Simulator of

Nuclear Power Plant Operation

Game Version: V 2.2.24.191

Manual Version: 1.8
Last Manual Update: 11/06/2025

Disclaimer

This manual is intended solely for use in conjunction with NUCLEARES game. Under no circumstances should the information provided in this manual be considered applicable or authoritative for any real-world applications or activities. The simulation within the game incorporates modified laws of physics and chemistry to enhance gameplay, and as such, it does not strive for exact replication of real-world reactor operation.

The content presented here is designed exclusively to assist players in understanding the mechanics and dynamics of the simulation game. Any resemblance to real-world nuclear operations is purely coincidental, and the simulation should not be regarded as a substitute for proper training, education, or professional guidance in the field of nuclear energy.

The creators of the simulation game have taken creative liberties to balance realism with gameplay enjoyment. Therefore, users should be aware that the information presented in this manual is fictionalized and may deviate from actual nuclear reactor operations.

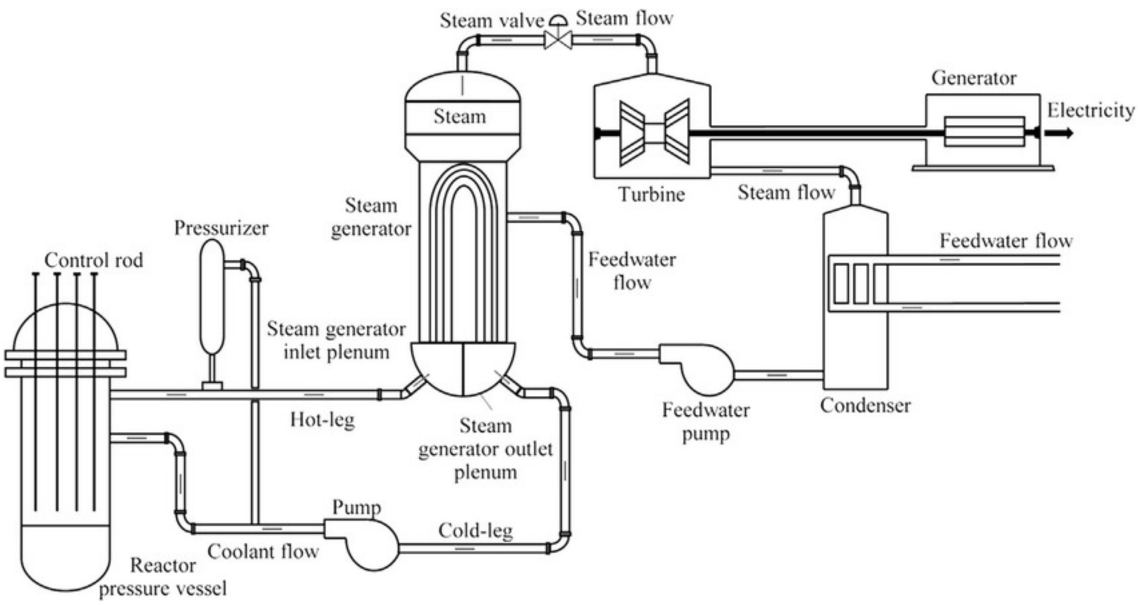
Players and users are strongly advised not to attempt to apply the knowledge gained from this manual to real-world scenarios, as doing so may lead to incorrect understanding of nuclear processes and potential safety hazards. Always rely on accurate, verified information and adhere to established guidelines and regulations when dealing with real-world nuclear operations.

By accessing and utilizing this manual, users acknowledge and accept the fictional nature of the content, understanding its exclusive purpose for enhancing the gaming experience. The creators of the simulation game disclaim any responsibility for the misuse or misapplication of the information presented herein in any real-world context.

Index

PRESSURIZED WATER REACTOR (PWR)

A Pressurized Water Reactor (PWR) is a complex system engineered to efficiently harness the energy produced by nuclear fission to generate electricity. Deep within the reactor vessel lies the heart of the PWR – the reactor core. Comprised of numerous fuel assemblies, typically containing uranium dioxide fuel pellets, this core facilitates controlled nuclear fission reactions. As uranium atoms split, they release tremendous amounts of heat energy in the form of radiation.



To manage the intense heat generated within the reactor core, a primary cooling circuit is employed. Water, acting as both a coolant and a moderator, circulates through the core, absorbing heat from the fuel assemblies. This heated water then flows through a network of pipes to transfer its thermal energy to the next stage of the system.

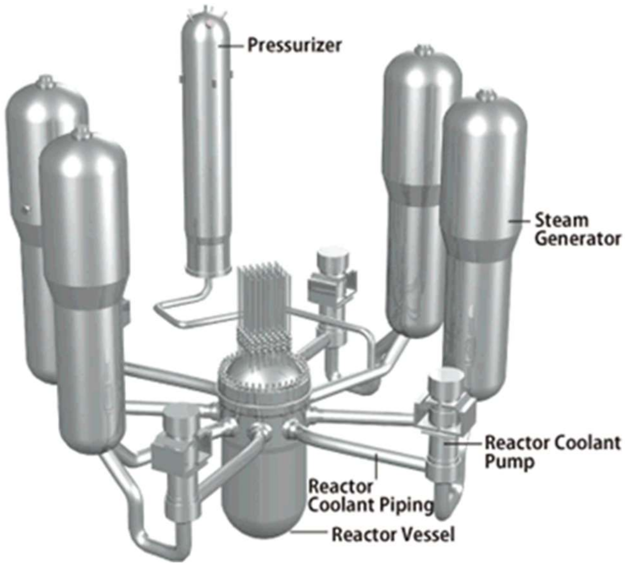
Within the primary cooling circuit, a critical component called the pressurizer plays a pivotal role. It maintains the water within the circuit at a high pressure, typically around 150 times atmospheric pressure. By doing so, the pressurizer ensures that the water remains in a liquid state, even at temperatures exceeding 300°C (572°F), preventing it from boiling within the reactor core.

The primary cooling circuit, now carrying heated water, directs it to the steam generator, a vital component where heat exchange occurs. Here, the hot water from the primary circuit transfers its thermal energy to a separate loop of water, typically known as the secondary circuit. As the secondary water absorbs heat, it undergoes phase change, transforming into steam. This steam is then superheated and pressurized, ready for the next stage of the process.

The high-pressure steam generated in the steam generator is channeled towards turbines, imposing its force on turbine blades. As the steam expands and flows over the blades, it causes the turbines to rotate at high speeds. This rotational motion is converted into mechanical energy, driving the connected shaft of the electrical generator.

The rotating shaft of the turbines is mechanically linked to an electrical generator. As the shaft spins, it induces electromagnetic fields within the generator's stator windings, resulting in the generation of electrical energy. This electricity, in the form of alternating current (AC), is then transmitted to the power grid for distribution to consumers.

After passing through the turbines, the steam, now significantly depleted of its thermal energy, enters the condenser. Here, it encounters a series of cold-water tubes, causing it to condense back into liquid form. The condensed water, known as condensate, is then collected, and pumped back to the steam generator to restart the cycle.



The **Nucleares** company's reactor is experimental, therefore, it has some design modifications that make it unique. The plant has a central building with three floors: distribution on the ground floor, the control room on the middle floor and the auxiliary power room on the top floor.

A containment building for the core, a radioactive waste building and an operational crane to move the fuel blocks (only when the plant is shut down). And finally, a power generation building for the generating turbines and the electric turbine.

In essence, the Pressurized Water Reactor (PWR) operates as a finely tuned system of controlled nuclear reactions, heat exchange mechanisms, and energy conversion processes. Each component plays a crucial role in the overall functionality of the reactor, ensuring the safe and efficient generation of electricity.

COOLANT / MODERATOR

Light water is used as the primary coolant. Water enters through the bottom of the reactor's core and is heated as it flows upwards through the reactor core. The water remains liquid despite the high temperature due to the high pressure in the primary coolant loop, usually around 155 bar (15.0 MPa 153 atm, 2,250 psi). The water in a PWR cannot exceed a temperature of 647 K (374 °C; 705 °F) or a pressure of 22.064 MPa (3200 psi or 218 atm), because those are the critical point of water.

Pressurized water reactors, like all thermal reactor designs, require the fast fission neutrons to be slowed (a process called moderation or thermalizing) to interact with the nuclear fuel and sustain the chain reaction. In PWRs the coolant water is used as a moderator by letting the neutrons undergo multiple collisions with light hydrogen atoms in the water, losing speed in the process. This "moderating" of neutrons will happen more often when the water is denser (more collisions will occur).

The use of water as a moderator is an important safety feature of PWRs, as an increase in temperature may cause the water to expand, giving greater 'gaps' between the water molecules and reducing the probability of thermalization — thereby reducing the extent to which neutrons are slowed and hence reducing the reactivity in the reactor. Therefore, if reactivity increases beyond normal, the reduced moderation of neutrons will cause the chain reaction to slow down, producing less heat. This property, known as the negative temperature coefficient of reactivity, makes PWR reactors very stable.

This process is referred to as 'Self-Regulating', i.e. the hotter the coolant becomes, the less reactive the plant becomes, shutting itself down slightly to compensate and vice versa. Thus, the plant controls itself around a given temperature set by the position of the control rods.

ENRICHED URANIUM DIOXIDE FUEL

After enrichment, the uranium dioxide (UO2) powder is fired in a high-temperature, sintering furnace to create hard, ceramic pellets of enriched uranium dioxide. The cylindrical pellets are then clad in a corrosion-resistant zirconium metal alloy Zircaloy which are backfilled with helium to aid heat conduction and detect leakages.

The fuel used in a pressurized water nuclear reactor, specifically enriched uranium dioxide, plays a crucial role in the nuclear fission process.

Composition

Enriched uranium dioxide is the primary fuel employed in pressurized water nuclear reactors. It consists of uranium dioxide (UO2), where the uranium is intentionally enriched in the isotope uranium-235 (U-235) to increase its fissile properties. Enrichment is the process of increasing the concentration of uranium-235, the fissile isotope responsible for sustaining a chain reaction. The enrichment level in the fuel is carefully controlled to ensure efficient and sustained nuclear reactions.

Pellet Form

The enriched uranium dioxide is typically processed into small ceramic pellets. These pellets are designed to withstand the harsh conditions within the reactor core while providing a stable and controlled environment for nuclear fission. The pellets are then loaded into fuel rod assemblies. Each fuel rod contains a specific arrangement of these pellets, forming a structured assembly. These assemblies are inserted into the reactor core.

Moderation and Control

Within the reactor core, the uranium dioxide undergoes nuclear fission when bombarded by neutrons. The heat generated from fission reactions is moderated and controlled to maintain a steady and controlled release of energy. In a pressurized water reactor, water serves as both the coolant and the neutron moderator. The enriched uranium dioxide fuel interacts with the pressurized water to transfer heat efficiently while also moderating the speed of neutrons to sustain the fission process.

Energy Generation

As fission reactions continue, a significant amount of thermal energy is produced. This heat is utilized to produce steam, which then drives turbines connected to generators, ultimately generating electricity.

Over time, as the reactor operates, the fuel undergoes burnup, where fissile isotopes are consumed, and fission products accumulate. The management of fuel burnup is a key consideration in reactor operation and maintenance.

