

Boiling

Water

Reactor

The core of a typical boiling water reactor (BWR) contains about 100 tons of nuclear fuel.

The fuel consists of uranium dioxide pellets loaded in metal fuel rods placed in a square array called a fuel bundle. BWRs like Browns Ferry and Peach Bottom have 764 fuel bundles in their cores.

BWRs operate for 18 to 24 months between refueling outages. During refueling, roughly one-third of the fuel bundles are removed from the core to the spent fuel pool and replaced with fresh fuel bundles.



The core is housed within the reactor pressure vessel (RPV). The RPV is forged of steel that is approximately seven inches thick. Steel plates are welded together to form a hollow cylinder. A domed lower head is welded to the bottom side of the cylinder. A domed upper head is bolted to a flange on the top side of the cylinder.

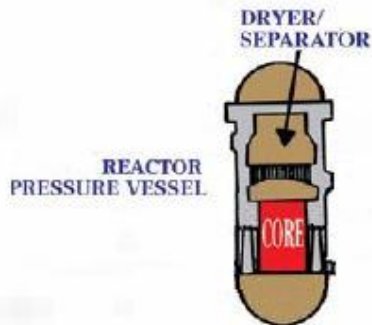
During refueling, the upper head is unbolted and removed to provide access to the core and RPV internals.

REACTOR
PRESSURE VESSEL



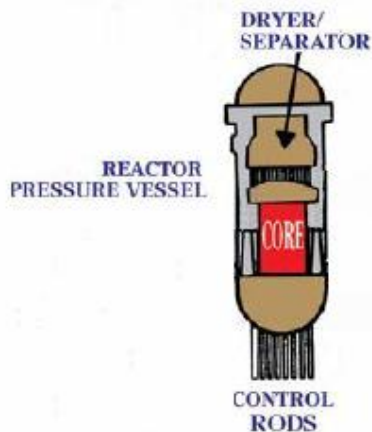
As the name implies, the water entering the reactor vessel of an operating BWR boils as it is heated passing upward through the reactor core.

The steam separator and steam dryer are located inside the reactor vessel above the reactor core. The steam exiting the reactor core is forced through them. They function to remove water droplets from the steam, returning the water to the reactor core area and providing along “dry” steam from the reactor vessel.



Control rods govern the power level of the core. Control rods contain material like boron that absorb the neutrons emitted by splitting atoms. Control rods are cross-shaped. A control rod slips between within four fuel bundles when inserted in the core.

Control rods enter the reactor core from below. When fully withdrawn, the control rods remain within the reactor pressure vessel in the lower plenum region. The control rods positioned by hydraulic pistons. Water pressure applied beneath the piston moves a control rod into the reactor core. Water pressure applied above the piston moves a control rod out of the reactor core.



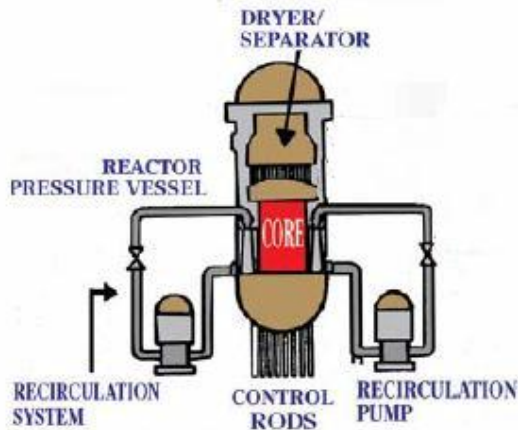
During normal operation, control rods can be incrementally inserted and withdrawn in 6-inch notches.

During a reactor trip, control rods are fully inserted into the core within a handful of seconds to interrupt the nuclear chain reaction and shut down the core.

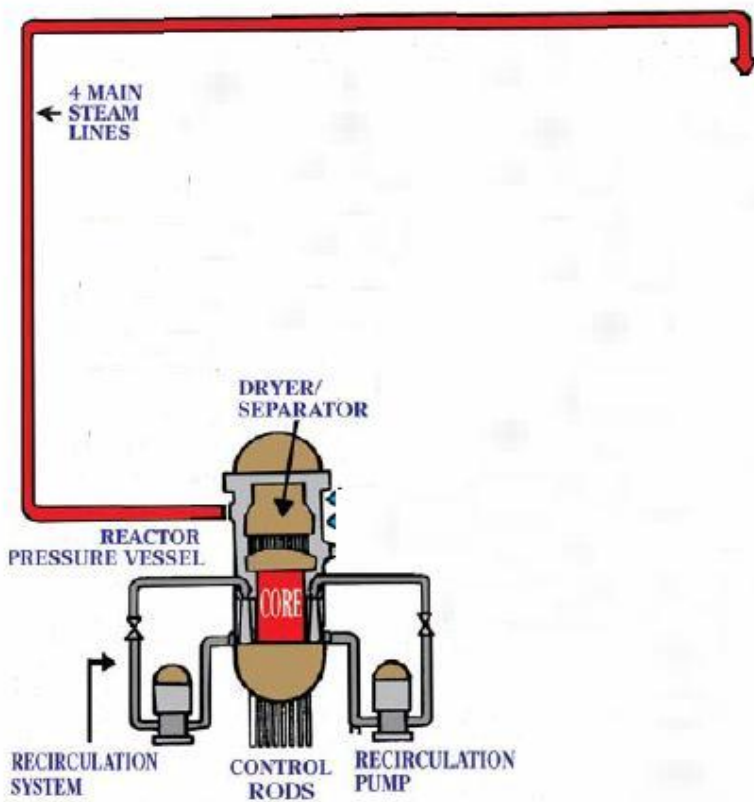
The reactor recirculation system consists of two loops. Each loop contains a recirculation pump and motor along with isolation and control valves.

The recirculation system simply takes water from the reactor vessel and returns it to the reactor vessel where it flows through jet pumps into the lower dome beneath the reactor core.

The operators use the recirculation system to control the reactor power level. By increasing the recirculation pump flow rates, more water enters the reactor core region to slow down more neutrons and allow more fissions to increase the reactor core output.



Conversely, decreasing the recirculation pump flow rates pushes less water through the reactor core, fewer neutrons are slowed down and the reactor core output decreases.

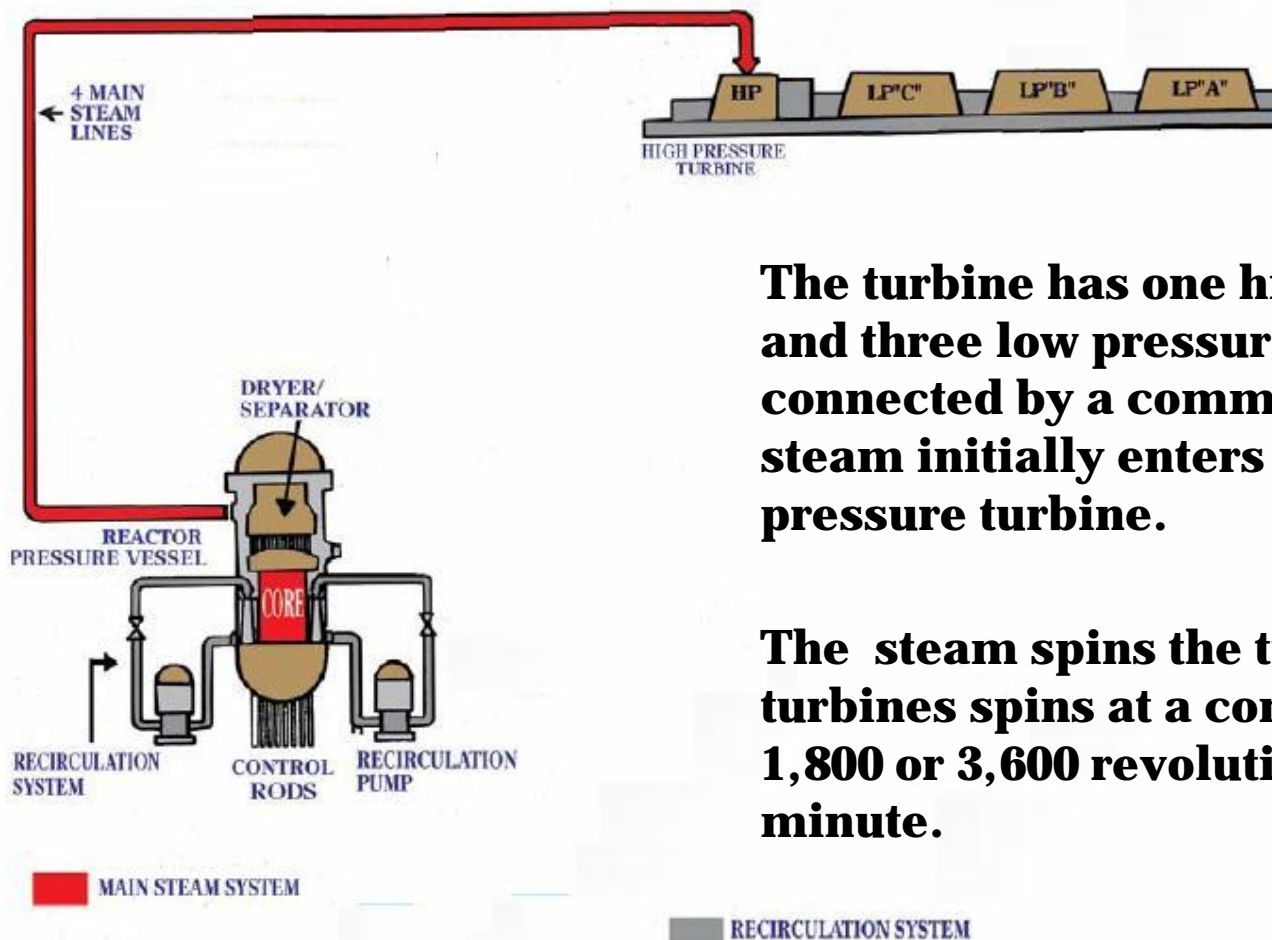


The main steam system transports “dry” steam from the reactor pressure vessel to the turbine via four pipes.

