PUMPS & SYSTEMS
The Leading Magazine for Pump Users Worldwide

Power Gen Pump Applications that Reduce NOx & CO_2 Emissions

By Jason Fouraker, November 1, 2021

Amine scrubbing is one way to remove flue gas from these applications.

Each day, hundreds-of-thousands of industrial boilers heat water to generate steam for turbines and generators to make electricity. Plants running boilers range in scale from large utilities, to smaller co-gen facilities that provide heat & power for universities, hospitals and industrial buildings.

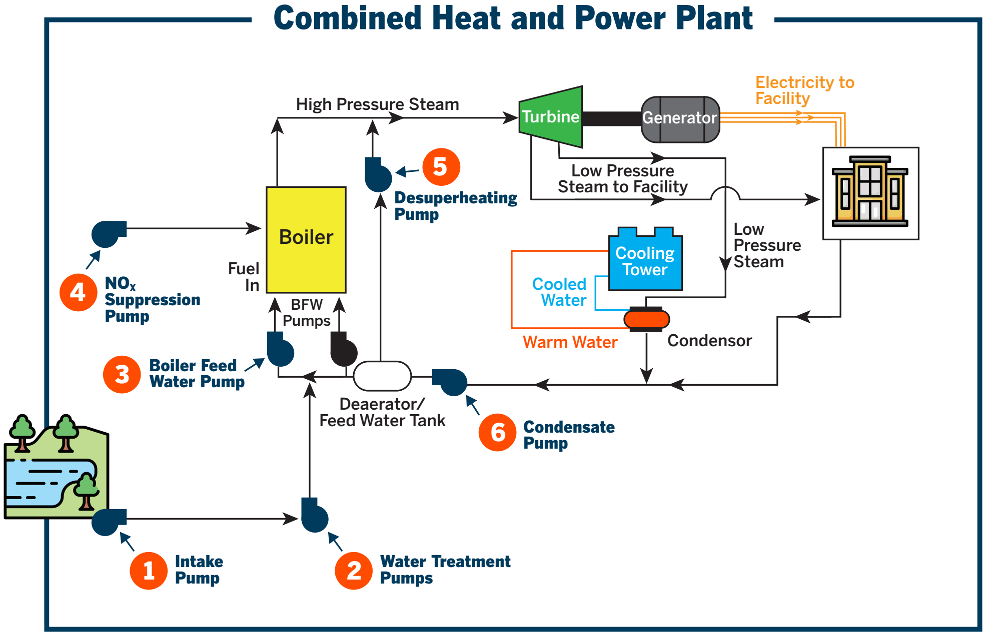
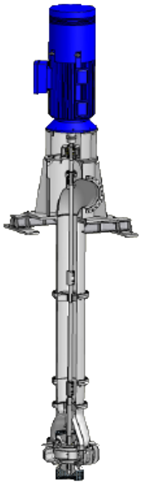


Figure A: water travels through a plant repeatedly during the power gen process.

Each plant requires a number of pumps to move water through various stages in the process. This article takes a look at pumping requirements, and it also highlights two areas where pumps play an important role in reducing harmful emissions created during the power generation process.

1 – Raw Water Intake Pumps:



Before water is recycled in the loop depicted in **figure A**, large volumes of raw water must enter the plant from a nearby lake, river or other body of water. Vertically Suspended (VS) pumps are typically used for this application. Selection criteria includes flows up to 10,0000 m³/hr (39,600 gpm) and head up to 150 m (490 ft). Reliability is also important, as submerged pumps are difficult to reach for maintenance.

2 – Water Treatment Pumps:

Once water enters a plant, it must be cleaned to manage micro-bio organisms and to prevent scaling & corrosion. Clean condenser heat transfer surfaces have a direct impact on efficiency, and fouling can lead to expensive plant de-rates and unplanned outages. To clean water, chemicals like sulfuric acid (for pH control) and sodium hypochlorite (for disinfection) are used. These can be dosed via metering pumps, however in higher flow applications, less complex and more reliable pumps such as sealless magnetic drive pumps are often used. The key requirements are high flow rates and relatively low pressures. Simplicity and reliability are important criteria, as many plants run operations around-the-clock – so unplanned maintenance is to be avoided wherever possible.

