyst
Cyclohexylamine	Condensate corrosion inhibition
Morpholine	Condensate corrosion inhibition
Diethylaminoethanol	Condensate corrosion inhibition

Appendix 3

FDA boiler water additive limitations

The following information is an extract from the Food and Drug Administration (FDA) regulation (USA), controlling the types and limitations of boiler water additives, when steam is used in direct contact with the process, (21 CFR173.310):

Boiler water additives may be safely used in the preparation of steam that will contact food, under the following conditions:

(a) The amount of additive is not in excess of that required for its functional purpose, and the amount of steam in contact with food does not exceed that required to produce the intended effect in or on the food.

(b) The compounds are prepared from substances identified in paragraphs (c) and (d) of this Section, and are subject to the limitations, if any, prescribed.

(c) List of substances:

Substances	Limitations
Acrylamide-sodium acrylate resin	Contains not more than 0.05 percent by weight of acrylamide monomer.
Acrylic acid / 2-acrylamido-2-methyl propane sulfonic acid copolymer having a minimum weight average molecular weight of 9,900 and a minimum number average molecular weight of 5,700 as determined by a method entitled ``Determination of Weight Average and Number Average Molecular Weight of 60 / 40 AA / AMPS'' (October 23, 1987), which is incorporated by reference in accordance with 5 U.S.C. 552(a). Copies may be obtained from the Center for Food Safety and Applied Nutrition (HFS-200), Food and Drug Administration, 5100 Paint Branch Pkwy., College Park, MD 20740, or may be examined at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202-741-6030, or go to: http://www.archives.gov/federal--register/code--of--federal--regulations/ibr--locations.html	Total not to exceed 20 parts per million (active) in boiler feedwater.
Ammonium alginate	
Cobalt sulfate (as catalyst)	
1-hydroxyethylidene-1, 1-diphosphonic acid (CAS Reg. No.2809-21-4) and its sodium and potassium salts	
Lignosulfonic acid	
Monobutyl ethers of polyethylene- polypropylene glycol produced by random condensation of a 1:1 mixture by weight of ethylene oxide and propylene oxide with butanol	Minimum mol. wt. 1,500.
Poly(acrylic acid-co-hypophosphite), sodium salt (CAS Reg. No. 71050-62-9), produced from a 4:1 to a 16:1 mixture by weight of acrylic acid and sodium hypophosphite	Total not to exceed 1.5 parts per million in boiler feedwater. Copolymer contains not more than 0.5 percent by weight of acrylic acid monomer (dry weight basis).
Polyethylene glycol	As defined in Section 172.820.
Polymaleic acid [CAS Reg. No. 26099-09-2], and/or its sodium salt. [CAS Reg. No. 30915-61-8 or CAS Reg. No. 70247-90-4]	Total not to exceed 1 part per million in boiler feedwater (calculated as the acid).
Polyoxypropylene glycol	Minimum mol. wt. 1,000.
Potassium carbonate	

Substances	Limitations
Potassium tripolyphosphate	
Sodium acetate	
Sodium alginate	
Sodium aluminate	
Sodium carbonate	
Sodium carboxymethylcellulose	Contains not less than 95 percent sodium carboxymethylcellulose on a dry-weight basis, with maximum substitution of 0.9 carboxymethylcellulose groups per anhydroglucose unit, and with a minimum viscosity of 15 centipoises for 2 percent by weight aqueous solution at 25°C; by the method prescribed in the ``Food Chemicals Codex,'' 4th ed. (1996), pp. 744-745, which is incorporated byreference in accordance with 5 U.S.C. 552(a) and 1 CFR part 51. Copies are available from the National Academy Press, Box 285, 2101 Constitution Ave. NW., Washington, DC 20055 (Internet address http://www.nap.edu), or may be examined at the Center for Food Safety and Applied Nutrition's Library, Food and Drug Administration, 5100 Paint Branch Pkwy., College Park, MD 20740, or at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202-741-6030, or go to: http://www.archives.gov/federal--register/code--of--federal--regulations/ibr--locations.html.
Sodium glucoheptonate	Less than 1 part per million cyanide in the sodium glucoheptonate.
Sodium hexametaphosphate	
Sodium humate	
Sodium hydroxide	
Sodium lignosulfonate	
Sodium metabisulfite	
Sodium metasilicate	
Sodium nitrate	
Sodium phosphate (mono-, di-, tri-)	
Sodium polyacrylate	
Sodium polymethacrylate	
Sodium silicate	
Sodium sulfate	
Sodium sulfite (neutral or alkaline)	
Sodium tripolyphosphate	

Continued overleaf...

Substances	Limitations
Sorbitol anhydride esters: a mixture consisting of sorbitan monostearate as defined in Section 172.842 of this chapter; polysorbate 60 ((polyoxyethylene (20) sorbitan monostearate)) as defined in Section 172.836 of this chapter; and polysorbate 20 ((polyoxyethylene (20) rbitan monolaurate)), meeting the specifications of the Food Chemicals Codex, 4th ed. (1996), pp. 306-307, which is incorporated by reference in accordance with 5 U.S.C. 552(a) and 1 CFR part 51. Copies are available from the National Academy Press, 2101 Constitution Ave. NW., Box 285, Washington, DC 20055 (Internet http://www.nap.edu), or may be examined at the Center for Food Safety and Applied Nutrition's Library, Food and Drug Administration, 5100 Paint Branch Pkwy., College Park, MD 20740, or at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202-741-6030, or go to: http://www.archives.gov/federal--register/code--of--federal--regulations/ibr--locations.html.	The mixture is used as an anticorrosive agent in steam distribution systems, with each component not to exceed 15 parts per million in the steam.
Tannin (including quebracho extract)	
Tetrasodium EDTA	
Tetrasodium pyrophosphate	

(d) Substances used alone or in combination with substances in paragraph (c) of this Section:

Substances	Limitations
Cyclohexylamine	Not to exceed 10 parts per million in steam, and excluding use of such steam in contact with milk and milk products.
Diethylaminoethanol	Not to exceed 15 parts per million in steam, and excluding use of such steam in contact with milk and milk products.
Hydrazine	Zero in steam.
Morpholine	Not to exceed 10 parts per million in steam, and excluding use of such steam in contact with milk and milk products.
Octadecylamine	Not to exceed 3 parts per million in steam, and excluding use of such steam in contact with milk and milk products.

(e) To assure safe use of the additive, in addition to the other information required by the Act, the label or labelling shall bear:

(1) The common or chemical name or names of the additive or additives.

(2) Adequate directions for use to assure compliance with all the provisions of this section.

Notes

Notes

Notes

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SB-GCM-31 CM Issue 3