The amount of steam produced is proportional to the reactor core’s power level. As core power level increases, more steam is produced.

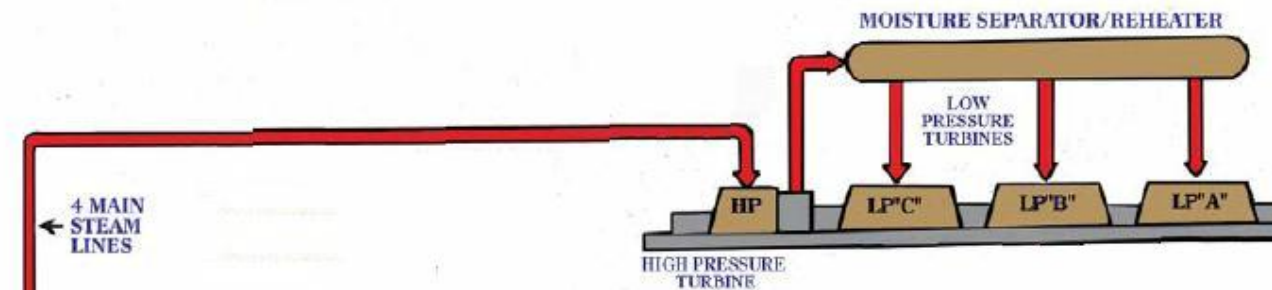
 MAIN STEAM SYSTEM

 RECIRCULATION SYSTEM

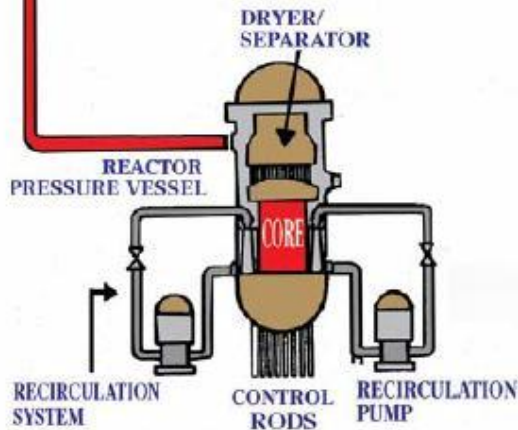


The turbine has one high pressure and three low pressure turbines all connected by a common shaft. The steam initially enters the high pressure turbine.

The steam spins the turbines. The turbines spins at a constant rate of 1,800 or 3,600 revolutions per minute.

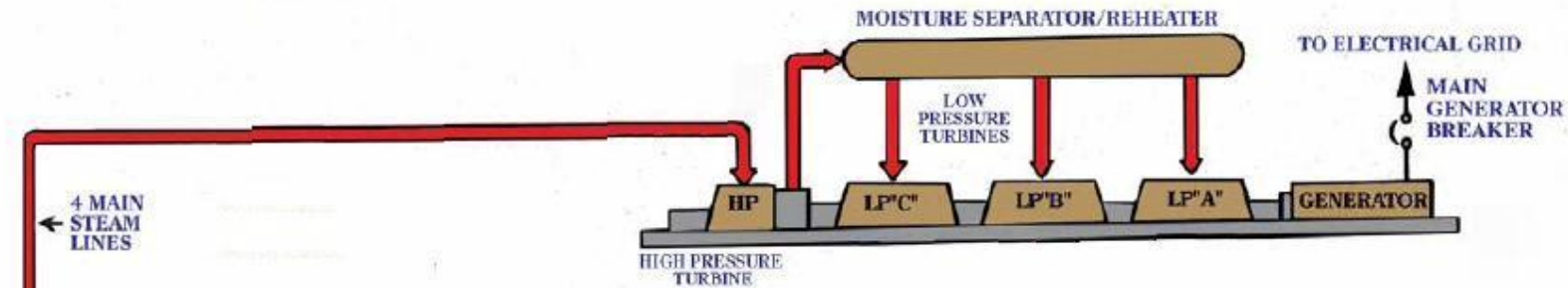


The steam exits the high pressure turbine and enters the moisture separator / reheater (MSR). The MSR removes any water droplets formed in the steam as it lost energy passing through the high pressure turbine. The steam exiting the MSE splits into three paths to flow in parallel through the low pressure turbines.

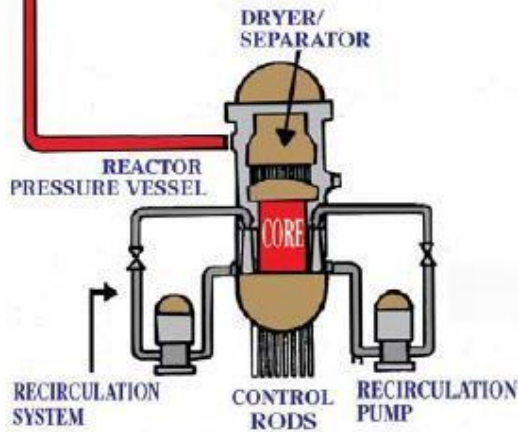


■ MAIN STEAM SYSTEM

■ RECIRCULATION SYSTEM

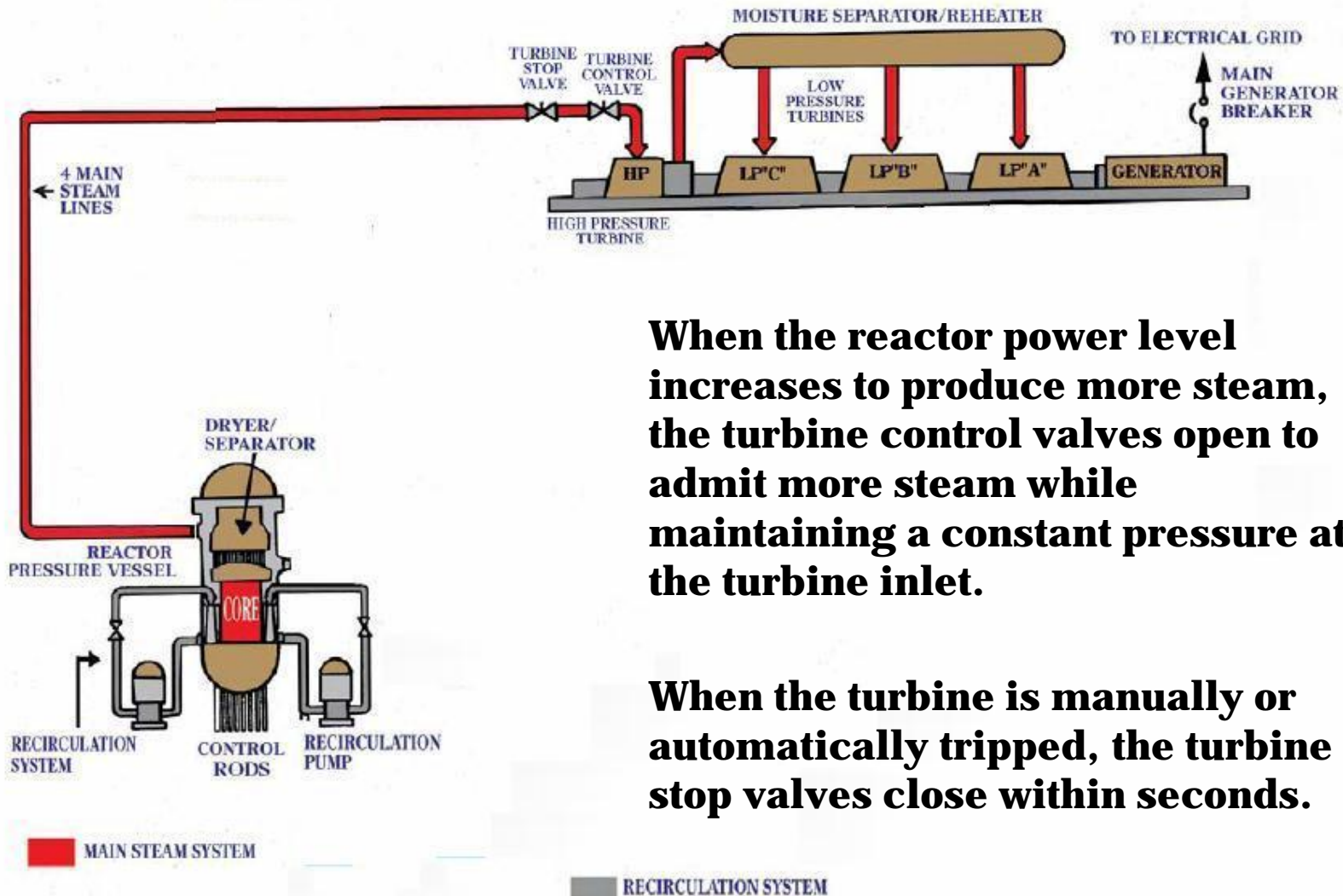


The generator rotor is connected to the turbine shaft. The electricity produced by the generator flows to an electrical transformer that increases the voltage level to that of the transmission system. Power lines radiate from the site to transport electricity to commercial and residential customers.