Safety Measures:

The design and characteristics of enriched uranium dioxide fuel are carefully engineered to ensure the safety and stability of the nuclear reactor. Emergency shutdown systems and control mechanisms are in place to manage the fuel under various conditions.

In summary, enriched uranium dioxide is a specialized fuel tailored for use in pressurized water nuclear reactors. Its composition, processing into pellets, and controlled use within the reactor core contribute to the efficient generation of nuclear power while prioritizing safety and stability.

DETERMINING THE FUEL LEVEL

Determining the remaining amount of fuel in a nuclear reactor based on the position of control rods involves monitoring the insertion or withdrawal of these rods within the reactor core.

Control Rods and Fuel Monitoring

Control rods are crucial components within a nuclear reactor responsible for regulating the rate of nuclear fission reactions. By adjusting the position of these rods, operators can control the neutron flux and, subsequently, the reactor's power output. Each control rod is equipped with position indicators that provide information about its location within the reactor core. These indicators are monitored by the reactor control system.

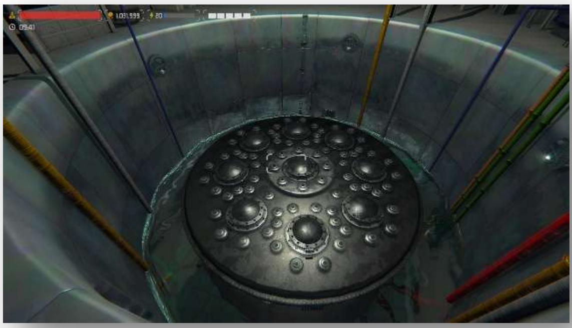
Fuel Burnup

As the reactor operates and nuclear reactions occur, the fuel undergoes burnup, meaning fissile isotopes are consumed. The position of control rods influences the distribution of neutron flux, affecting the burnup rate. When control rods are partially or fully withdrawn, more neutrons are available to initiate fission reactions, leading to an increase in reactor power. The position of the control rods is correlated with the power level of the reactor.

Control rod positioning is a key aspect of fuel management strategies. By strategically adjusting the position of control rods, operators can optimize fuel utilization, extending the overall lifespan of the fuel and maximizing energy output.

MEASURING THE CORE TEMPERATURE

In a nuclear reactor, the core is where nuclear fission takes place and generates heat. Due to the high radiation and temperature, it is not possible to directly measure the temperature of the nuclear fuel in the core accurately. Therefore, an indirect technique is used to measure the core temperature by measuring the temperature of the coolant that surrounds the core.



The coolant in a nuclear reactor circulates through the core, absorbs the heat generated by nuclear fission, and transports it through the cooling system. Since the coolant is in direct contact with the core, its temperature provides a good indication of the core temperature.

Moreover, the temperature of the fuel may vary in different parts of the core. By measuring the temperature of the coolant that surrounds the core, temperature differences in various parts of the core can be detected. This can be useful in detecting problems in the distribution of heat in the core and in preventing damage to the fuel.

Attention, if in game the fuel is exposed to high temperatures, it could be damaged and could even cause the core to explode.

In summary, it is impossible to directly measure the core temperature in a nuclear reactor due to the high radiation and temperature. Instead, an indirect technique of measuring the coolant temperature that surrounds the core is used to determine the core temperature and to detect problems in the heat distribution in different parts of the core.

MEASURING THE TEMPERATURE OF A CONTAINER

The correct temperature reading of a container cannot be obtained if it does not have sufficient liquid volume. This is because the temperature of the liquid in the container and its surroundings can be different.

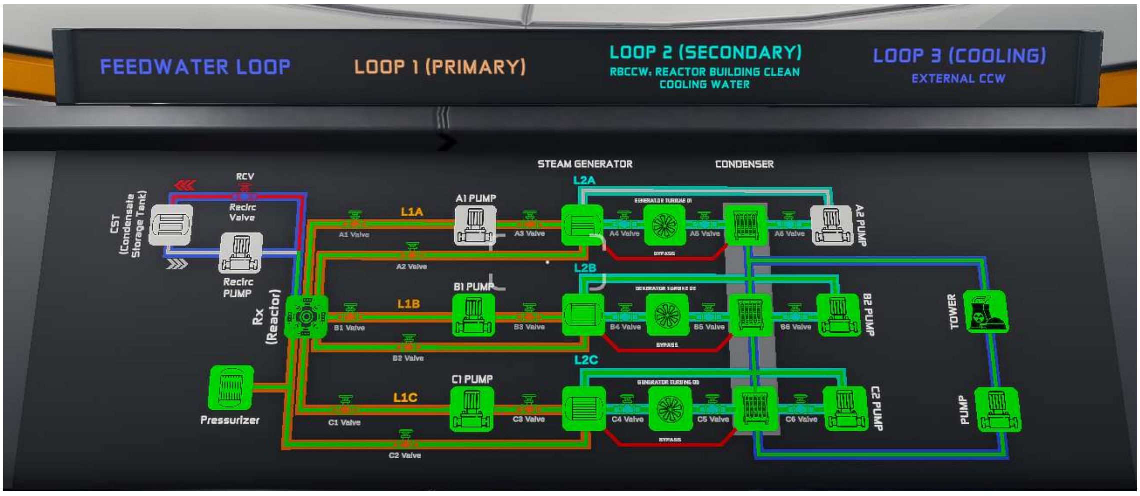
If there is too little liquid, the temperature may increase significantly, as heat will not be distributed evenly in the container. Likewise, if there is too little liquid in a cooled container, the temperature may decrease significantly. If the container does not have the proper volume, or is empty, the temperature reading on the gauges will be incorrect or it will read 0°C. This can lead to significant issues, especially in processes where temperature is critical.

Inaccurate temperature readings can also result in safety hazards. For instance, in a process where overheating of a vessel can cause a rupture or explosion, an inaccurate temperature reading could cause operators to fail to take appropriate corrective action in time, leading to a potential safety incident.

In summary, it is important to have sufficient liquid volume in a container to obtain an accurate temperature reading. Otherwise, temperature measurement may be incorrect, which can lead to problems in the operation and control of processes where temperature is critical.

PRIMARY, SECONDARY COOLING AND FEEDWATER LOOP

In the context of a nuclear power plant, a "loop" refers to a closed and interconnected circuit or system through which a specific medium, such as water or coolant, circulates to perform various functions within the plant. These loops are essential for the transfer of heat, energy, and the overall operation of the nuclear reactor.



Within the primary valve panel, a system of visual indicators employs a formal color code to convey the operational status of each valve. The **red** color designates a closed valve, signaling the complete cessation of fluid flow. Conversely, a **green** hue signifies an open valve, denoting unobstructed passage for the fluid.

In instances of valve transition, where the valve is in the process of either opening or closing, a **yellow** color is employed. This intermediate state, denoted by yellow, serves to communicate the ongoing adjustment of the valve, highlighting its dynamic movement from open to closed, or vice versa.

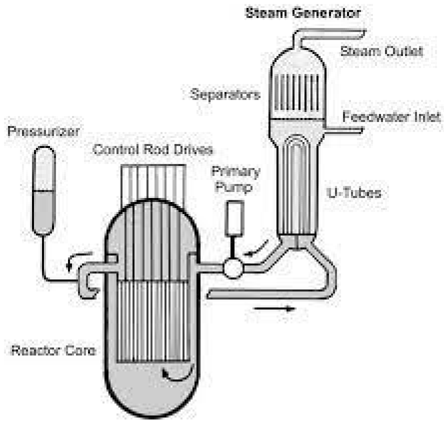
FEEDWATER LOOP

The feedwater loop is responsible for supplying water to the steam generator in the secondary loop. It ensures a continuous and controlled flow of water to facilitate the generation of steam for electricity production.

Water from an external source is pumped into the steam generator, where it absorbs heat from the primary coolant (water in the reactor vessel). As the water in the steam generator heats up, it turns into steam, which is then used to drive turbines for electricity generation.

PRIMARY LOOP (LOOP 1)

The primary loop involves the circulation of the primary coolant within the reactor vessel where nuclear reactions occur. It is responsible for transferring heat generated by nuclear fission to the steam generator in the secondary loop.



Water in the reactor vessel absorbs heat from the nuclear reactions, reaching high temperatures and remaining in a liquid state due to the pressurized environment.

This hot water is then pumped through the steam generator, where it transfers its thermal energy to the water in the secondary loop, producing steam.

SECONDARY LOOP (LOOP 2)

The secondary loop encompasses the circulation of water in the steam generator and the transfer of heat to produce steam. This loop is crucial for driving turbines connected to generators, converting thermal energy into electricity.

Water from the Feedwater Loop is pumped into the steam generator, absorbing heat from the primary coolant in LOOP 1. The absorbed heat turns the water into steam, which is then directed to turbines in the Circulation Turbines Loop for electricity generation.

COOLING LOOP (LOOP 3)

The cooling loop is designed to dissipate excess heat from various components, maintaining proper temperature levels in the system. It plays a key role in preventing overheating and ensuring the safety and efficiency of the reactor by removing excess heat to an external medium. These loops work in a coordinated manner to facilitate the transfer of heat, generate steam, and produce electricity in a nuclear power plant. Each loop has a specific function, and their interconnections contribute to the overall efficiency and safety of the plant's operation. A cooling system, which may involve water or another coolant, is used to remove excess heat from various components, such as the pressurizer and other auxiliary systems.

Heat exchangers or cooling towers are often employed to transfer the heat to an external medium, preventing the system from reaching critical temperatures.

PRESSURIZER

The pressurizer plays a critical role in maintaining the primary coolant (water) at a specific pressure level within the reactor vessel. Its primary function is to prevent the water from boiling at normal operating temperatures, ensuring it remains in a liquid state.

- The pressurizer is a vertically mounted cylindrical vessel connected to the reactor's primary coolant loop.
- It contains a mixture of water and steam, and its internal temperature and pressure are carefully controlled.
- Heating elements within the pressurizer are used to adjust the temperature of the water-steam mixture. This control is crucial for maintaining the desired pressure level.

Pressure in the primary circuit is maintained by a pressurizer, a separate vessel that is connected to the primary circuit and partially filled with water which is heated to the saturation temperature (boiling point) for the desired pressure by submerged electrical heaters.

To achieve a pressure of 155 bars (15.5 MPa), the pressurizer temperature is maintained at 345 °C (653 °F), which gives a subcooling margin (the difference between the pressurizer temperature and the highest temperature in the reactor core) of 30 °C (54 °F). As 345 °C is the boiling point of water at 155 bars, the liquid water is at the edge of a phase change. Thermal changes in the reactor coolant system cause significant fluctuations in the volume of liquid and steam in the pressurizer. The total volume of the pressurizer is designed to absorb these changes without exposing the heaters or draining the pressurizer completely. Pressure changes in the primary coolant system appear as temperature changes in the pressurizer. These changes are managed using heaters and water spray, which respectively increase and decrease the temperature of the pressurizer.

Pressure Relief Valve (PRV): A safety feature, the PRV is designed to release excess pressure from the pressurizer in case it exceeds the set limit. This valve ensures that the pressure within the pressurizer remains within safe operational parameters. **In game is Vent Valve.**

(pressurizer valve control module within the game)

Spray Valve: The valve is responsible for maintaining the proper water level within the pressurizer. Adds water to the pressurizer when needed, while the spray valve releases excess steam to maintain the desired water-steam mixture. **In the game it is Cooling Valve.**

Relationship between volume and pressure

If the reactor is off, the volume inside the Pressurizer will depend on the overall volume of the circuit. If the volume inside the circuit is correct, it will also be correct in the Pressurizer.

