Components of a Steam Generator in an Advanced Passive 1000 Nuclear Reactor

A steam generator in an Advanced Passive 1000 (AP 1000) nuclear reactor is one of the main components of a power station. This is where the water goes from water to steam, and then the steam leaves the steam generator goes to the turbine to make power. There are four steam generators in an AP 1000 nuclear reactor design, and they are all exactly the same. A steam generator's general shape is a cylinder, which can be seen in figure 1. An AP 100 steam generator is approximately 74 feet tall and can weigh as much as 800 tons. In an AP 1000 steam generator there are two different loops of water: the primary water loop and the secondary water loop. The components in a steam generator are split into the two different loops: the primary water loop components and the secondary water loop components. In figure 2 all of the components are labeled, and the primary loop is in blue and the secondary loop is in pink.

Figure 1: 3D View of a Steam Generator
From modelbuilders.net

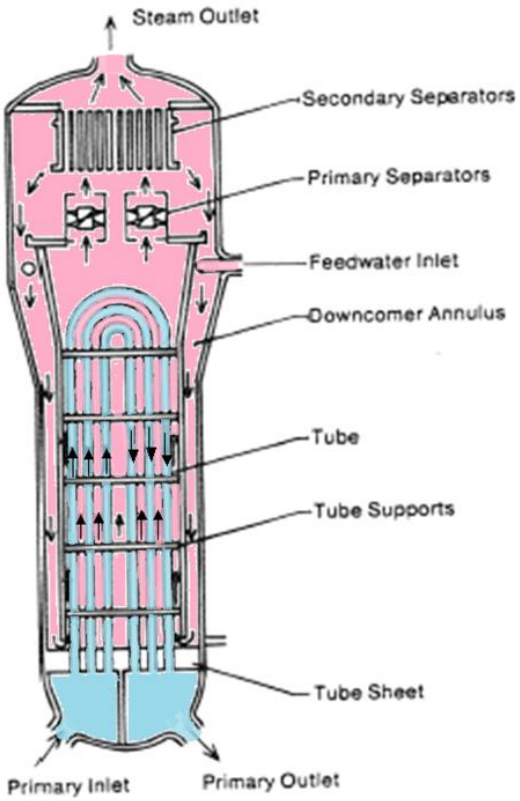

Figure 2: Components of a Steam Generator
From thermopedia

PRIMARY WATER LOOP

The primary loop is where the water that is hot exchanges the heat to the water in the secondary loop. The water in the secondary loop will become steam. The loop's foremost goal is to exchange as much heat to the second water loop as possible. In figure 1 the primary loop is blue. The primary water loop components include the nozzle, tube sheet, tubes, tube supports, and primary outlet.

Inlet Nozzle

The inlet nozzle is where the water comes in to go through the primary loop. All the water that goes in through the inlet nozzle goes through the primary outlet at the same rate: 416 lb/sec. This nozzle has water coming in to the steam generator with a pressure of 2500psia. For a comparison the normal air pressure is 14.7psia. The temperature of the water coming through the inlet nozzle is at 650°F, and boiling water at normal air pressure is 212°F. The water coming in is at a very high pressure and a high temperature.

Tubes

There are many tubes in a steam generator, and each are very thin. There are 10,025 tubes inside the generator, and one tube is about three-quarters of an inch in diameter. The tubes are where the heat is exchanged to the secondary water loop. The tubes are usually made out of nickel chromium iron Alloy 690 which allows easy heat exchange.

Tube Sheet

The tube sheet is where the tubes go into the steam generator. The tube sheet is a plate with holes in it; the holes are in a pattern that allows the tubes to go through. This plate is also made of the same material as the tubes; nickel chromium iron Alloy 690, and it is 31.13 inches thick. When the hot water goes through the tubes; the plate and the tubes both expand and touch which then make a seal.

Tube Supports

The tube supports do exactly what the component title says; they are the supports of tubes going through the steam generator. The tube supports are needed because the tubes are thin and long. Since there is so much water moving around in the steam generator the tubes are not very stable on their own, and supports are needed. The supports are made of the same material as the tubes and tube sheet, and are placed at varying intervals on the tubes.