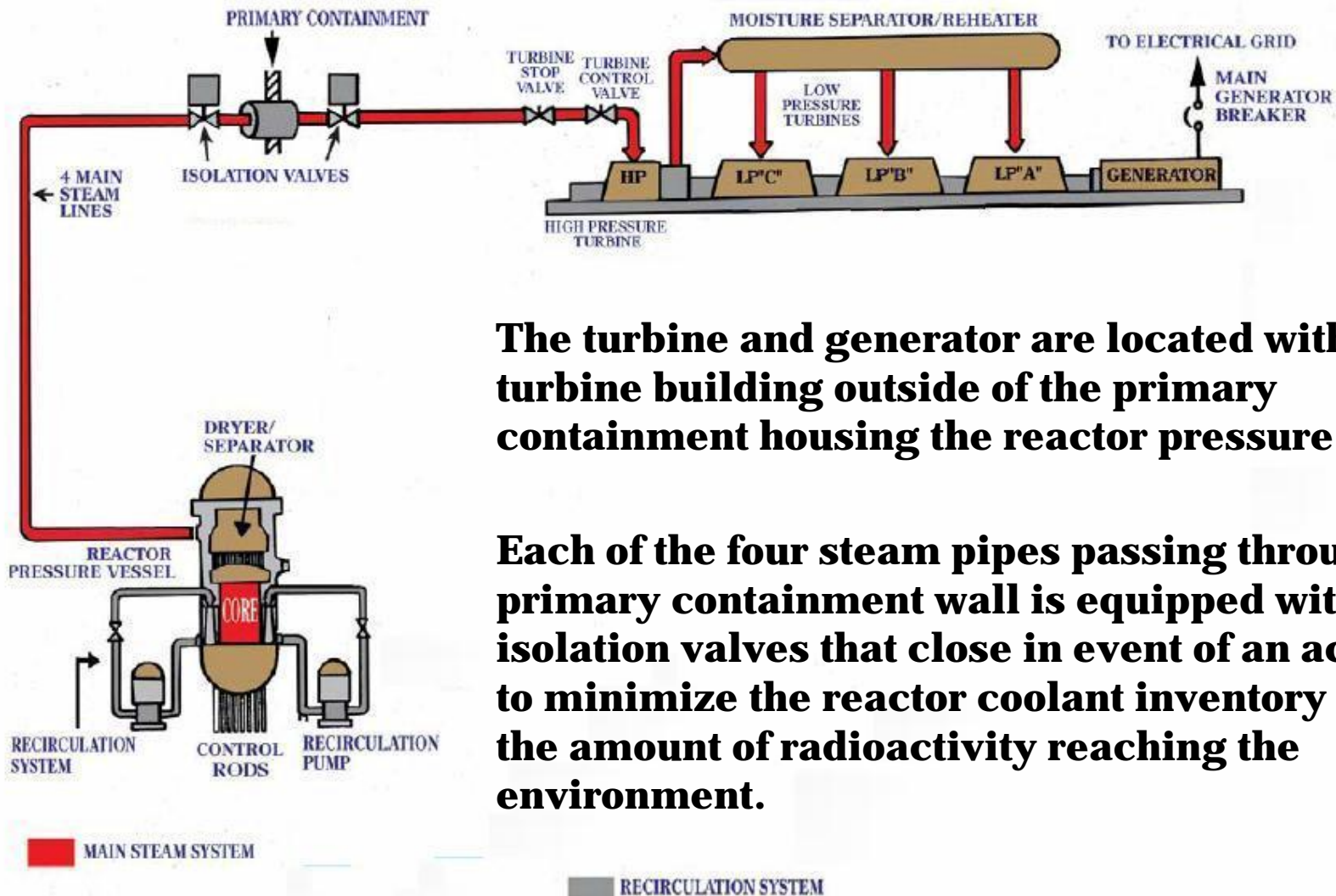
■ MAIN STEAM SYSTEM

■ RECIRCULATION SYSTEM



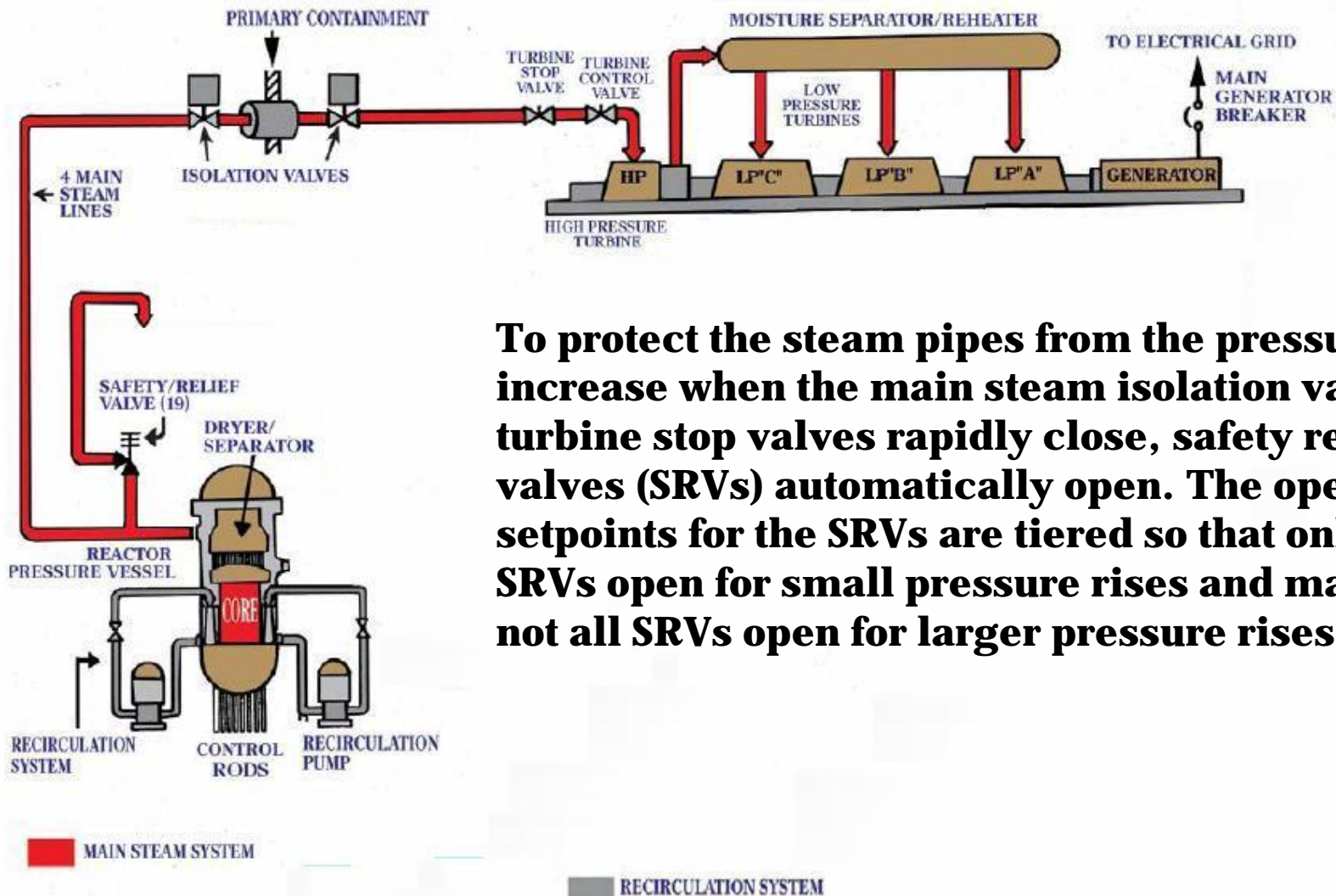
When the reactor power level increases to produce more steam, the turbine control valves open to admit more steam while maintaining a constant pressure at the turbine inlet.

When the turbine is manually or automatically tripped, the turbine stop valves close within seconds.