If the reactor is running, and there is excess pressure inside the Pressurizer, the volume will drop, as the pressure pushes out the coolant.

If there is low pressure and excess refrigerant in the primary circuit, the volume of the Pressurizer will increase. Therefore, if you need the volume of the Pressurizer to go down, you should close the valves and turn on the heaters.

Pressurizer Behavior

Normal Operating Conditions: During normal reactor operation, the Pressurizer is designed to maintain a specific pressure level within the primary circuit. It acts as a pressure control device to ensure the system operates within safe and efficient parameters. If there is an excess of pressure within the primary circuit, the Pressurizer responds by adjusting its volume. In this scenario, the Pressurizer's volume decreases as the excess pressure forces coolant out of the primary circuit.

Volume Adjustment Mechanism: The Pressurizer achieves volume adjustment through a dynamic interplay of pressure and coolant flow. It acts as a pressure vessel with the capability to vary its volume based on the prevailing pressure conditions.

- **Excess Pressure Scenario:** In cases where the reactor is running, and there is an undesirable excess pressure within the primary circuit, the Pressurizer actively works to reduce this pressure. This is accomplished by decreasing its volume, allowing excess coolant to be expelled.

- **Low Pressure and Volume Increase:** Conversely, if there is low pressure and an excess of refrigerant within the primary circuit, the Pressurizer adjusts by increasing its volume. This process helps restore and stabilize the pressure within the system.

Control Mechanism: To actively manage the volume of the Pressurizer and control pressure levels, specific actions can be taken. Closing certain valves and activating heaters are effective measures to influence the Pressurizer's behavior:

- **Valve Closure Impact:** Closing valves that control the flow of coolant within the primary circuit has a direct impact on the Pressurizer. It restricts the influx of coolant, contributing to a reduction in volume and pressure.

- **Heater Activation:** Turning on heaters within the Pressurizer aids in adjusting its volume. The addition of heat influences the behavior of the coolant, facilitating volume reduction and pressure control.

Dynamic System Interaction: The Pressurizer's response to pressure changes is a dynamic and integral part of the overall reactor cooling and pressure control system. It ensures that the reactor operates within specified safety margins and operational limits.

STEAM IN THE PRIMARY CIRCUIT

In a pressurized water nuclear reactor, the primary circuit is where the nuclear fuel is located and where the neutrons that drive the fission reaction are produced. It is critical that the primary circuit remains filled with water, as water acts as a coolant to dissipate the heat generated by the fission reaction. If, for some reason, water in the primary circuit becomes vapor, there can be serious and even catastrophic consequences.

There are several reasons why it is important that no vapor is formed in the primary circuit of a pressurized water nuclear reactor:

- **Cooling capacity is reduced:** Liquid water is a much more effective coolant than vapor. If vapor forms in the primary circuit, the cooling capacity is significantly reduced, and the nuclear fuel can overheat. If the fuel overheats, there can be damage to the fuel elements and the release of radioactive products.

- **Loss of pressure:** When vapor forms in the primary circuit, the pressure decreases. Loss of pressure can negatively impact the effectiveness of the cooling system and the ability to control the fission reaction. If the pressure continues to decrease, there can be a leak in the primary circuit and the release of radioactive substances.

- **Risk of explosion:** If vapor forms in the primary circuit and the pressure continues to decrease, there can be a risk of explosion. This is because when water turns into vapor, its volume increases dramatically. If the pressure in the primary circuit is not properly controlled, the increase in volume of the vapor can cause an explosion and the release of radioactive products.

Therefore, it is crucial that an adequate amount of water is maintained in the primary circuit of a pressurized water nuclear reactor to ensure effective cooling and prevent the formation of vapor. Various safety systems are used to ensure this does not happen, including safety valves and emergency cooling systems.

How can I check for the presence of vapor in the primary circuit, and what are the consequences if vapor is detected?

- To check for the presence of vapor in the primary circuit, a indicator has been installed on the control console, which will illuminate in yellow if vapor is detected and red if the value detected is critical for the normal operation of the reactor.

- If vapor is detected in the primary circuit, the core will heat up more than normal and become difficult to cool. The volume of coolant will decrease, the evaporators will lose temperature, and the generating turbines will lose power.

- To address the issue, if the vapor concentration is low, the internal pressure of the circuit can be increased. If the concentration is high, the ventilation valve of the reactor core should be opened, and an emergency shutdown initiated. In both cases, it will be necessary to inject coolant into the primary circuit.

CONTROL RODS

Control rods in a nuclear reactor serve a critical function in managing and controlling the nuclear chain reaction. Their primary purposes include:

- **Neutron Absorption:** Control rods are typically made of materials that absorb neutrons, such as boron or cadmium. By inserting control rods into the reactor core, they absorb neutrons, reducing the number available to sustain the chain reaction. This neutron absorption capability allows for precise control over the reactor's power output.

- **Power Regulation:** Adjusting the position of control rods enables operators to regulate the reactor's power output. Inserting control rods decreases power, while extracting them increases power. This power regulation capability is crucial for meeting varying energy demands and ensuring the stability of the reactor.

- **Shutdown Capability:** In emergency situations or during planned maintenance, control rods can be fully inserted to shut down the reactor rapidly. Complete insertion of control rods stops the chain reaction by absorbing a significant portion of the neutrons.

- **Temperature Control:** Control rods play a role in managing the temperature of the reactor. By controlling the rate of nuclear fission, operators can prevent overheating and maintain the reactor within safe temperature limits.

- **Safety Measures:** Control rods serve as a fundamental safety feature in nuclear reactors. In the event of unexpected fluctuations or emergencies, the rapid insertion of control rods provides a quick and effective means to shut down the reactor and prevent potential hazards.

The insertion or extraction of control rods within the core of a nuclear reactor has a significant impact on the ongoing nuclear reaction. Control rods, typically composed of neutron-absorbing materials, play a crucial role in regulating and controlling the chain reaction.

- **Insertion of Control Rods:** Inserting control rods into the core increases the neutron-absorbing capacity. This process reduces the number of neutrons available to participate in the chain reaction, decreasing the rate of nuclear fission. Inserting control rods has a cooling effect and allows for precise and rapid control of reactor power.

- **Extraction of Control Rods:** Extracting control rods decreases the neutron-absorbing capacity. This allows more neutrons to be available to initiate and sustain the chain reaction, increasing the rate of nuclear fission and, consequently, heat production. Extracting control rods raises the reactor power.

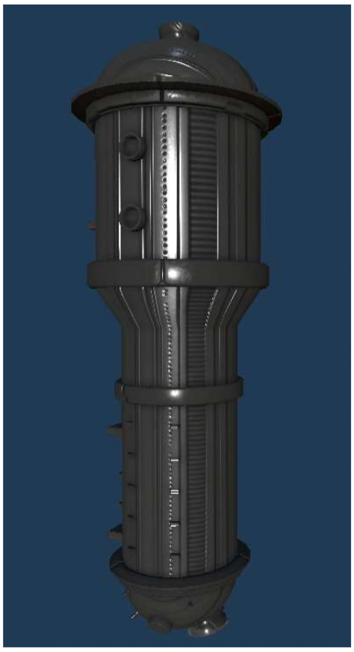
STEAM GENERATOR

The Steam Generator plays a pivotal role in the energy conversion process within a PWR. The Steam Generator is crucial for transforming the thermal energy produced by the nuclear reaction into usable mechanical energy, which is ultimately converted into electricity.

- The Steam Generator is a heat exchanger located in the primary circuit of the reactor. It consists of a series of tubes through which pressurized water from the primary circuit flows.

- Water from the primary circuit is maintained at high pressure to prevent it from boiling. This high-pressure water transfers its heat to a secondary circuit, where water is allowed to boil and produce steam.

- The steam generated in the secondary circuit is then used to drive turbines, which generate mechanical energy.



Related Valves

- **Feedwater Control Valve:** This valve regulates the flow of water into the Steam Generator from the primary circuit. It controls the rate at which pressurized water enters the generator, influencing the heat transfer process. **In game valves A3, B3 and C3.**

- **Steam Outlet Valve:** Once steam is generated in the secondary circuit, this valve controls the release of steam towards the turbines. It helps manage the flow of steam, ensuring optimal turbine performance. **In game valves A4, B4 and C4.**

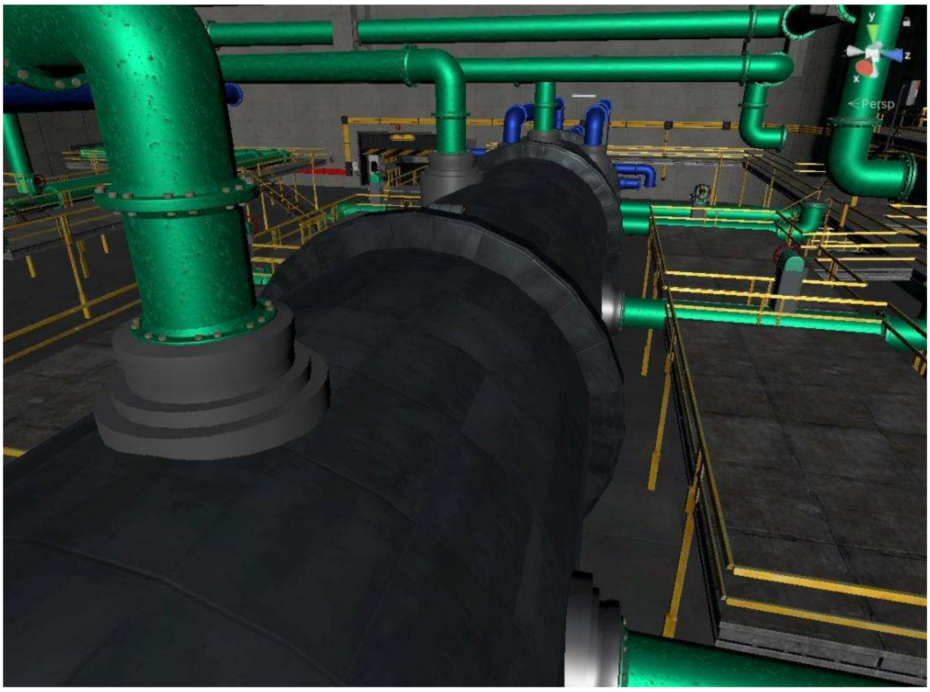
- **Safety Relief Valve:** In the event of excess pressure in the Steam Generator, the safety relief valve opens to release steam and prevent over pressurization. This is a crucial safety feature to maintain the integrity of the system.

The Steam Generator facilitates the efficient transfer of heat from the primary circuit, where the nuclear reaction occurs, to the secondary circuit, where steam is generated for electricity production. It allows for the separation of radioactive primary water from the turbines, ensuring the safety of the electricity generation process.

CONDENSER

The condenser plays a critical role in the power generation process by converting the high-pressure steam exiting the turbines back into water. It facilitates the efficient recycling of the working fluid, ensuring a continuous cycle of steam generation and electricity production.

