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Learning Objectives

1. Define "noncondensible gases" and understand how they may impact sterilization.

2. Describe the sources of noncondensible gases.

3. Describe the role of steam traps in venting noncondensible gases.

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Noncondensible gases: Undesirable contaminants in your steam supply

by Walt Deacon, Thermo Diagnostics

The purpose of this self-study article is to discuss air and other noncondensible gases in steam systems. Noncondensible gases, i.e. "gases that cannot be liquefied by compression under the conditions of temperature and pressure used during the sterilization process"[1] entrained in the steam supply are an undesirable contaminant in your steam supply. Noncondensible gases are one of the causes of failing Bowie-Dick type tests. Where do the gases come from? Why do they end up in the sterilizer? What problems do they cause with the sterilization process? How can they be eliminated? What other problems do they cause in the system that might affect the sterilization process? What role do steam traps play? Let's learn more.

Background - Definitions

First let's define the gases. "**Air**" means the atmospheric air that is introduced to the sterilizer chamber when the door is opened, or into the steam piping when the system is opened for maintenance. Some air also comes into the sterilizer from the steam supply. It gets into the boiler through the water supply. Air is a noncondensible gas (NCG), but not all NCGs are air. Some noncondensible gases (NCGs) like oxygen (O_2) and carbon dioxide (CO_2) may also be found in air, but we name them separately because of their source. These NCGs originate in the boiler from the water supply.

Sources of NCGs

Atmospheric air. Each time the sterilizer door is opened, air is allowed to enter the chamber. Air enters the piping when the steam system is opened for maintenance, for example - to repair a pressure-reducing valve. Any time the steam system is turned off, the collapsing steam creates a vacuum that can draw in air.

Boiler feedwater. Air and other gases are dissolved in water. You can see them by leaving a glass of water on the nightstand overnight. In the morning there will be bubbles around the edge of the glass. This is normally air that is dissolved in water that comes from a municipal water system. The steam system normally loses water over time due to leaks, humidification, and boiler blowdown (flushing the boiler). The system needs some fresh water to make up for these losses. Air is introduced into the system with this fresh makeup water.

Figure 1: *Leave a glass of water out overnight and see gas bubbles accumulate by morning*

Carbonates. Carbonates are the primary source of NCG's. Calcium carbonate is one of the most freely distributed minerals on the earth's surface. Potassium and magnesium can also form carbonates. These minerals dissolve easily in water. Calcium carbonate, especially, will cause major problems in the boiler if left untreated. It has a characteristic called "retrograde solubility" in which it becomes less soluble in water as the temperature increases. When heated in the boiler, the carbonates (CO_3) break down producing oxygen (O_2) and carbon

Figure 2: *Boiling water on a stove top. A long time before the water boils, bubbles form in the water near the heated surfaces. You can tell these bubbles are air, not steam, because they stay on the surface of the water as a bubble.*

dioxide (CO_2). These two gases can cause problems with corrosion. Boiler treatment specialists will add treatment chemicals to the system to try and head off these negative impacts.

How are NCGs removed?

In the typical hospital boiler room, makeup water is treated before it is pumped into the boiler. The steam system has a special device that tries to remove air and other NCGs. It is called the deaerator, or DA tank. The primary purpose of the DA tank is to remove dissolved oxygen from the boiler feedwater. Oxygen is corrosive to mild steel. When combined with carbon dioxide, it can become 40% more corrosive. The DA tank removes gases the same way boiling a pot of water on the stovetop does.

There are two types of DA tanks, spray and tray. In the spray DA tank, a jet of steam mixes with the feedwater being sprayed into the unit, heating up the flow and allowing the gases to escape. In the tray style, incoming water falls over a series of trays, spreading it out so that it can mix with incoming steam. It spreads incoming water out over the surface, so water is heated easily and the gases can escape. Air comes out of solution with the water and is vented from the system. Typically, you'll see a small pipe on the roof of the boiler room, which is constantly venting a small amount of visible steam. That is usually the vent from the DA tank. DA tanks are very effective at removing air, but if they are not operating properly, there will be elevated levels of air and other NCGs in the steam supply that can impact sterilization cycles.

Potential DA tank problems

The DA tank is designed to handle a fixed maximum amount of makeup water. If the makeup water load is increased beyond the capacity of the DA tank, elevated air and NCG levels might result. Think of the DA tank as a big water heater. When water is heated, minerals can plate out, and the spray nozzles of the DA tank can become plugged. Oxygen released in the DA tank can corrode its internal parts and spray nozzles. The vent piping, which releases gases, can become restricted.

Impact of NCGs

How do NCGs behave?