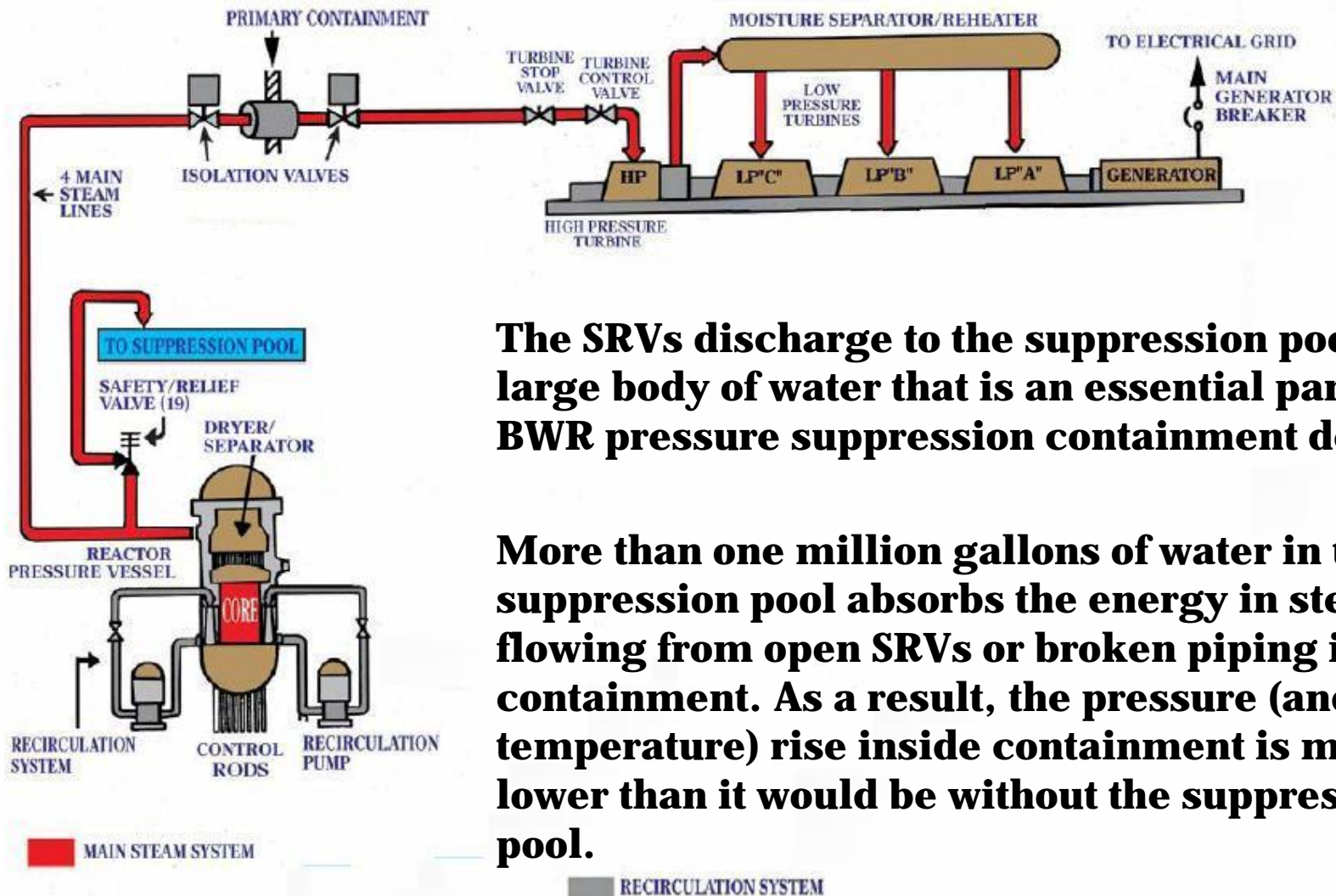


The turbine and generator are located within the turbine building outside of the primary containment housing the reactor pressure vessel.

Each of the four steam pipes passing through the primary containment wall is equipped with two isolation valves that close in event of an accident to minimize the reactor coolant inventory loss and the amount of radioactivity reaching the environment.

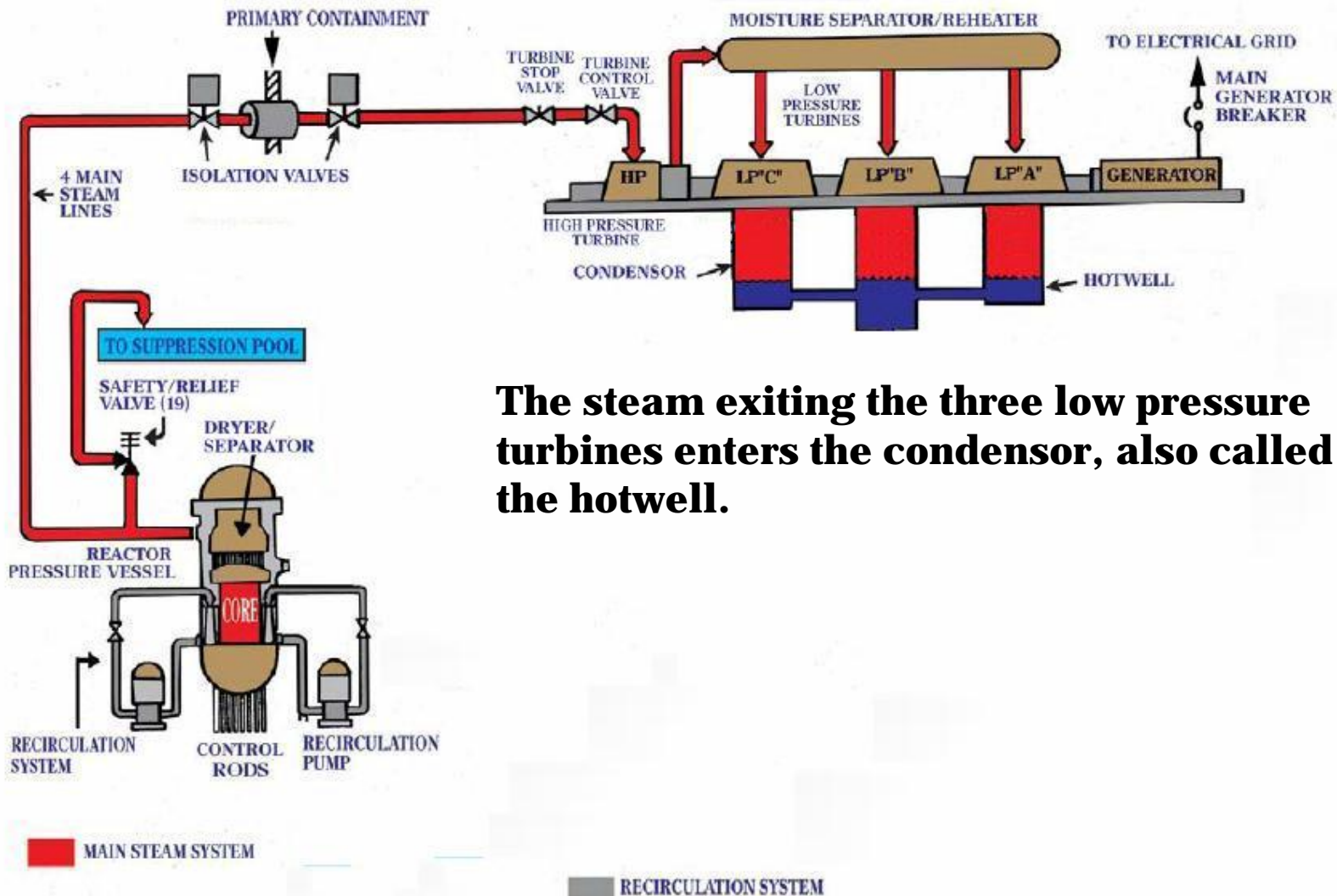


To protect the steam pipes from the pressure increase when the main steam isolation valves or turbine stop valves rapidly close, safety relief valves (SRVs) automatically open. The opening setpoints for the SRVs are tiered so that only a few SRVs open for small pressure rises and many if not all SRVs open for larger pressure rises.