Traditional Demineralizer Systems are also utilized to purify water for steam generating loops. Large ion exchange resin beds remove contaminants by substituting H+ ions and OH- ions for dissolved salts, resulting in water that is free of any dissolved salts. When exhausted, resins are re-generated by pumping Sulfuric Acid and Sodium Hydroxide – typically via sealless mag drive pumps. This re-generation process also requires large dosing rates at relatively low pressures.

3 – Boiler Feed Water Pumps:

Boilers require continuous feed water, which is delivered by feed pumps. Boiler feed applications require high pressures, because of the high temperatures of the feed water. Water changes to gas at 212°F, but boiler feed water can range anywhere from 225°F up to 350°F. In order to maintain feed water in a liquid state, the pump (and the inlet piping) must maintain pressures that are higher than the water vapor pressure.

For most co-gen plants, integrally geared pumps are ideally suited to transfer feed-water into steam drums and back from condensers in closed loop cycles. Pumps must generate enough pressure to overcome the steam pressure in the boiler. Many Boiler feed water pumps should be able to deliver flows up to 230 GPM (52 m^3/hr) with heads up to 3,000 feet and a temperature range up to 650°F (340°C).

For larger plants, with high flow and high head requirements, BB3 multi-stage pumps (up to 14 stages) are an option. Often times, heavy duty pumps that can deliver heads to 4,260 feet (1,300 m) with flows of 2,640 gpm (600m^3/hr) are API pumps, which are more expensive. Although a full range of API features and packaging is not always necessary for boiler feed pump applications, some operators consider the ruggedness and reliability of API pumps to be worth the incremental cost. Many horizontal axial split case pumps, running back-to-back impellers in heavy-duty double volute casings are deployed at larger plants for boiler feed applications.

4 – NOx Suppression Pump:

Nitrogen Oxides are a family of poisonous, highly reactive gases that form when fuel is burned at high temperatures in industrial boilers and turbines. NOx forms when heat forces nitrogen atoms to split, and re-combine with oxygen atoms. This processes increases exponentially at combustion temperatures. NOx is a strong oxidizing agent that reacts with volatile organic compounds (VOC) in the atmosphere to produce smog.

One of the best ways to reduce NOx is to keep it from forming in the first place. A simple (pre-combustion) method is achieved by reducing temperatures in boilers via water injection applications. Centrifugal High Head Low Flow pumps are often used to inject demineralized water (at high pressure) into boilers, to lower flame temperature, reduce local oxygen concentration within the boiler, and to decrease the formation of thermal and fuel-bound NOx.

Another type of post-combustion NOx reduction is Selective Non-Catalytic Reduction (SNCR). This reduces NOx from boilers by injecting ammonia or urea into the furnace or cyclone inlet where it mixes with the hot flue gas. Ammonia reacts with nitrogen oxides to produce water and nitrogen. The ammonia is typically injected using a centrifugal high-head, low flow pump.

5 – Desuperheating Pumps:

Steam performs mechanical work by turning turbines. Every power plant is different, and each plant has an optimal steam velocity for its process. Water can flow through piping at velocities of 15 to 25 ft/sec, but steam line velocities can range as high as 400 ft/sec. Unintentional superheat lowers efficiency, and excessive steam pressure can harm pipes. In order to optimize steam temperature and pressure for a given plant, desuperheating and steam-conditioning systems are used. These skids features monitors, valves and pumps, which are typically centrifugal high-head, low flow pumps.

6 – Condensate Pumps:

As indicated in **Figure A**, steam exiting the turbine is routed to cooling towers and condensers that turn the steam back into warm water. Often times, impurities (such as carbonic acid) form during this stage of the process, which can reduce pH and potentially corrode pipes and pumps that aren't made of stainless steel. Condensate pumps (made of stainless steel or other resistant alloys) are used to move water into a deaerator – which takes oxygen and carbon dioxide out of the feed water, before it is recycled to the boiler.

A Common Deaerator Issue and a Simple Fix:

Plant operators and maintenance personnel in smaller co-gen facilities should ask themselves two simple, but important questions: how high is the roofline, and how much vertical distance is there between the deaerator and the boiler feed pump?