If air and other NCGs are in the steam system, how do they behave compared to the steam? To understand that we'll look at the expansion and contraction of water and steam. In a typical hospital 100 psi steam distribution system, each pound of water expands in volume from 1 pint to almost 4 ft^3 as it is vaporized in the boiler. In the heat transfer and sterilization equipment, each pound of steam condenses and collapses back down to a pint. It's this expansion and contraction that drives steam through the system. During the sterilization cycle, each pound of 30 psi steam condenses and collapses from almost 10 ft^3 back down to a pint. The steam can move at a velocity of 100 mph as it is collapsing. On the other hand, air and NCGs do not expand and contract this way. They stay at a relatively constant volume. (that's why they are called NON-CONDENSE-ible) The velocity of the 100 mph steam is just like wind, and the air and noncondensible gases behave like balloons on a windy day. They will be pushed to wherever the steam velocity is lowest. One of these areas of lowest velocity is the sterilizer, where the steam condenses and collapses as it gives up its heat. Anytime air and NCG's are introduced into the system, they are potentially going to end up in the sterilizer chamber.

How air and other NCGs impact steam sterilization

Air and NCGs cause problems with the sterilization process in two specific ways. First they lower steam temperature, and second, they take up space, insulating the instruments we are trying to heat and sterilize. The lowered steam temperature takes place because there is a mixture of steam and air as opposed to pure steam. At 30 psi, steam is supposed to be 274°F. If the mixture is 10% air, the temperature will fall by 7°F. At 30% air, the temperature falls by 22°F, and at 50% air the temperature is reduced by 49°F. The more air is present, the harder it becomes to reach the 270°F required by the sterilization cycle. Because it's a gas and occupies space, as more air accumulates, it can eventually block the flow of steam altogether. This is called "air-binding" and can happen to any steam condensing equipment, not just sterilizers. During a sterilization cycle, steam flows towards the instruments and condenses and collapses as it transfers heat to the instrument. The steam flow also pushes air and noncondensible gases towards the instruments.

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Figure 3: *Deaerator (DA) tank in boiler room*

Self-Test Answers: 1. B, 2. A, 3. A, 4. B, 5. B, 6. B, 7. A, 8. B, 9. B, 10. A

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Visualize wind pushing balloons towards the surface of the instrument. Since they do not condense, they can collect at the instrument surface, and create a heat transfer barrier. Air is a very effective insulator -- 0.01 inches of air is the same barrier to heat transfer as 15 inches of steel, or 11 feet of copper. Double pane windows, down-filled jackets, and fiberglass wall insulation are all examples of using trapped air to insulate against heat transfer.

What other effects can NCGs have?

In addition to keeping instruments from being sterilized effectively, CO_2 and O_2 have other undesirable effects that can affect sterilization. These gases don't condense under steam conditions. But when cooler condensate is present, the CO_2 can dissolve into the condensate and become metal-attacking carbonic acid. The O_2 causes oxidation. In combination, they are very aggressive. The acid dissolves piping, and then the dissolved metal is oxidized and carried away in the condensate. This is how specks can form on instruments. Green specks are typically caused by copper or bronze piping corrosion. Black specks are caused by steel and iron pipe corrosion. The 100 mph steam picks up the condensate and pushes it into the sterilizer. Filters might not remove this contamination. Remember that the acid dissolved the metal. It is not a chip or a flake that can be easily stopped by the filter.

How are NCGs vented from the rest of the steam system?

Since the DA tank does not remove all of the gases, there has to be additional provisions within the steam system and on the sterilizing equipment to remove the gases.

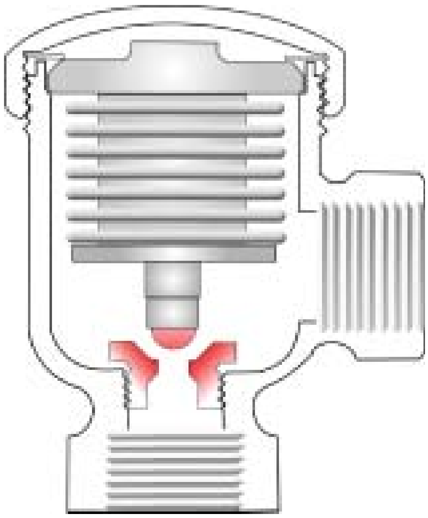

Figure 5: *Thermostatic Trap*

Steam traps have three functions: 1) to drain condensate from the system 2) to keep steam from being vented from the system and 3) remove air and other NCGs. Unfortunately, these latter two functions (2 and 3) are hard to accomplish together. Since both steam and NCGs are gases, that trap must distinguish between the two types of gases, keep one and discharge the other. The various types of traps can be more (or less) effective at removing the gases. The most effective device for gas removal is the "balanced pressure" thermostatic trap. You normally see them on the bottom of the sterilizer where it drains condensate from the jacket and chamber. In this piping configuration the thermostatic element is doing "double duty" since it is also handling condensate.