Primary Outlet

The primary outlet is where the water which has gone through the tubes leaves the steam generator. The outlet water pressure is still 2500psia (same as the inlet nozzle pressure), but the temperature has lowered to 600°F, 50°F less than the inlet nozzle temperature.

SECONDARY WATER LOOP

The secondary water loop is where the water becomes steam and then will leave the steam generator to turn the turbine. The secondary loop's main goal is to get hot enough to create really hot steam. The secondary loop in figure 2 is pink. The secondary water loop components include the: feedwater inlet, downcomer annulus, primary separators, secondary separators, and steam outlet.

Feedwater Inlet

The feedwater inlet is where the secondary water loop starts. This is where the water comes in to be able to go over the hot tubes. This inlet temperature is 440°F, and at a pressure of 1200psia. This inlet is at the same height of the top of the tubes but it is right above the downcomer annulus.

Downcomer Annulus

The downcomer annulus is part of the steam generator's shape that makes the water get pushed down toward the bottom of the steam generator. This water is pushed down so the cooler water can flow over the tubes of the primary loop. This component goes around the steam generator like a ring.

Primary Separators

The primary separators are the first place where the steam and hot water is separated. This is necessary because the steam needed to turn the turbine needs to be very hot and without any liquid water in the air. This separator has swirl vane moisture separators, figure 3 gives a visual of what each little tube in the primary separator looks like up close and inside. A primary separator makes the steam move around so much that it is very difficult to have water droplets continue up with the steam.

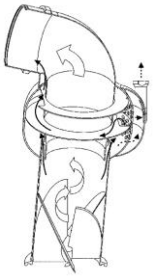

Figure 3 Swirl Vane Moisture Separator
From patentimages

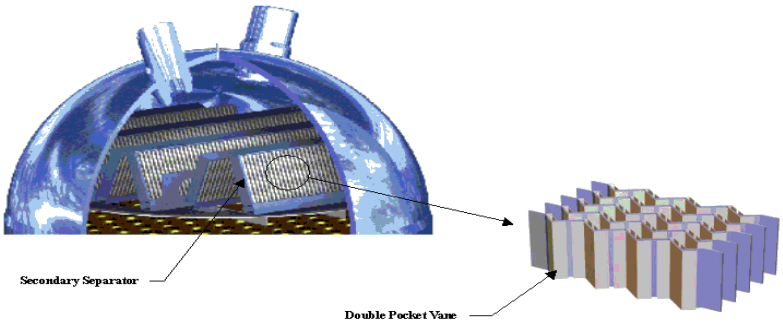

Figure 4 Secondary Separator
From thermopedia.com

Secondary Separators

The secondary separator is the final separator before the steam leaves the steam generator. This is where the steam goes through the double packet dryer; a visual of this separator is figure 4. This is the last attempt to remove any liquid water droplets before the steam leaves the steam generator. This is very similar to the primary separator, but there are more surfaces for the liquid droplets to attach to and separate from the steam.

Steam Outlet

The steam outlet is the opening in the top of the steam generator where the steam leaves. The temperature of the steam leaving the generator is 557°F and a pressure of 836psia. The rate the steam leaves the generator is 7,490,000 lb/hour (2,080.6 lb/second). After the steam outlet the steam goes through a pipe to the turbine to create power.

CONCLUSION

AP 1000 steam generators are where water is changed into steam which then goes to the turbine to create power. The primary loop exchanges the heat from the radioactive fuel to the secondary loop which is turned into the steam. The primary loop comes into the steam generator and goes through very thin tubes to heat up the secondary loop. After heating the secondary loop the water in the primary loop is cooler and leaves the steam generator. The primary loop water then goes back to the radioactive fuel to be heated again. After the primary water is heated again it goes back into the steam generator to start all over again. The secondary loop comes into the steam generator and is forced to the bottom of the steam generator. The water in the secondary loop moves from the bottom to the top while being heated by the water in the primary loop. When the secondary water turns into steam it goes through the primary and then the secondary separators to remove any liquid water droplets. After all or almost all of the liquid water droplets are removed from the steam, the steam leaves the steam generator. The steam travels down a pipe to the turbine to create power. After the power is created the steam goes to a condenser and starts all over again at the steam generator. Without a steam generator in an AP 1000 nuclear reactor, power cannot be made and then there is no point to a nuclear power station.

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