- After the steam has passed through the turbines, losing much of its energy in the process, it enters the condenser.
- Inside the condenser, the steam is exposed to a network of tubes or surfaces cooled by a separate water supply (often from a cooling tower or a body of water).
- As the steam encounters these cooled surfaces, it undergoes a phase change, condensing back into water.
- The condensed water is then collected and returned to the steam generator, completing the cycle.



Associated Valves

- **Condensate Extraction Valves:** These valves control the flow of condensed water from the condenser to the feedwater system. They ensure a smooth and controlled transfer of water back to the steam generator. **In game valves A6, B6 and C6.**

- **Air Removal Valves:** Air removal is crucial to maintain the efficiency of the condenser. Valves are employed to vent any non-condensable gases (such as air) that may accumulate within the condenser, preventing them from impeding the condensation process. **In the game it is automatic.**

- **Cooling Water Inlet/Outlet Valves:** These valves regulate the flow of the cooling water that absorbs heat from the steam inside the condenser. By controlling the cooling water flow, the temperature within the condenser is managed, optimizing the condensation process. **In the game it is automatic.**

What's the Condenser For?
The condenser is in charge of turning steam back into water so it can go back into the system. Without it, the reactor would just keep pumping out steam with nowhere to go.

Why It Needs to Be Under Vacuum
To condense steam, the pressure inside the condenser has to stay very low — ideally around 0.1 BAR. At that low pressure, water boils (and condenses) at a much lower temperature. This makes it easier for steam to turn back into liquid water.

If the pressure is too high or the temperature gets too hot, condensation stops. The steam just builds up, and that's not good for the system.

In a PWR setup, the steam jet ejector by itself creates a partial vacuum in the condenser, but its suction is limited by available steam pressure and flow. The vacuum pump amplifies the ejector's effect, pulling a deeper vacuum much faster. That's why—during reactor startup—you run the pump at maximum power: it helps the condenser reach the target 0.1 bar (or lower) as quickly as possible. Once the plant is up and running, you can reduce the pump to minimum power to maintain vacuum with lower energy (and steam) consumption.

Turbines and the Vacuum
The condenser's vacuum isn't just for show — it's essential for the turbines, too.

When steam leaves the reactor, it pushes the turbine blades and gives you power. But for that to work well, the steam needs somewhere to go after — and that "somewhere" is the condenser.

Why the Vacuum Matters
A good vacuum creates a pressure drop between the turbine and the condenser. This pressure difference is what pulls the steam through the turbine faster and harder, giving you more efficiency and power output.

Without that vacuum: The pressure behind the turbine rises, the steam flow slows down, the turbine has to fight backpressure, which it's not built for.

What Happens Without Vacuum?
Running the turbine without proper vacuum can lead to serious problems:

- Low performance: Steam doesn't move fast enough, so the turbine produces less or no power.

- Overheating or mechanical stress: The turbine blades are under strain they weren't designed for.

- System imbalance: Pressure builds up in places it shouldn't.

Keeping the vacuum system active at all times is important because—even if the condenser already sits at 0.1 bar—small leaks or gas diffusion will slowly raise its pressure. If the ejector and pump stop, non-condensable gases build up, condenser efficiency drops, and turbine performance suffers. By leaving the vacuum train online (even at low power), you prevent pressure spikes, sustain proper condensation, and protect the reactor's thermal cycle.

In real reactors, this is a big deal — and in Nucleares, it means trouble for your setup.

Vacuum Circuit Valves

The valves allow precise control over steam and gas flow through the vacuum system—enabling safe startup, stable operation, and protection against overpressure, cavitation, and loss of mass in the condenser.

1. Suction Intake Valve

Controls the link between the retention tank and the vacuum pump. When open, it allows the vacuum pump to draw steam and non-condensable gases from the retention tank. When closed, it isolates the retention tank from the pump, preventing any suction.

2. Retention Tank Vent Valve

Regulates the release of non-condensable gases to the atmosphere from the retention tank. If the retention tank's internal pressure becomes too high, opening this valve vents accumulated gases in a controlled manner. If left closed while the tank is full, backpressure builds up and can block the ejector's discharge.

3. Condensate Return Valve

Allows condensed motive steam (and any after-ejector condensate) to return to the main condenser. When open, it routes condensed fluid back into the condenser so the water can re-enter the cycle. When closed, it stops that return flow, which can cause liquid levels or pressures to shift incorrectly in the condenser.

4. Startup Motive Steam Inlet Valve

Controls the flow of steam coming directly from the evaporators during plant startup. In startup mode, this valve sends hot steam from the evaporators straight into the ejector to establish vacuum in the condenser without sending steam through the turbine. Closing it prevents evaporator steam from reaching the ejector.

5. Operational Motive Steam Inlet Valve

Regulates the steam extracted from the turbines (low-pressure side) that feeds the ejector during normal operation. Once the plant is up and running, opening this valve delivers a portion of the turbine's exhaust steam to the ejector. Closing it cuts off turbine steam to the ejector, which forces the vacuum system to switch back to startup steam or stop altogether.

6. Condenser Suction Valve

Acts as an isolation point for vacuum draw between the condenser and the vacuum train (ejector and pump). Opening this valve connects the condenser to the vacuum line so air and vapor can be extracted. Closing it blocks suction from the condenser, so neither the ejector nor the pump can pull gas out of it.

Condenser Vacuum System

The Ejector requires motive steam to work. It can't create vacuum on its own. The Vacuum Pump helps, but it depends on how the gases are flowing. Condensation is calculated realistically.

Condensate Flow Rate: Shows how much steam is being condensed into water each second.

- High values: Lots of steam is entering the condenser, and condensation is working well.

- Low values: Might mean there's little steam left, or that condensation efficiency is dropping.

This tells you if the system is actively turning steam into water — and how well it's doing it.

Extraction Flow: Indicates how much condensed water (feedwater) is being pumped back to the steam generators.

- If this value is higher than the condensate flow, you're extracting more water than you're producing — the condenser will eventually run dry.

- If it's lower, water is building up — and the condenser could eventually overflow.

You want the incoming steam, the condensed water, and the extraction rate to stay in harmony. When you're ramping up power, shutting down the reactor, or adjusting valves, temporary imbalance is expected.

CIRCULATION PUMPS IN THE PRIMARY LOOP

Circulation pumps play a crucial role in maintaining the flow of coolant within the primary loop of the reactor. They ensure a consistent and controlled circulation of coolant through the reactor core, allowing for efficient heat transfer from the fuel rods.

The circulation pumps draw coolant from the reactor pressure vessel and push it through the reactor core, where it absorbs heat generated by nuclear fission.

The heated coolant then flows to the evaporators (steam generators), where it transfers heat to the secondary circuit, generating steam that drives the turbines. The coolant itself remains within the primary loop and does not mix with the steam.

The efficiency and reliability of these pumps are critical for the reactor's performance and safety. A failure or malfunction could disrupt core cooling, potentially leading to hazardous conditions. These pumps, typically powered by electric motors, operate under high-pressure conditions to ensure continuous coolant flow.

Heat Transfer Considerations

During normal operation, the pumps regulate coolant flow to prevent the core from overheating. However, increasing pump speed does not always improve heat transfer efficiency. This is due to the relationship between flow rate, residence time, and heat exchange efficiency:

Residence Time and Heat Absorption in the Core

- If the coolant moves too fast through the reactor core, it has less time to absorb heat from the fuel rods, reducing overall heat transfer.
- If it moves too slowly, it absorbs more heat, but this could lead to localized overheating and a higher core outlet temperature.

Heat Transfer in Evaporators (Steam Generators)

- The primary coolant transfers its heat to the secondary circuit in the evaporators. For efficient heat exchange, the coolant must spend enough time in contact with the heat transfer surfaces.

- If the flow rate is too high, the coolant passes through the evaporators too quickly, reducing the amount of heat transferred to the secondary circuit. This can result in lower steam generation and decreased power production efficiency.

- If the flow is too slow, the heat transfer may be greater, but at the cost of an increased coolant outlet temperature, which could affect the system's thermal stability.

For these reasons, pump speed must be carefully adjusted to maintain a balance between thermal efficiency, core safety, and system stability.

CIRCULATION PUMPS IN THE SECONDARY LOOP

Circulation pumps play a vital role in maintaining the flow of water within the secondary loop of the reactor. They ensure a continuous and controlled movement of coolant, facilitating the transfer of heat from the steam generator to the turbines.

- The circulation pumps are responsible for drawing water from the steam generator and pumping it towards the turbines, where the thermal energy is converted into mechanical energy.

- This continuous circulation is essential for sustaining the power generation process.

Pump Efficiency: Regular monitoring of pump efficiency is crucial for optimal performance. Efficiency can be affected by factors such as wear and tear, so routine maintenance is essential.

Flow Control: Precise control of water flow is necessary to match the reactor's power output. This is often achieved through adjustable impeller blades or variable speed control.

FREIGHT PUMP IN PRIMARY LOOP

The primary circuit charging pump plays a critical role in maintaining the integrity and functionality of the primary coolant system in a nuclear reactor. Its primary function is to ensure the appropriate level of coolant within the reactor vessel.

The pump is responsible for replenishing coolant in the primary circuit, compensating for any volume losses due to leaks or other operational factors. By maintaining the desired coolant level, it supports the efficient transfer of heat generated in the reactor core to the steam generator, facilitating the energy conversion process.

- Coolant Level Control: The pump plays a pivotal role in controlling and regulating the coolant level within the reactor vessel, preventing potential overheating or undercooling scenarios.

- Stability: Ensuring a stable and consistent coolant level contributes to the overall stability of the reactor, optimizing its performance.

During regular operation, the pump operates to maintain the desired coolant level, ensuring continuous and controlled heat transfer. In the event of coolant loss due to minor leaks or fluctuations, the pump compensates by injecting additional coolant to maintain the necessary levels.

The pump can also be crucial during emergency scenarios, preventing potential overheating of the core by swiftly injecting coolant. Routine inspections need to be conducted to ensure the pump is free from wear and tear. This includes checking for any signs of corrosion or mechanical issues.

FREIGHT PUMP IN SECONDAY LOOP

The secondary circuit charge pump is a critical component designed to maintain the flow of coolant within the secondary loop of the reactor system. Its primary function is to ensure a consistent and controlled circulation of coolant, facilitating the transfer of heat generated in the primary circuit to produce steam and generate electricity.

The charge pump holds immense importance in the overall functionality of the reactor. It guarantees a continuous flow of coolant, preventing overheating in the secondary circuit. This reliable circulation is pivotal for sustaining steam generation and subsequent electricity production.

During regular operation, the charge pump actively maintains the desired flow rate, allowing for efficient heat transfer and power generation.

- Startup: When initiating reactor operations or restarting after maintenance, the charge pump plays a crucial role in establishing the necessary coolant flow for a smooth and controlled startup process.

- Coolant Circulation: In cases where there is a need to adjust the coolant flow rate or redistribute heat within the secondary circuit, the charge pump ensures flexibility and adaptability.

DIFFERENCE BETWEEN FREIGHT PUMP AND CIRCULATION PUMP

Unlike circulation pumps, charge pumps are not designed for continuous operation in a nuclear reactor system. While circulation pumps are built to provide sustained and uninterrupted flow of coolant throughout the system during normal operation, charge pumps serve a specific purpose in certain scenarios.