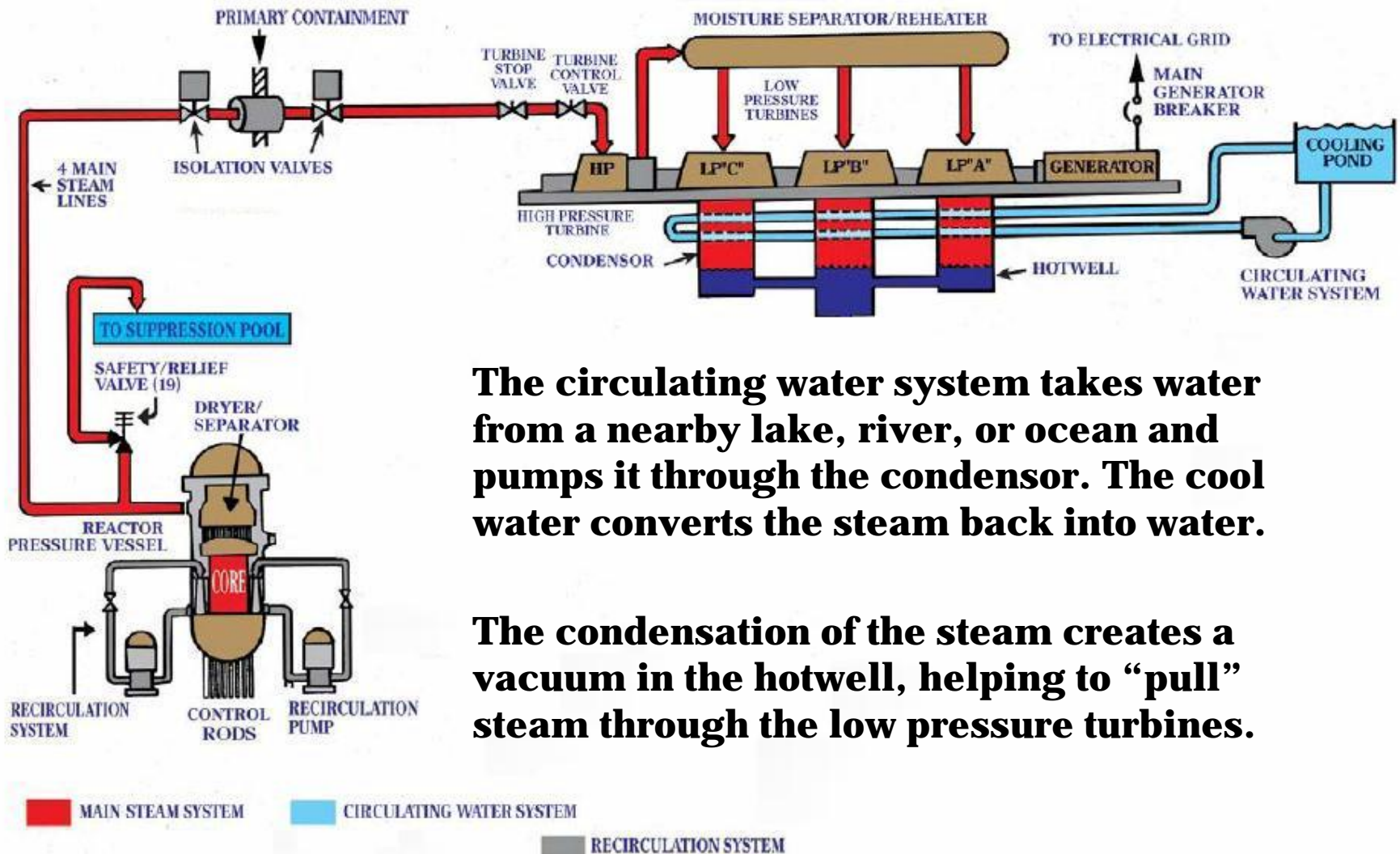


The SRVs discharge to the suppression pool, a large body of water that is an essential part of the BWR pressure suppression containment design.

More than one million gallons of water in the suppression pool absorbs the energy in steam flowing from open SRVs or broken piping inside containment. As a result, the pressure (and temperature) rise inside containment is much lower than it would be without the suppression pool.

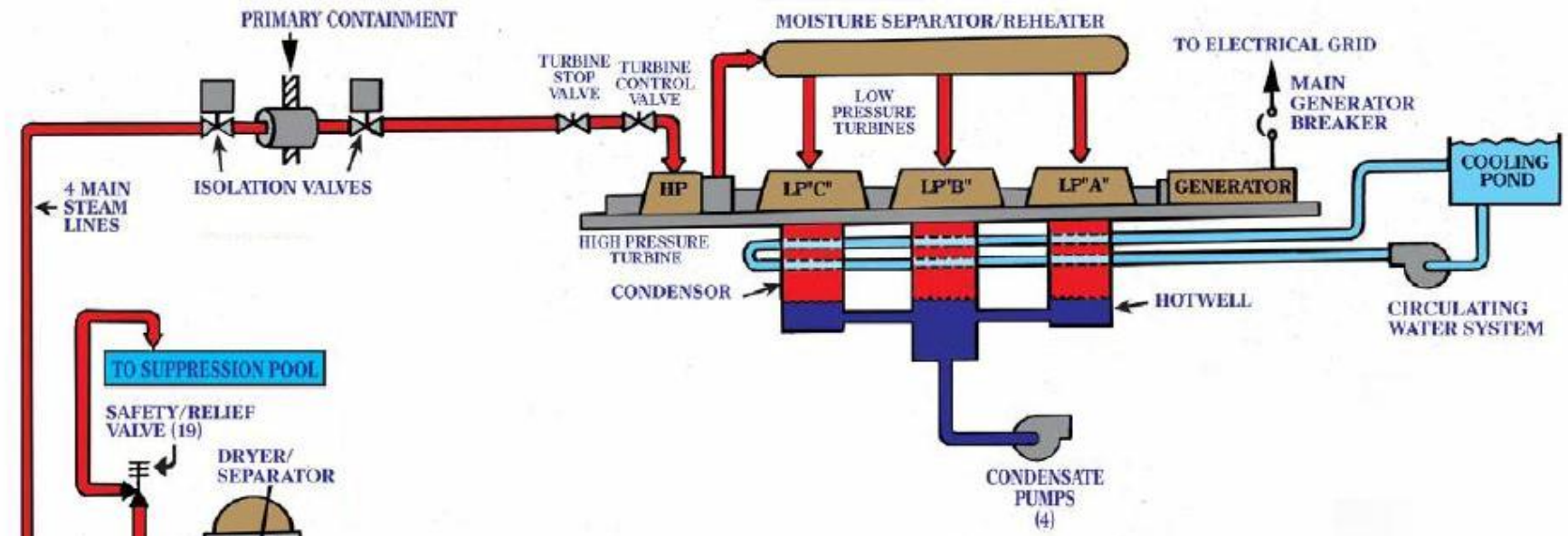


The steam exiting the three low pressure turbines enters the condenser, also called the hotwell.



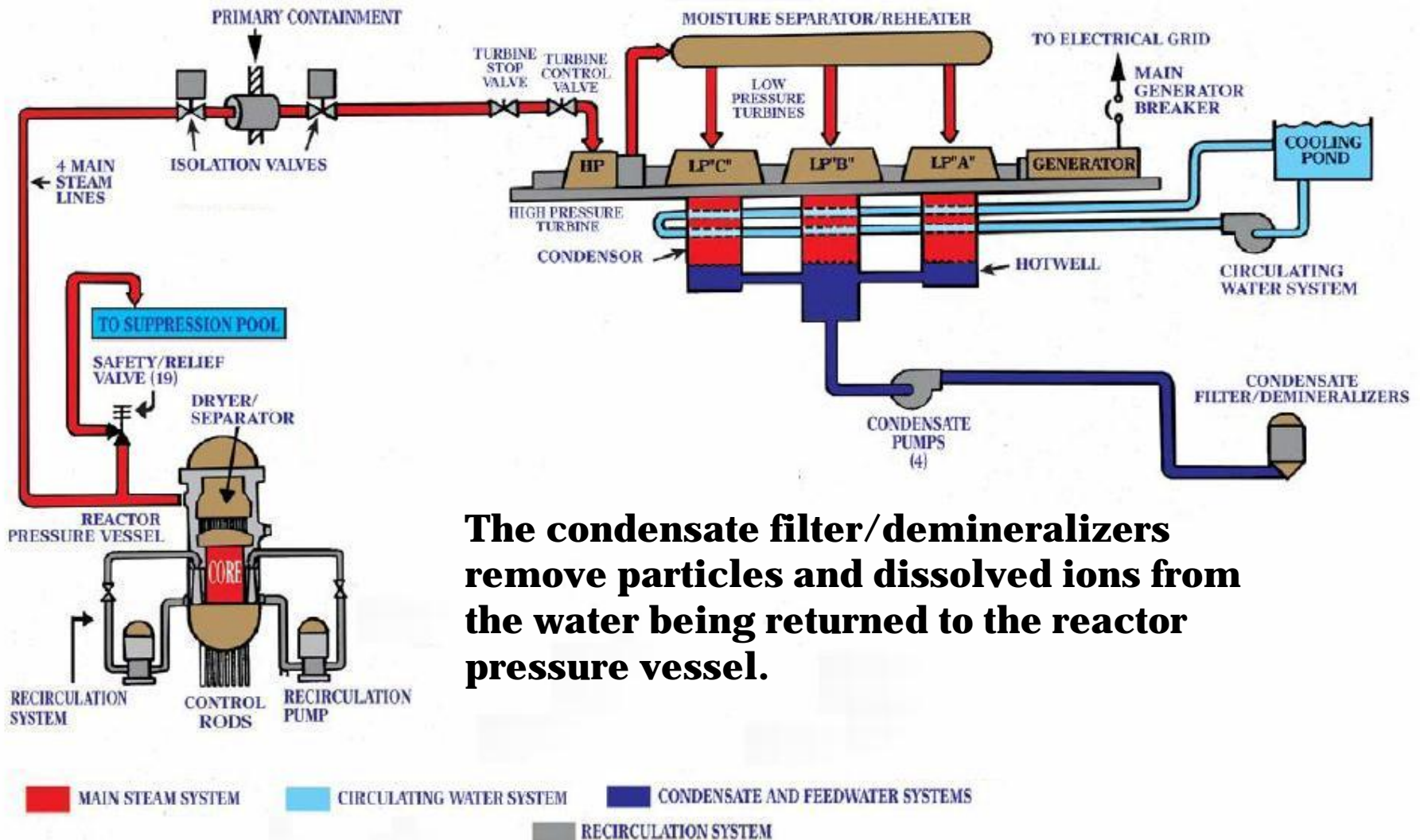
The circulating water system takes water from a nearby lake, river, or ocean and pumps it through the condenser. The cool water converts the steam back into water.

The condensation of the steam creates a vacuum in the hotwell, helping to “pull” steam through the low pressure turbines.