In most boiler rooms at smaller Co-gen plants in universities, hospitals or industrial office buildings, the height of the roofline limits the vertical distance between the deaerator and the boiler feed water pump. As a result, Net Positive Suction Head (NPSH) available to pumps is limited – and suction transient conditions enable vapor to travel from the deaerator to the pump. This causes cavitation, and can lead to fierce radial and axial thrust loads on a pump's rotating assembly. Some pump types – such as segmented ring pumps – feature multi-stage designs with a dynamic hydraulic balancing disc. Under normal operating conditions, water flowing through the pump keeps everything in balance – but suction transient conditions can enable vapor to reach the bearings, which upsets the balance and causes the rotor to shift back-and-forth. Because the clearances are extremely tight in ring pumps, even a slight shift can cause the impeller to hit the casing, which can lead to pump failures.

Larger utilities do not suffer this problem because the physical distance between the deaerator and boiler feed water pumps can be three-to-five times larger. But for smaller co-gen plants, pumps with

thrust bearings included in their modular shaft assembly should be chosen, because these pumps are designed to handle axial thrust without problematic balancing devices.

A Simple Carbon Capture, Utilization and Storage (CCUS) Application for Power Generation

Water moves around a power plant in numerous ways, to make steam that delivers the mechanical power needed to turn turbines and generators. But what happens at the end of process? The remnants of the hydrocarbon heat source used to heat the boilers exits the plant in the form of Flue Gas – which is the combustion-exhaust that comes out of a plant's smoke-stack. Flue emissions in many power plants (or refineries) are approximately 67% nitrogen (N_2), 20% water (H_2O), 10% carbon di-oxide (CO_2) and the remaining 2-3% is soot or particulate matter containing sulfur oxides.

Removing CO_2 from Flue gas is a CCUS application that can be accomplished in many ways – one of which is via Amine Scrubbing. While advanced technologies are still being developed to capture & remove CO_2 emissions, Amine scrubbing has is a proven process for removing CO_2 that is energy-efficient and simple to implement. Its track record dates back to the 1930s.