- **Circulation Pumps:** These pumps are intended for continuous use during regular reactor operation. They maintain a consistent flow of coolant to facilitate heat transfer and power generation. Their primary role is to ensure a continuous and steady flow of coolant throughout the system to support the core's cooling and power generation processes.

- **Freight Pumps:** Designed for intermittent use, charge pumps are typically activated during specific situations, such as reactor startup, certain operational adjustments, or as emergency backup pumps. Serve specific functions, such as assisting in the initial coolant fill during startup or providing backup circulation in emergency scenarios when primary pumps may be offline.

Operational Limitations

- Circulation Pumps: Engineered for prolonged and consistent operation, these pumps can sustain the required coolant flow rate for extended periods.

- Freight Pumps: Due to their intermittent usage and specific roles, charge pumps may not be designed to withstand continuous operation for prolonged durations.

Regular maintenance of both types of pumps is crucial for ensuring their reliability.

MAINTENANCE OF CIRCULATION PUMPS

Regular maintenance and monitoring are essential to ensure the proper functioning of circulation pumps. Scheduled inspections, lubrication of moving parts, and testing of pump performance are standard practices to prevent unexpected failures.

- Lubrication: The pumps contain various moving parts, and proper lubrication is necessary to minimize friction and reduce wear.

- Vibration Monitoring: Regular vibration analysis helps identify any irregularities or potential issues with the pump's mechanical components. **Not yet implemented in the game.**

- Seal Integrity: Ensuring the integrity of seals is vital to prevent leaks and maintain the efficiency of the pump.

- Temperature Control: Monitoring and controlling the temperature of the coolant to prevent overheating is essential for the safety of the system.

HIGH-PRESSURE TURBINES AND LOW-PRESSURE TURBINES

Within the turbine system of a pressurized water reactor (PWR), there are distinct sections designed to efficiently utilize the varying pressure levels of steam produced in the reactor's primary circuit. These sections are commonly referred to as High-Pressure Turbines and Low-Pressure Turbines.

- **High-Pressure Turbines**

  Positioned at the beginning of the turbine system, the High-Pressure Turbines are the first set of turbines that steam encounters after leaving the steam generator.

  They are specifically designed to handle the high-pressure steam generated in the reactor.

  As the steam flows through this turbine, its high energy is harnessed to drive the turbine blades, initiating the process of converting thermal energy into mechanical energy. **In the game it is called Turbine Generator.**

- **Low-Pressure Turbines**

  Positioned downstream from the High-Pressure Turbines, the Low-Pressure Turbines come into play to further extract energy from the steam. **Not yet implemented in the game.**

  Although steam has experienced a decrease in pressure after passing through the High-Pressure Turbines, it still possesses significant energy. The Low-Pressure Turbines efficiently capture this remaining energy, ensuring that the steam's full potential is utilized in the energy conversion process.

Turbine blades are of two basic types, blades, and nozzles. Blades move entirely due to the impact of steam on them, and their profiles do not converge. This results in a steam velocity drop and essentially no pressure drop as steam moves through the blades. Nozzles move due to both the impact of steam on them and the reaction due to the high-velocity steam at the exit.

These turbines play a pivotal role in converting thermal energy into mechanical energy. High-Pressure Turbines extract energy from the high-pressure steam, and Low-Pressure Turbines extract remaining energy from the lower-pressure steam, maximizing energy extraction from the steam.

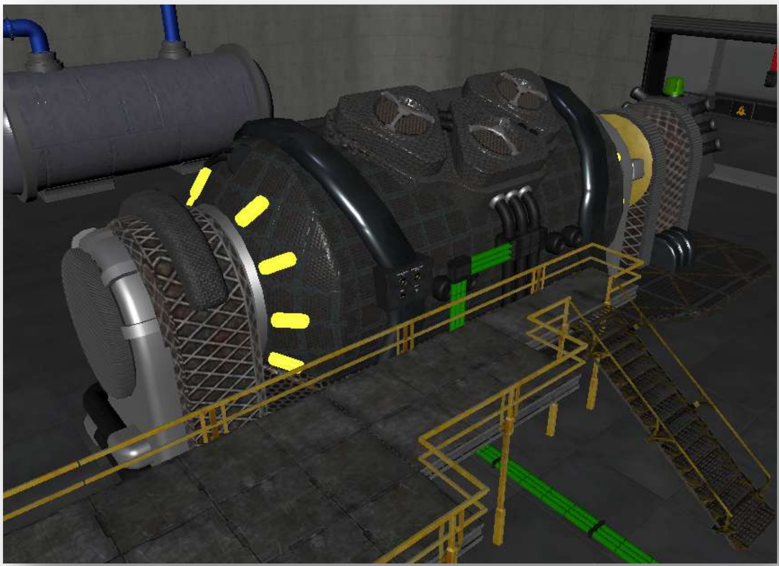
Maintenance

Regular inspections are crucial to ensure the blades and other components are free from wear and tear. Monitoring steam conditions and temperatures is vital to prevent overheating and maintain turbine efficiency. Proper lubrication of moving parts is essential for smooth operation.

GENERATOR TURBINES / ELECTRIC TURBINES

The turbines that convert mechanical energy into electricity are often referred to as Generator Turbines. These turbines are directly connected to an electric generator. As they rotate due to the mechanical energy supplied by the steam turbines, the generator converts this rotational motion into electrical energy.

The conversion of mechanical energy to electrical energy is the final step in the energy production process. The generated electricity is then distributed to the power grid for consumption.



(In the game it is called Electric Turbine)

Regular checks are required to ensure the alignment of the turbines and the generator for efficient energy conversion. Monitoring electrical output and addressing any fluctuations promptly is essential for the stability of the electrical grid.

Both sets of turbines are integral to the overall efficiency and power output of the nuclear power plant. Proper maintenance and monitoring of these turbines are essential for ensuring a stable and reliable power generation process.

Turbines contribute significantly to the safety of the plant by regulating steam pressure and energy conversion processes. Regular inspections and adherence to safety protocols are crucial to prevent accidents and ensure the long-term viability of the plant.

Synchronous Generator:

The turbine is coupled to a synchronous generator. The rotation of the turbine drives the generator's rotor, surrounded by a stationary magnetic field. This relative movement induces an electric current in the rotor conductors, generating electrical power.

- **Frequency Synchronization:**

  The rotational speed of the turbine and, consequently, the generator rotor is designed to maintain a constant frequency of AC output, typically 50 or 60 Hertz, depending on the electrical system.

- **Power Control:**

  Power control is achieved by adjusting the torque applied to the generator's rotor. This torque is controlled by opening or closing the steam valves that regulate the amount of steam entering the turbine.

- **Synchronization with the Grid:**

  Before connecting the generator to the electrical grid, a synchronization process takes place. This involves adjusting the speed and phase of the generator's output to precisely match the grid, avoiding imbalance issues.

Detailed overview

- The process begins with the nuclear reactor core producing heat through nuclear fission reactions. This heat is used to boil water, creating high-pressure steam.

- The steam is then directed to the turbines in the turbine hall.

- The high-pressure steam enters the high-pressure turbine blades, causing the turbine to rotate. As the steam expands and loses pressure, it moves through the low-pressure turbine, further contributing to turbine rotation. **Low-pressure turbine is not implemented in the game.**

- The rotating shaft of the turbine is connected to a generator. The mechanical energy from the turbine's rotation is transferred to the generator. **Electric Turbine in the game**.

- The generator converts mechanical energy into electrical energy through electromagnetic induction. This process produces alternating current (AC) electricity.

- The generated electricity is then transmitted through power lines to supply electrical grids.

- After passing through the turbines, the steam is condensed back into water using a condenser.

- The condensed water is then returned to the steam generator to start the cycle anew.

CHEMICAL TREATMENTS

Boron is used in pressurized water nuclear reactors as an additional method for controlling reactivity. While it's possible to operate a reactor solely with control rods, the use of boron offers several advantages:

- Increased control precision: Boron can be injected into the reactor circuit in small amounts to finely adjust the core reactivity. This allows for more precise control of reactor power and a faster response to changes in operating conditions.

- Corrosion reduction: Boron can also help reduce corrosion in certain parts of the reactor, as it can form a protective layer on metal surfaces.

- Reactor stability: Controlled addition of boron can help maintain reactor stability during changes in load or operating conditions. This can be especially important during power transitions, reactor startup, or shutdown.

- Reduced dependence on control rods: By using boron in conjunction with control rods, reliance solely on control rods to manage reactor reactivity can be reduced. This can increase operational flexibility and reactor safety.

Nuclear Reactor Startup and Equilibrium Process

Upon initiating fission within the pressurized water reactor, various types of nuclear isotopes are generated. For this simulator, only two will be considered: iodine-135 and xenon-135.

During the initial operation phase of the reactor, nuclear fission produces iodine-135 in proportion to the fission rate and the reactor's efficiency in capturing fission neutrons. **It is important to note that changes in reactor power can influence the production of iodine-135 due to variations in the fission rate.**

Iodine-135 isotope has a half-life of **6 hours**, after which it decays and transforms into xenon-135. During the initial decay, the reactor may experience an increase in power due to the production of xenon-135. Although xenon-135 is a more efficient neutron absorber than iodine-135, its production is not proportional to the amount of iodine-135 decayed.

The presence of xenon-135 can decrease the reactor's reactivity, requiring compensation by the reactor operator to maintain the desired power level. The amount of xenon-135 formed depends on factors such as reactor power and fuel loading. **Xenon-135** has a half-life of **9 hours** before it decays.

The reactor is considered to reach equilibrium approximately after 14 hours of operation, when the production of xenon-135 and the decay of iodine-135 balance each other. This equilibrium may vary depending on the specific reactor conditions. It is essential to keep operation within normal operating parameters to avoid drastic changes in power and ensure safe and efficient reactor operation.

Summarized and structured explanation in steps

- *Production of Iodine-135:* During the initial operation, iodine-135 is produced in proportion to the fission rate and the reactor's efficiency in capturing fission neutrons.

- *Decay of Iodine-135:* After 6 hours, iodine-135 decays and forms xenon-135.

- *Initial Power Increase:* The initial decay may cause a power increase due to the production of xenon-135.

- *Formation of Xenon-135:* Xenon-135 is a more efficient neutron absorber than iodine-135, but its production is not proportional to the amount of iodine-135 decayed.

- *Reactivity Reduction:* Accumulation of xenon-135 can reduce the reactor's reactivity, necessitating adjustments in operation to maintain desired power levels.

- *Achieving Equilibrium:* After approximately 14 hours of operation, the production of xenon-135 and the decay of iodine-135 reach equilibrium.

- *Continuous Operation:* It's important to maintain operation within normal operating parameters to ensure safe and efficient reactor operation.

Variations in power during reactor operation

During normal reactor operation, it is important to consider the transient behavior of Xe-135, especially during power variations. Any variation in power (increase or decrease) of a nuclear reactor in operation produces a temporary behavior of Xe-135 for a period that will depend on the magnitude of such variation.

For example, if the reactor's operating power is increased, the concentration of Xe-135 initially decreases and then increases to its new equilibrium concentration value. Conversely, if the reactor power is reduced, Xe-135 initially increases, then decreases to the new equilibrium value.