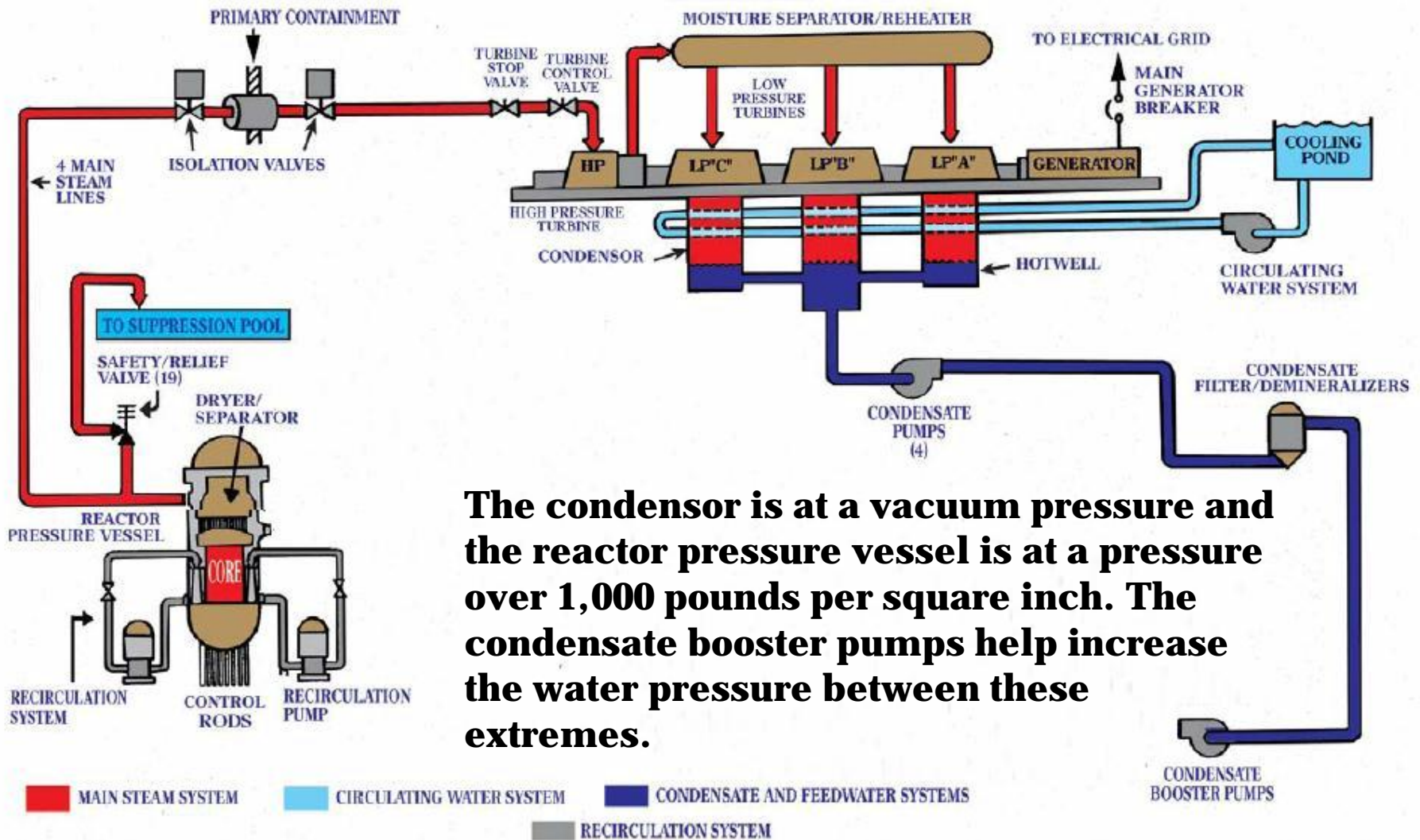


The condensate pumps, powered by electric motors, take water from the hotwell.

■ MAIN STEAM SYSTEM
 ■ CIRCULATING WATER SYSTEM
 ■ CONDENSATE AND FEEDWATER SYSTEMS
■ RECIRCULATION SYSTEM

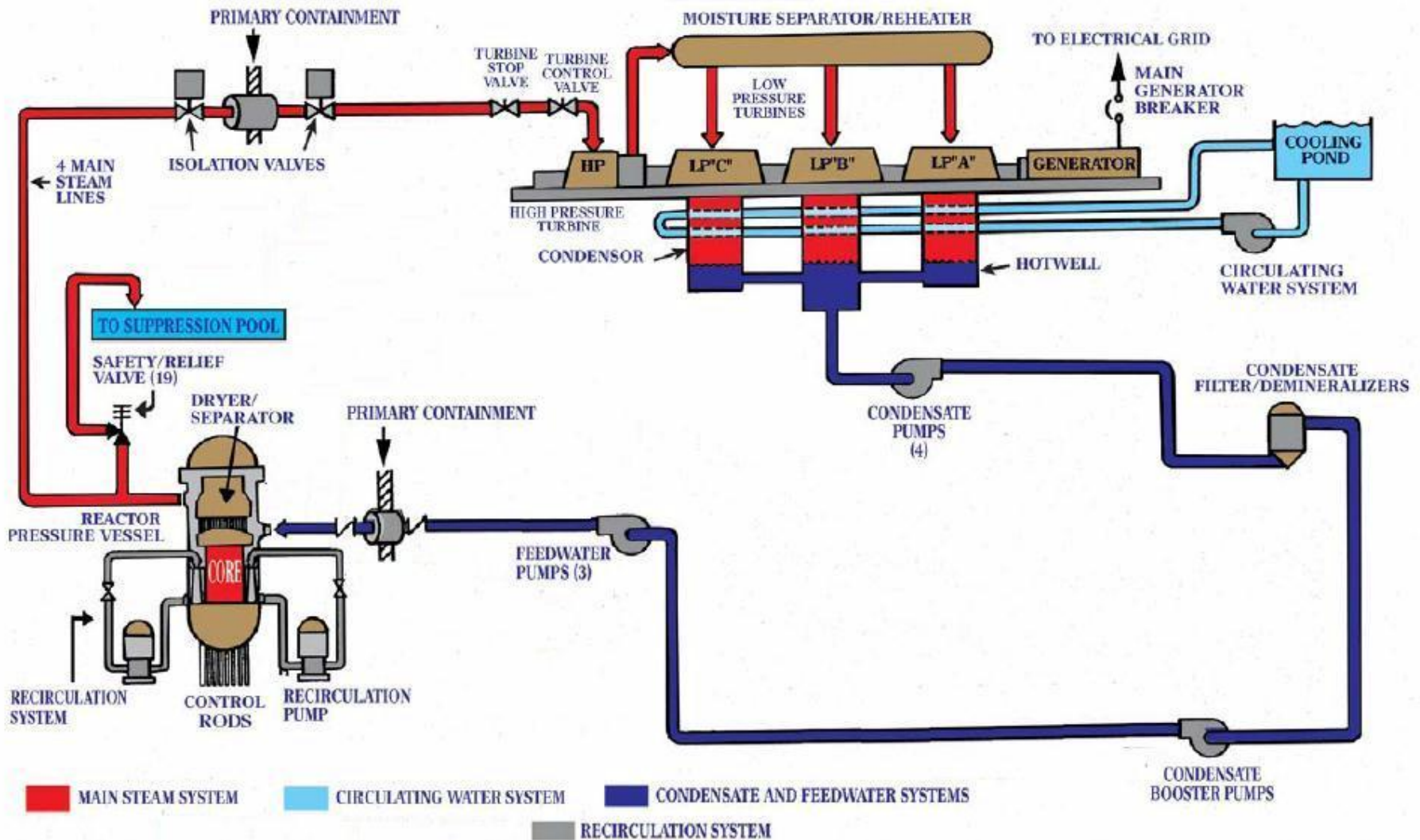


The condensate filter/demineralizers remove particles and dissolved ions from the water being returned to the reactor pressure vessel.