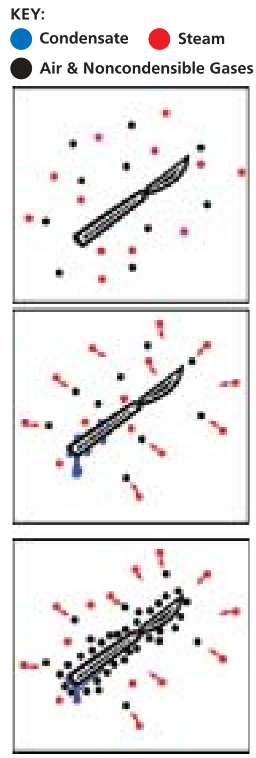

Figure 4: *Steam collapsing towards the instrument surface "pushes" air toward the surface.*

These same thermostatic elements can be used to vent NCGs wherever they may accumulate. They are then called a thermostatic air vent, but it's usually an identical unit. The distinction comes from how it is installed. A trap will be installed at the bottom of equipment, to handle condensate. As an air vent, it needs to be located above the condensate level. Large autoclaves often come with connections for installing thermostatic vents at high points away from the steam inlet. Technically, the air and NCG's are heavier than steam, and should "sink" to the bottom. Remember though, the steam can travel at 100 mph, and the gases will be pushed and held in any region of low velocity.

Some steam traps are called float and thermostatic (F&T for short). They are equipped with both a float operated valve for removing condensate, and a thermostatic element specifically for removing gases. These traps are larger since two separate valves are in the casting. Clearances around the sterilizer can make them difficult to install.

What can keep NCGs from being vented?

The thermostatic element is a flexible metal bellows. The bellows chamber is sealed with a small amount of fluid inside. The fluid might be purified water, or typically a water and alcohol mix. Since the bellows is flexible, it can act like a piston. The movement of the bellows is controlled by the fluid inside. It can extend when the pressure inside increases, and retract when the pressure inside decreases. If it gets heated up to steam temperature, it extends and closes the valve.

Thermostatic traps can fail due to fatigue, typically after three to five years. They typically last only three years when handling condensate and longer when installed as an air vent. Depending on the type of fluid charge, a trap may fail in the open position (in which case it blows expensive steam), or it can fail closed (and fail to vent noncondensible gases). Finding units that are "failed closed" can be accomplished with a temperature gun. The unit will be cold, even with the steam pressure on. Finding units that are "failed open" requires a steam specialist. A small $200 dollar trap that has failed on an intermediate pressure (60 psi) steam line can easily waste $5,000 per year in steam energy.

Summary

The source of most noncondensible gases in the steam supply is makeup water introduced to the boiler system. Noncondensible gases can negatively impact sterilization by lowering the steam temperature, insulating the surgical instruments being sterilized and dissolving piping metals resulting in specks on instruments. If your failed Bowie-Dick test investigation points to the presence of noncondensible gases in the steam supply, this self-study provides points you can discuss with your facilities engineer. Discussion points would include boiler treatment chemicals, status of the deaerator (DA) tank, presence of steam traps, and verification that traps are functioning properly. HPN

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2. American Society of Heating, Refrigerating, and air Conditioning Engineers, Inc. 2000 ASHRAE Systems and Equipment Handbook Chapter 10 Steam Systems – Steam Traps.

3. Ondeo Nalco Chemical Company. Boiler Feedwater Treatment – An Introduction. Bulletin 30, 1997

Questions you can ask Facilities Engineering if you suspect heavy noncondensible gas flow:

Preface: We might be seeing a lot of air and other non-condensable gases along with our steam

- **Is the DA tank working well?**
- **Have we changed boiler treatment chemicals dosage or formula?**
- **Has any part of the system been shut down or opened up for maintenance?**
- **Have we brought a boiler back "on line" from maintenance or annual inspection?**
- **Have we changed valves or equipment on the intermediate pressure (probably 60 psi) system?**
- **When did we last do a steam trap testing audit?**

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Noncondensible gases: Undesirable contaminants in your steam supply

Circle the one correct answer:

1. Air and noncondensible gases can help sterilization by increasing the temperature of steam.
A. True
B. False

2. NCG is an abbreviation for noncondensible gas.
A. True
B. False

3. Air is captured in the sterilizer every time the door is closed.
A. True
B. False

4. The boiler room injects air into steam in the DA tank.
A. True
B. False

5. The DA tank works by cooling off hot condensate and raw feedwater to recover energy.
A. True
B. False

6. Steam is attracted to cold instruments and this helps to repel air and NCG's.
A. True
B. False

7. Steam traps discharge air and NCG's as one of their three functions.
A. True
B. False

8. Thermostatic air vents are installed exactly like other steam traps.
A. True
B. False

9. NCG's help make piping more resistant to corrosion by neutralizing acid.
A. True
B. False

10. Air can get into the steam system through: maintenance on the piping; along with fresh feedwater; and when the sterilizer door is closed.
A. True
B. False

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