During this temporary period, it is necessary to move the control rods or introduce liquid poisons into the water where the fuel elements are submerged, much more than usual.

In the game simulation, these variations are set at 5 minutes for each significant power change.

Simulations and behaviors of the current version:

- Degradation of Xenon by lifetime.

- Temporary degradation of Xenon due to power increase.

- Indirect xenon degradation due to the presence of boric acid.

- Xenon increases due to reactivity when equilibrium state has not yet been reached.

- Increase in Xenon due to low temperature during shutdown.

- Temporary increase of Xenon due to power decrease.

Effects of boric acid

Boric acid absorbs neutrons, reducing the number of neutrons available for uranium fission. Decreases xenon production: Reduced reactivity also decreases the rate of xenon production through uranium-235 fission.

The concentration of xenon in the core begins to decrease as it decays into cesium-135. As the xenon concentration decreases, core reactivity increases. This allows the reactor to fission more uranium and generate more power.

Advantages of using Boric Acid vs Control Rods

In pressurized water reactors (PWRs), boric acid is used in the primary coolant as an additional method for controlling the reactor's reactivity, alongside the control rods. Both the use of boric acid and control rods have advantages and disadvantages.

Advantages of using boric acid:

- Distributed reactivity control: Boric acid is uniformly distributed in the primary coolant, providing more uniform reactivity control throughout the reactor core.

- Ability to compensate for large reactivity changes: Boric acid can compensate for large reactivity changes, such as xenon poisoning during reactor startups and shutdowns.

- Backup for control rods: Boric acid provides a redundant reactivity control system, backing up the control rods in case of failure.

- Operational flexibility: Adjusting the boric acid concentration allows for more precise reactivity control and greater flexibility during operational maneuvers.

Disadvantages of using boric acid:

- Corrosion: Boric acid can cause corrosion in the primary cooling system components if not properly controlled.
- Need for purification systems: Coolant purification systems are required to adjust and control the boric acid concentration.
- Impact on reactor efficiency: A high concentration of boric acid can reduce reactor efficiency by absorbing neutrons.

Advantages of using control rods alone:

- Simpler system: No need for boric acid purification and control systems.
- Less corrosion: Without boric acid, the risk of corrosion in components is reduced.

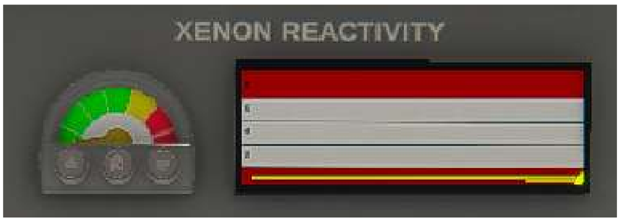
Disadvantages of using control rods alone:

- Limited compensation capacity: Control rods have a limited capacity to compensate for large reactivity changes, such as xenon poisoning.
- Less operational flexibility: Adjusting reactivity with control rods alone may be less precise and flexible during operational maneuvers.

Indicators and controls in the game

Fission Product Xenon Activity

Radioactive activity of the xenon isotopes that are fission products from the nuclear fission of fuel in the reactor. The fission rate occurring in the reactor and the production of fission products. As the Xenon generation increases, the indicator will move to the red zone.



Xenon Concentration Monitor

Measures the actual concentration levels of xenon isotopes, present in the reactor coolant and off-gas systems. Indicates the amount of Xenon inside the core in relation to the total capacity. Too high a value could indicate rector poisoning.

One crucial aspect of xenon concentration is its effect on reactor operation, particularly its potential to cause reactor poisoning. Xenon is a strong neutron absorber, meaning it readily captures neutrons, which are crucial for sustaining the chain reaction within the reactor core. When xenon concentration increases, can absorb a significant portion of the neutrons, leading to a decrease in reactor power output. This buildup can occur because xenon is continuously being produced by fission reactions, while its decay is slower due to its short half-life.

If the xenon concentration becomes too high, it can lead to reactor shutdown or instability. This phenomenon is known as xenon transients. During transient conditions, such as changes in reactor power level or reactor startup from shutdown, the xenon concentration can change rapidly, impacting reactor reactivity and stability.

Dissolved Gamma Iodine Activity

Measures the radioactive gamma activity of iodine isotopes dissolved in the reactor coolant and primary coolant system. These iodine isotopes are fission products generated during the nuclear fission process in the reactor core.

Iodine Concentration Monitor

Measures the actual concentration levels of iodine isotopes present in the reactor coolant or off-gas systems. Specifically quantifies the amount or concentration of these iodine atoms in the various systems.

Control Panel | Chemical Treatments

Within the control panel located in the control room, you will find the following elements:

- Boric Acid Dosing Pump: This pump indicates the amount of boric acid to be supplied. The unit is grams per minute, based on the concentration of the acid. Note that boric acid is a liquid, therefore, there must be space within the primary circuit to add the necessary amount of liquid to reach the required grams.

- Boric Acid Filtration Pump: This pump redirects the coolant from the primary circuit to an ion exchange column to extract boron. Note that the extraction of boron from the coolant does not reduce the total volume, as it is a filtration process.

- "Ion Exchange Capacity" Indicator: This indicator allows you to monitor the status of the ion exchange columns and their absorption capacity. The ion exchange columns require maintenance to function properly. If they accumulate too much boron, they will lose their absorption capacity. To clean the ion exchange columns, you must use sodium hydroxide.

The valves connecting the primary circuit to the chemical treatment building are manual, therefore, to add boron, filter the added boron, or clean the ion exchange columns, you will need to adjust them manually.

- Coolant pH Level: This indicator provides information on the pH level of the primary circuit coolant. pH plays a crucial role in determining the absorption capacity of boron within the coolant. The optimal operating range for pH falls between 7 and 9. If the pH deviates from this range and becomes excessively acidic, it can lead to increased corrosion of the pipes and other components within the system.

Corrosion

The presence of corrosion within the primary circuit pipes deteriorates their structural integrity over time. This deterioration occurs due to the gradual wearing away of the metal surfaces, leading to thinning and weakening of the pipes.

As corrosion progresses, it can compromise the functionality of hydraulic valves and circulation pumps connected to the primary circuit. Corrosion may cause valve components to become stuck or malfunction, hindering their ability to control the flow of coolant effectively.

Similarly, corrosion-related damage to circulation pumps can reduce their efficiency and reliability, potentially impeding the proper circulation of coolant throughout the reactor system.

CITY RELATIONSHIP | APPROVAL SYSTEM

Startup Permission

Before initiating power generation, the plant must request permission from the city. The city has the authority to approve or deny the request based on various factors like energy demand, safety considerations, and environmental impact. The plant receives information on the approved start time.

Shutdown Permission

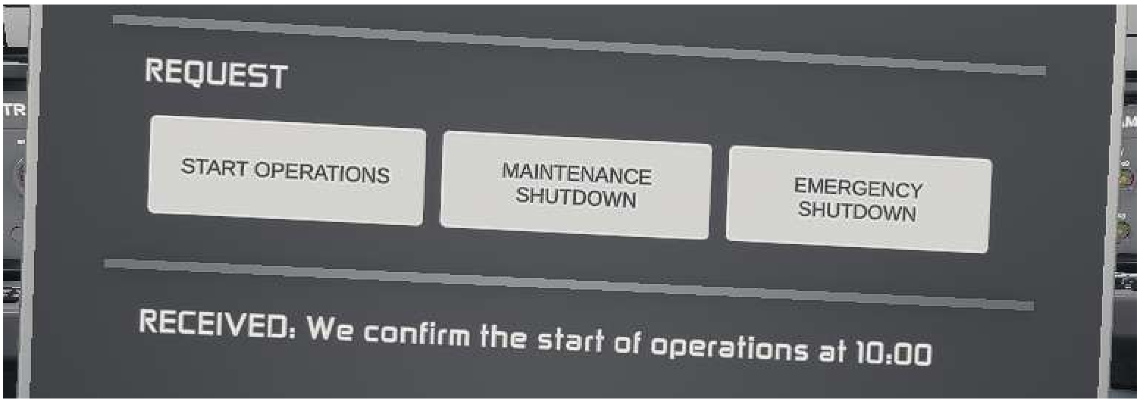
Similarly, when the plant decides to shut down, it must request permission from the city. The city provides a specified time window during which the shutdown is allowed. The plant cannot shut down outside of this approved timeframe. The city reserves the right to deny the shutdown request, especially if there are critical energy needs or other factors.

Emergency Shutdown

In case of an emergency shutdown, where the operator declares an urgent need to stop operations, the city will not deny the request. However, the city will schedule an audit to investigate the reasons for the emergency shutdown.

Strategic Planning

Players need to strategically plan their power generation and shutdown times based on city approvals. Balancing energy demand, city needs, and potential emergency situations becomes a crucial aspect of the game.



City Relationship

The player's relationship with the city evolves based on the number of approvals and emergency shutdowns. A positive relationship might result in faster approvals or additional benefits, while a negative relationship could lead to stricter conditions.

Emergency situations can arise randomly or due to specific in-game events, keeping players on their toes. Successfully handling emergencies contributes to the city's trust, but frequent emergencies might raise concerns.

it's crucial to understand that the distribution network can accommodate up to a 10% excess in power generation over the demand. However, exceeding this threshold could potentially initiate a deterioration of the distribution network. On average, if the excess is slightly above 10%, the city may tolerate this condition for a period ranging from 4 to 8 hours. However, if the excess reaches a significantly high peak, the damage to the distribution network can be almost immediate, resulting in a disconnection between the power plant and the city.

Tolerance Threshold

The distribution network is designed to handle a certain level of excess power generation, up to 10% above the demand. This is to ensure a balanced and reliable power supply to the city.

Deterioration Risk

Beyond the 10% threshold, there is a risk of deterioration in the distribution network. This could lead to instability, potential equipment damage, and a decrease in the overall reliability of the power supply. If the excess is moderately above 10%, the city can typically tolerate this condition for a limited time, ranging from 4 to 8 hours. During this period, efforts may be made to address the imbalance and prevent further network degradation. In cases of exceptionally high peaks more than the tolerance threshold, the damage to the distribution network may occur almost immediately. This could result in a rapid disconnection between the power plant and the city.

Warning Alerts

The city may, if possible, send warning alerts to the power plant before proceeding with disconnection. These alerts serve as a proactive measure to address the excess generation and maintain network stability. However, in situations where the excess over the demand is extremely high, a disconnection may occur without warning. This is done to prevent severe damage to the distribution network and ensure the overall safety of the power supply system.