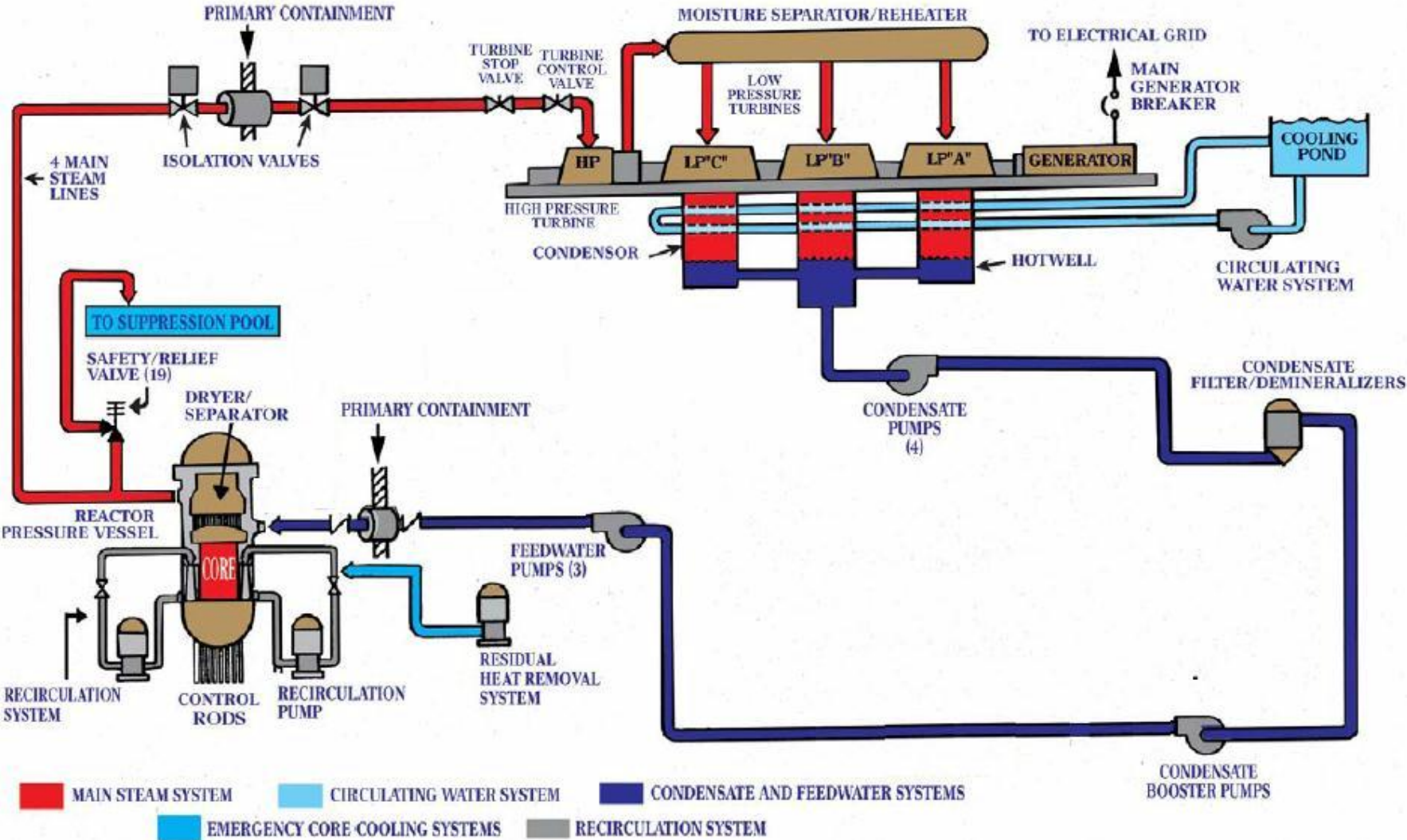


The condensor is at a vacuum pressure and the reactor pressure vessel is at a pressure over 1,000 pounds per square inch. The condensate booster pumps help increase the water pressure between these extremes.

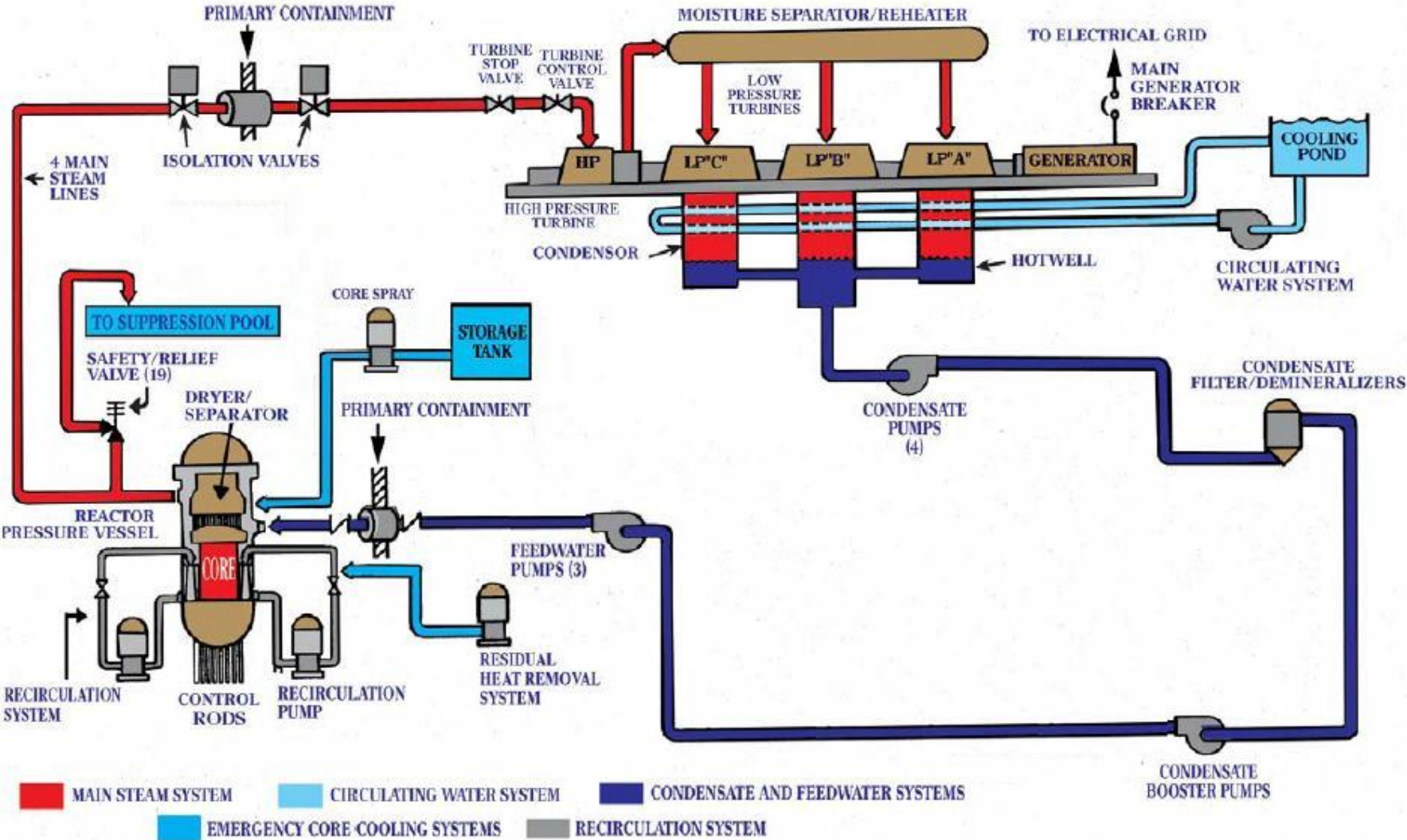
The steam-driven feedwater pumps send water into the primary containment and the reactor pressure vessel. Each feedwater pipe is equipped with a check valve, not an isolation valve, to enable flow to enter – but not leave – the primary containment and reactor vessel.



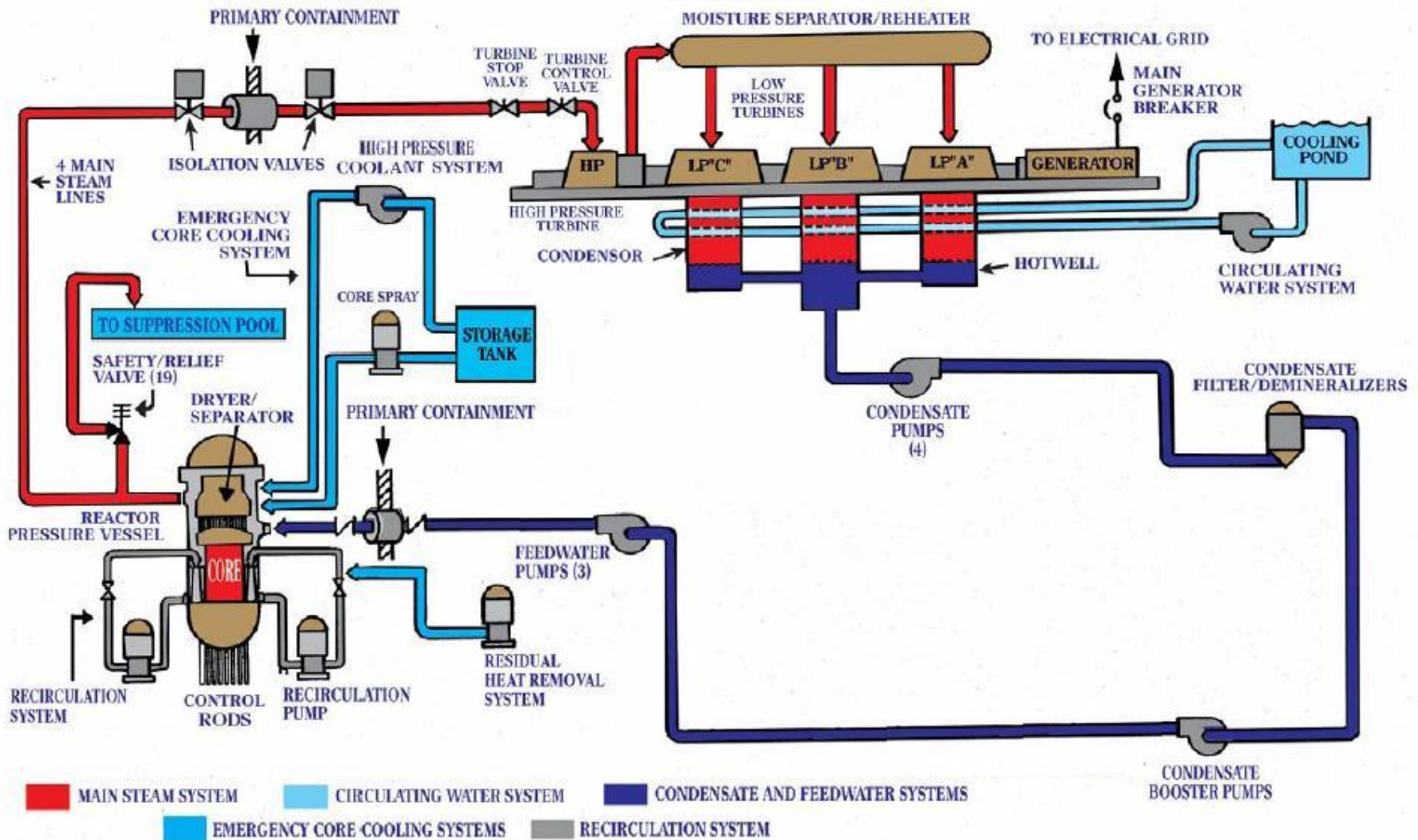
The residual heat removal (RHR) system performs many functions including cooling when the reactor is shut down, cooling the suppression pool water during normal operation and accidents, and providing makeup water to the reactor pressure vessel during accidents.