PUMPS&SYSTEMS
The Leading Magazine for Pump Users Worldwide

Power Gen Pump Applications that Reduce NOx & CO_2 Emissions

By Jason Fouraker, November 1, 2021

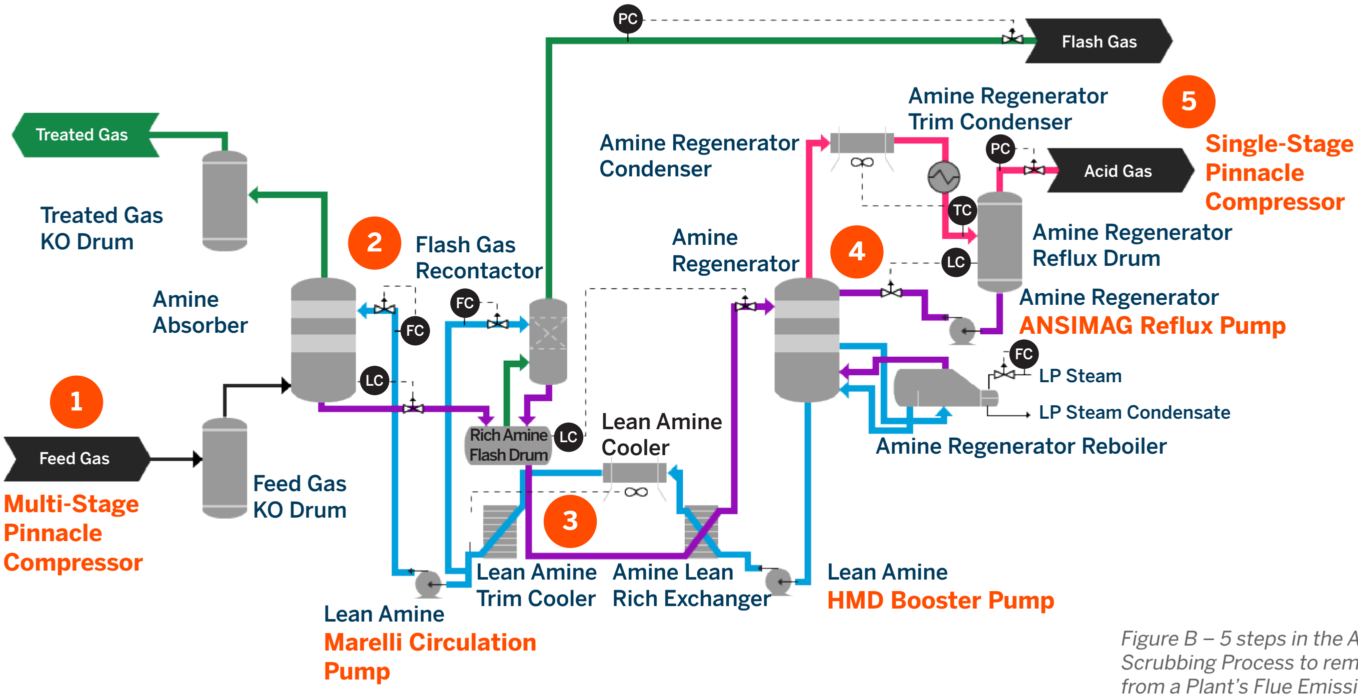


Figure B – 5 steps in the Amine Scrubbing Process to remove CO_2 from a Plant's Flue Emissions

How does Amine Scrubbing Work?

Amines are aqueous chemical solvents (such as Monoethanolamine (MEA) or Diethanolamine (DEA)) that bond with H_2S and CO_2 in a way that absorbs & removes them from gas streams. The "scrubbing" process works as follows:

1. **Multi-Stage Gas Compressors** move gas into a vapor-liquid separator (called a KO, or knockout drum), which removes water and liquid hydrocarbons from the gas stream.

2. The untreated "sour" gas enters an amine absorber, where **API-610 circulation pumps** inject aqueous amine solutions containing molecules that bind onto CO_2 and H_2S. A key requirement for pumps is the ability to handle high suction pressures. Safety & reliability are important, because amines are corrosive and dangerous to plant personnel.

3. The "rich amine" (containing the CO_2 and H_2S) settles at the bottom of the absorber, where it goes to a multi-phase separator. At this point, light hydrocarbons are flashed out of the amine; heavy hydrocarbons are separated; and the rich amine is heated and fed to a regenerator column via **sealless booster pumps**. The pumps must be capable of supporting extremely high temperatures. Sealless pumps are a preferred choice. They provide leak-free performance, and a small footprint, as there are no seal support systems taking up space on crowded amine skids.

4. Steam generated in the reboiler heats the amine and removes the hydrogen sulfide (H_2S) and carbon dioxide (CO_2) from the amine. Regenerator reflux pumps move liquid hydrocarbons at, or close to their bubble points (the phase at which gas bubbles emerge at a specific temperature). Sealless pumps, made of ETFE or metallic construction are the preferred choice for this application.

5. The lean amine from the regenerator is cooled in an exchanger, where it's returned to the absorber. The H_2S is removed from the amine and cooled in a condenser. From there it could be sent to sulfur recovery units for processing into sulfur. Similarly, the removed CO_2 can be processed into catalysts/polymers that are used to make plastics, adhesives, pharmaceuticals and many other products. Sealless pumps, made of ETFE or metallic construction (duplex Stainless Steel, Alloy 20 and Alloy C276) are the preferred choices, because they're specifically designed for toxic, aggressive, hot or crystallizing processes.

In Summary:

As **figure A** indicates, pumps move water around power plants in many ways. The hydrocarbon heat sources used to make steam contain impurities. Everyone today understands the need to treat, absorb, capture and wherever possible eliminate these impurities. While new approaches and soon-to-be-developed technologies may one day deliver on the promise of lowering harmful emissions – existing technologies such as NOx suppression and Amine Scrubbing can be efficiently deployed today – to eliminate 5-10 percent of the pollution that comes out of the smokestack of every power plant, refinery, chemical manufacturer and petrochemical plant.

The pumps referenced in these processes have a long & successful track record. To learn more, visit www.sundyne.com.

About the Author:
Jason Fouraker is in Engineered Direct Sales for Sundyne. Jason graduated from Missouri University of Science & Technology with a Bachelor of Science degree in Mechanical Engineering. He is a registered professional engineer in the state of Oklahoma. For more information, visit www.sundyne.com.