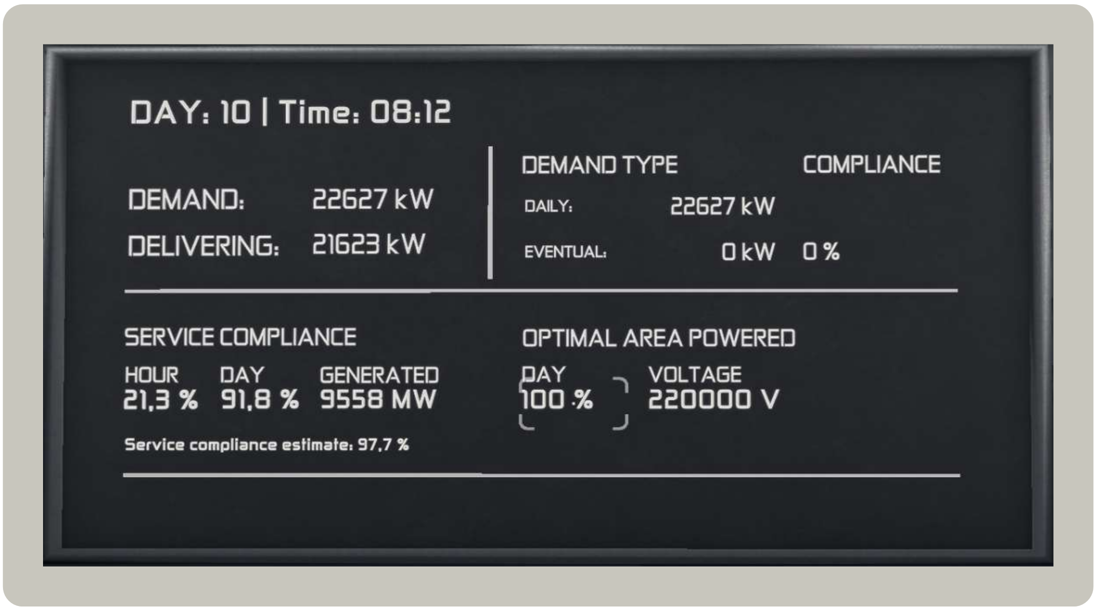
Collaborative Approach

It's essential for the power plant and the city to work collaboratively to monitor and manage power generation levels. Effective communication, timely responses to alerts, and adherence to established protocols contribute to maintaining a stable and reliable power distribution system.

OPERATING LICENSES

Minimum Service Level

The city sets a minimum service level that the player must maintain to retain their licenses. Failure to meet this minimum service level results in the loss of licenses. The service level could be based on factors like energy output, environmental impact, or safety measures.



Auditor Anomalies

During audits following emergency shutdowns, auditors may detect anomalies or non-compliance issues. Anomalies could range from safety breaches to environmental concerns. Each anomaly detected leads to a reduction in operating licenses. Audits following emergency shutdowns may present challenges related to rectifying the detected anomalies, adding an extra layer of gameplay depth.

License Recovery

To recover a lost license, the player must successfully operate the reactor and meet the city's minimum service level for a full in-game day. This emphasizes the importance of consistent and high-quality performance.

Strategic Decision-Making

Players must balance the need for energy generation with maintaining a high service level to retain licenses. Strategic planning becomes crucial to avoid unnecessary license depletions.

Handling emergency situations effectively is not only vital for immediate safety but also to prevent excessive license loss during audits. Successfully recovering lost licenses not only allows the player to continue operating but also contributes to building a positive reputation with the city.

This Operating Licenses System adds a dynamic and challenging element to the game, encouraging players to maintain a delicate balance between operational efficiency, city relations, and emergency response.

GENERATION AND DISTRIBUTION OF ELECTRICAL ENERGY

A power generation plant should meet demand rather than generating any arbitrary amount of energy for several key reasons:

Operational Efficiency

Generating only the amount of energy required to meet current demand ensures efficient plant operation. Unnecessary overproduction can result in energy and resource losses.

Economy

Generating more energy than needed involves additional costs associated with the production, transmission, and distribution of that surplus energy. Meeting demand adjusts operational costs and maintains economic efficiency.

System Stability

Maintaining a balance between supply and demand is essential for the stability of the electrical system. Energy excess can lead to issues such as overvoltage and unstable frequencies, impacting the reliability of the electrical supply.

Order of actions

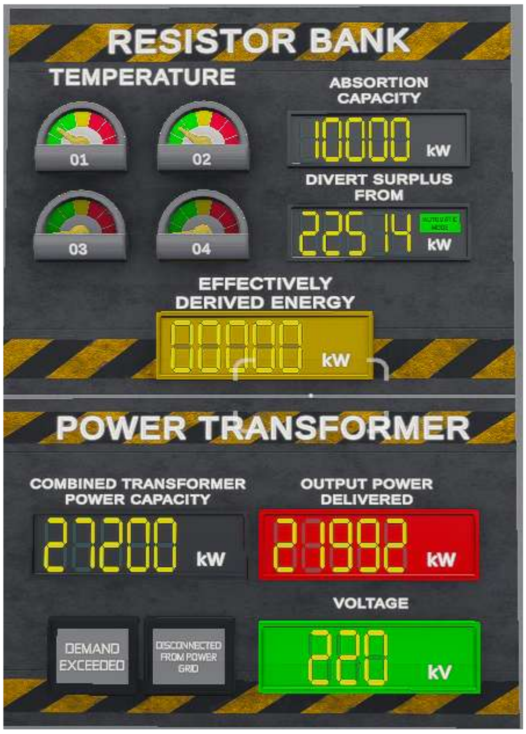
1. Electric power generation

2. Absorption of excess energy

3. Transformation and distribution

Excess energy generated

Excess energy generated in a power generation plant refers to a situation where the energy production exceeds the current demand.



This can occur due to fluctuations in energy demand, operational conditions of the plant, or the intermittent nature of some energy sources, such as solar or wind. It is crucial to address this excess energy to maintain the stability of the electrical system.

Resistance banks are devices designed to absorb and dissipate the excess generated energy. When there is surplus energy in the grid, resistance banks are activated to convert the unused electrical energy into heat. This process helps balance supply and demand, preventing issues such as overvoltage that could damage electrical equipment and ensuring system stability.

Energy transformation

Transformers are used in power generation plant for several fundamental reasons. Firstly, they allow the adjustment of voltage levels to optimize the efficiency of electrical energy transmission and distribution.

By stepping up the voltage using transformers before long-distance transmission, energy losses on transmission lines are reduced, as power is proportional to the square of the current, and increasing voltage decreases current.

Secondly, transformers facilitate the adaptation of voltage levels across different stages of the electrical system. In power generation, electricity is often generated at relatively low voltages, and step-up transformers increase this voltage to levels suitable for efficient transmission.

Subsequently, in substations near consumption centers, step-down transformers are used to decrease the voltage to safe and practical levels for domestic and industrial distribution.

Voltage Adjustment: Nuclear power plant generators produce electricity at a relatively high voltage. To efficiently transmit this energy over long distances and distribute it to end consumers, a transformer is used to adjust the voltage to appropriate levels.

Reduction of Transmission Losses: Transmitting electricity at higher voltages reduces energy losses during transmission. According to Ohm's Law, power lost in a transmission line is proportional to the square of the current. By increasing the voltage, the current is reduced, and thus energy losses are minimized.

Integration with the Electrical Grid: Transformers enable the connection of the nuclear power plant to the electrical grid efficiently. They adapt the energy generated in the plant to the grid's characteristics, ensuring smooth and secure integration.

Circuit Separation: Transformers are also used to separate circuits within the plant. For example, there can be transformers connecting the generators to the electrical grid and others supplying power to internal plant systems, ensuring the stability and safety of the internal power supply.

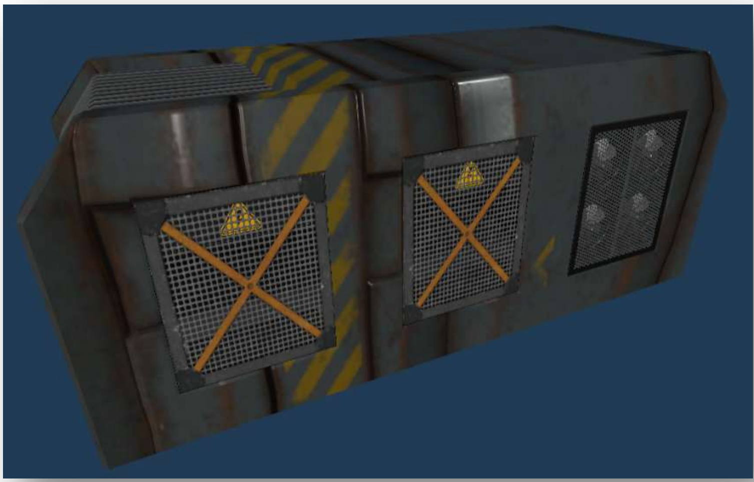
Phase Isolation: In nuclear plants, where safety is paramount, transformers are used to isolate the phases of the electrical system. This helps prevent short circuits and enhances the safety of the electrical system.

Voltage and Frequency Control: Transformers allow for the control of voltage and frequency of the generated energy, ensuring it meets the standards and requirements of the connected electrical grid. **It is not implemented in the game.**

Adaptation to Variable Loads: Transformers facilitate the adaptation of the plant to variations in electrical load. They can adjust the voltage as needed to maintain system stability, especially during abrupt changes in demand. **It is not implemented in the game.**

Resistance Banks

Each resistor bank contains four resistance blocks and a cooling system. The absorbed energy is transformed into heat and then dissipated by the cooling system. <u>If the bank fails to dissipate the heat from the absorbed energy</u>, it will degrade, and the resistance blocks could burn out.



The absorption capacity of a resistance bank is given by the number of resistance blocks installed and in good condition. A burned resistance block decreases the absorption power by 25%.

Attention: AO can repair the resistor bank, but cannot replace the burned resistance blocks. That is an exclusive task of the plant operator.

Resistance banks serve as emergency devices for load control within the power plant. During periods of high demand or unforeseen circumstances, these banks can be activated to absorb excess electrical energy, preventing overloading of the system.

Importance of Resistance Banks

Load Balancing: Resistance banks assist in balancing the electrical load within the system. During peak demand, they provide a means to absorb excess energy and prevent strain on the grid. *Grid Stability:* Utilizing resistance banks helps maintain grid stability by preventing overloads and ensuring a consistent and reliable power supply to consumers. *Emergency Control:* These devices serve as emergency load control measures, activated only when necessary to address sudden spikes in demand or unexpected events.

Reasons for Controlled Usage

Preventing Wear and Tear: Continuous use of resistance banks can lead to wear and tear. Therefore, they are designed for occasional and controlled activation to preserve their effectiveness during emergencies. *Thermal Stress:* Excessive heating due to prolonged usage can cause thermal stress on the resistance elements, affecting their longevity and performance. *Efficient Emergency Response:* Limiting the use of resistance banks to emergency situations ensures their availability and effectiveness when urgently needed, contributing to a more efficient emergency response.

Safety Considerations

Ensures that the resistance bank operates within safe temperature limits, minimizing the risk of overheating and potential damage.

Emergency Use Only: It's emphasized that resistance banks are devices of emergency use and should not be activated routinely. This approach ensures their readiness and reliability during critical situations.

- The energy generated must not exceed the demand: to achieve this, reduce the power of the reactor or divert the surplus to the resistor banks.

- The energy generated must be transformed before being delivered to the electrical grid: to achieve this, it uses energy transformers.

- The energy generated that cannot be delivered or absorbed by the resistor banks will seriously damage the generating turbine, the intermediate hubs and the internal and distribution cables of the plant.

Disconnecting for Normal Operation

During normal operation or when emergency load control is not required, operators may choose to disconnect the resistor banks using the switches. This prevents unnecessary energy absorption by the resistors.