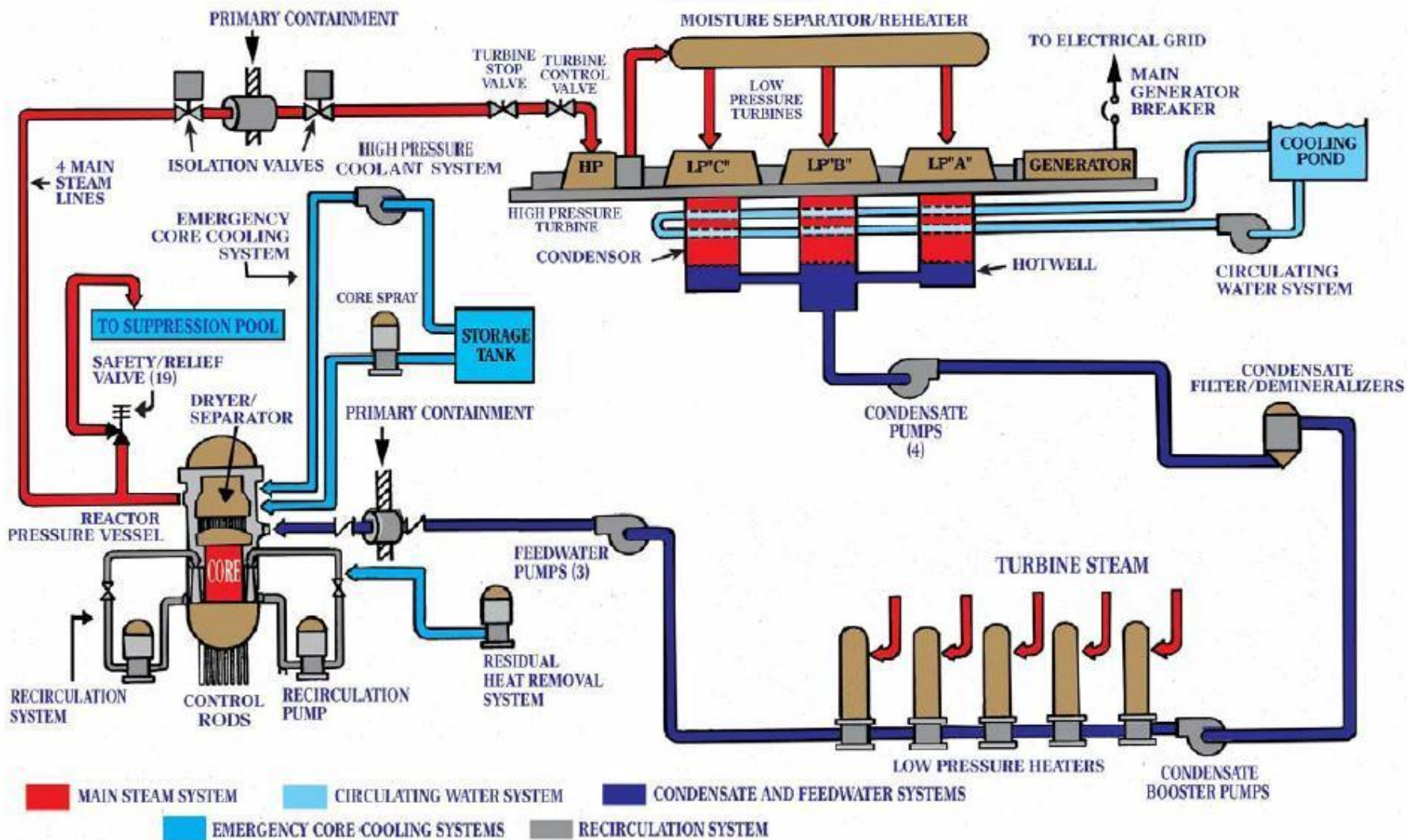
The core spray system has a single function: in event of an accident, the core spray pumps transfer water from the suppression pool (or storage tank) to the reactor pressure vessel to compensate for inventory lost through a large broken pipe.



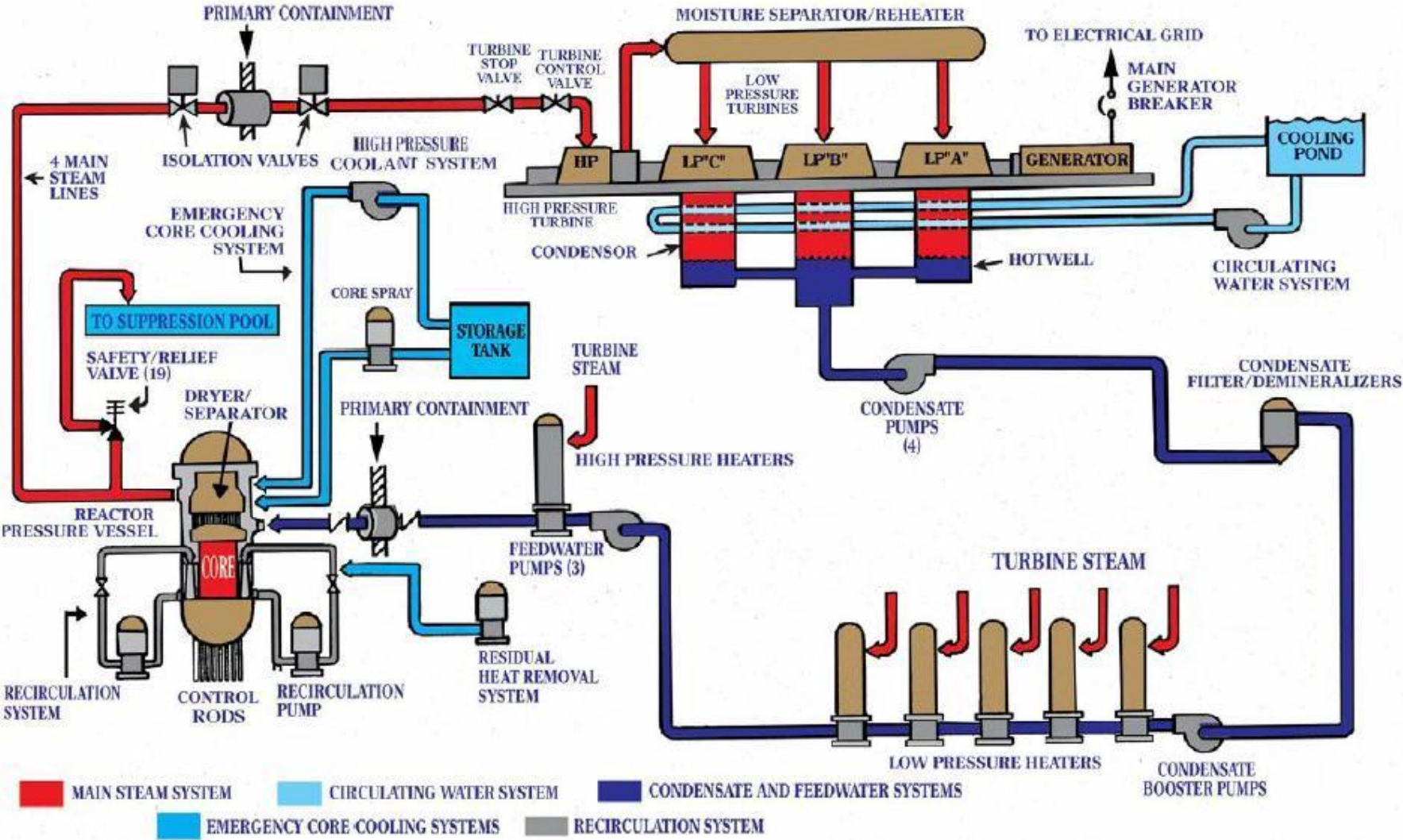
In event of a small broken pipe, the high pressure coolant injection (HPCI) system uses a steam-driven pump to transfer water from a storage tank (or suppression pool) to the reactor pressure vessel.



Several stages of low pressure heaters use steam from the turbine to warm up the water being returned to the reactor vessel. This improves the efficiency of the plant as less reactor power is wasted warming water and more goes to boiling water and making steam.



The high pressure heaters use turbine steam to warm the water up to 375 to 400 degrees Fahrenheit. Water leaving the condenser has its pressure increased by the condensate, condensate booster, and feedwater pumps. The increasing pressure allows its temperature to rise from around 100F to nearly 400F before entering the reactor vessel.



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