Emergency Load Control

In situations where there is excess electrical energy generated by the turbines and the grid cannot absorb it, operators can connect the resistor banks to absorb and dissipate the excess energy, preventing overloading.

Connecting resistor banks provides a means of load balancing in the power plant. It helps stabilize the electrical grid by absorbing surplus energy and preventing disruptions. The resistor banks serve as a protective mechanism for the power generation equipment. By absorbing excess energy, they prevent potential damage to turbines and associated components.

Operators have control over when to connect or disconnect the resistor banks based on real-time operational needs. This control allows for efficient energy management and system stability.

SYNCHRONIZATION OF TURBINE-GENERATED ENERGY

It’s crucial to understand the importance of synchronizing the energy generated by the turbine before delivering it to the electrical grid. Synchronization ensures a harmonious integration of the turbine-generated power with the existing power grid.

Grid Stability

Synchronization ensures that the frequency and phase of the generated power match precisely with the electrical grid. This harmony prevents disruptions and contributes to the overall stability of the grid.

Unsynchronized power injection can lead to electrical disturbances, such as voltage and frequency fluctuations. These disturbances may damage connected devices and compromise the integrity of the electrical infrastructure.

Protection of Equipment

Synchronizing the turbine's output protects both the turbine and the electrical grid equipment. It ensures that the power transfer is seamless, reducing the risk of overloads and potential damage to the generator and connected components.

Synchronization enables efficient power transfer from the turbine to the grid. When the frequencies match, the power transfer is optimized, maximizing the effectiveness of the generated energy.

Safe Connection

Prior synchronization prevents sudden surges or drops in power during the connection process. This safety measure ensures a smooth integration of the turbine into the grid without causing disruptions or damage.

SYNCHRONOSCOPE IMPLEMENTATION

Understanding the role of synchronization, coupled with the use of a synchronoscope, becomes pivotal for effective power generation.

Precision Alignment with Grid

The synchronoscope facilitates the precise alignment of the turbine-generated power with the grid's frequency and phase. This ensures that the energy produced seamlessly integrates with the existing power supply.

The synchronoscope provides real-time monitoring of the turbine's frequency in comparison to the grid. This instantaneous feedback allows for immediate adjustments to maintain synchronization, preventing potential disruptions.

Prevention of Overloads

By utilizing the synchronoscope, operators can carefully control the connection process, avoiding sudden overloads or imbalances in the electrical system. This protective measure prevents damage to the turbine and connected equipment.

The synchronoscope contributes to enhanced grid stability by allowing operators to observe and manage the synchronization process. This is particularly crucial during power startup and connection phases.

CONTROL PANEL OVERVIEW

Each control panel within the reactor facility is equipped with an activation lever, a pivotal component that serves to energize the panel and its associated sensors distributed throughout the plant. When the lever is engaged, it initiates the power supply to the panel, enabling the functionality of meters, indicators, and other monitoring devices.

- Activation Lever: The activation lever, often prominently positioned on the control panel, is the mechanism used by operators to power up the panel.

- Energizing Sensors: Activating the lever results in the energization of not only the control panel itself but also the sensors strategically located throughout the facility. These sensors play a critical role in monitoring various parameters and ensuring the smooth operation of the reactor system.

The activation of the panel brings to life the indicator lights, meters, and other display elements. These components provide real-time feedback to operators regarding the status and performance of different systems within the plant.

Troubleshooting

If the control panel fails to power up or certain meters/lights do not function as expected, it may indicate an electrical issue in the room or machine where the sensor is located.

Operators should conduct a systematic check to identify potential electrical problems, including examining power sources, connections, and conducting visual inspections of the panel components.

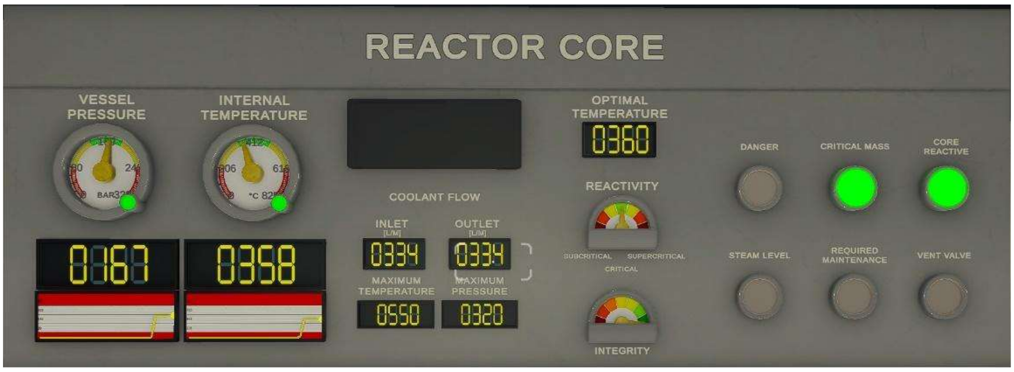
The activation lever serves as a safety and control measure, ensuring that the sensors and monitoring devices are only operational when explicitly required. This mechanism allows for efficient energy utilization, as the panels are activated when needed and can be deactivated when not in active use.

Operator Responsibilities

Operators are trained to be vigilant in monitoring the functionality of the control panels. Any anomalies in the activation process or issues with panel components require prompt attention and resolution. Regular checks and maintenance of the electrical systems associated with the control panels are crucial to prevent potential disruptions in monitoring and control.

CONTROL PANEL: CORE

The core control panel in the central control room consolidates reactor oversight. Displaying vital data such as water temperature, pressure, and nuclear activity, enables real-time monitoring for operators to ensure safe and efficient operation.



The pressure and temperature gauges serve as crucial instruments on the control panel, offering real-time insights into the reactor's operational conditions.

- **Pressure Gauge:** The pressure gauge provides a continuous readout of the pressure within the reactor's primary circuit. Elevated pressure is vital to maintaining water in a liquid state, preventing it from boiling even at high temperatures. Operators closely monitor this gauge to ensure that pressure remains within safe operational limits, preventing any risks of overheating or loss of coolant.

- **Temperature Gauge:** The temperature gauge offers a dynamic display of the water temperature circulating within the reactor. Control over temperature is pivotal for regulating the efficiency of the nuclear reaction and ensuring the structural integrity of the reactor components. Monitoring temperature variations allows operators to make precise adjustments to the reactor's cooling and heating systems, maintaining a stable and controlled environment.
- **Inlet Meter:** The inlet meter is essential for monitoring the rate at which coolant is introduced into the reactor core. This measurement is vital for maintaining proper temperature and pressure conditions within the reactor, ensuring optimal efficiency and safety.

- **Outlet Meter:** The outlet meter tracks the flow of coolant as it leaves the reactor core. Monitoring the outlet flow is instrumental in assessing the heat transfer and energy extraction processes within the reactor. It provides valuable data on the efficiency of the reactor's operation and aids in maintaining the desired temperature and pressure levels.

- **Reactivity:** Serve as pivotal instruments on the control panel, offering real-time insights into the dynamic behavior of the reactor core. These meters depict the current state of reactivity, indicating whether the reactor is in a subcritical, critical, or supercritical condition. In a ***subcritical*** state, the reactor is below the point of sustained nuclear reactions, ensuring a controlled and stable condition. Conversely, a ***critical*** state signifies a delicate equilibrium where the rate of neutron production matches neutron loss, resulting in a steady and sustainable nuclear chain reaction. The ***supercritical*** state indicates an excess of reactivity, necessitating immediate corrective measures to prevent an uncontrolled escalation of nuclear reactions. Monitoring these reactivity status gauges empowers operators to fine-tune control rod positions and other parameters, maintaining the reactor within the desired operational range for optimal safety and performance.

- **Integrity:** Serve as critical indicators, offering insights into the structural soundness and reliability of reactor vessel and coolant system, providing real-time data on their condition. **Green** signifies optimal integrity, **red** indicates potential issues or anomalies, and yellow denotes transitional states.

- **Danger:** The presence of red or flashing indicators on these meters signals an urgent need for attention and corrective action.

- **Critical mass:** The light signals that the reactor has reached a state of criticality, implying that the fissile material within the core has attained a point where a self-sustaining chain reaction is occurring.

- **Core reactive:** The light signals an active and responsive core, indicating that the nuclear reactions are occurring within the desired parameters.

- **Steam Level:** The light indicates that the steam content has surpassed the predefined threshold, prompting attention from operators. This alert is crucial for maintaining operational safety, as it prompts timely adjustments to prevent potential issues associated with excessive steam levels, ensuring the system operates within specified parameters.

- **Required Maintenance:** The maintenance required indicator light signals that certain components or systems within the reactor are due for maintenance. This indicator acts as an alert for operators to address and rectify any impending issues, ensuring the continued reliability and optimal performance of the reactor. Ignoring or delaying maintenance after this indicator is triggered may lead to potential operational challenges or a decrease in overall system efficiency.

- **Vent Valve:** The indicator light illuminates when the ventilation valve for the core is in the open position. This visual signal informs operators that the valve, responsible for releasing excess pressure or managing specific operational conditions within the reactor core, is actively allowing the controlled release of gases. Monitoring this indicator is crucial for maintaining optimal conditions and ensuring the safety of the nuclear reactor system.

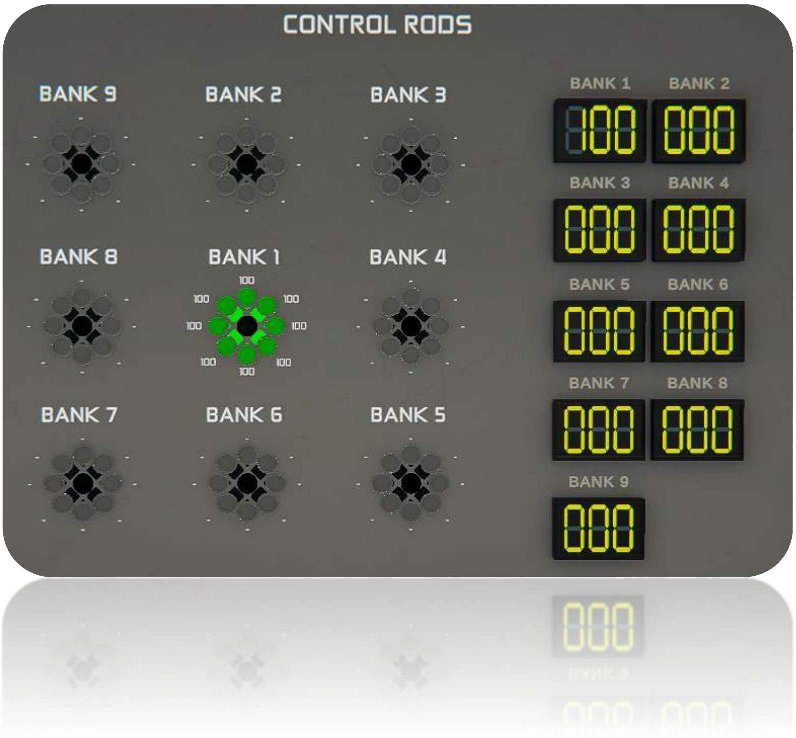
- **Emergency Stop**: serves as a critical safety mechanism, instantly halting all reactor operations in the event of an unforeseen crisis or imminent danger. When pressed, this button triggers an immediate shutdown procedure, overriding regular protocols. Unlike standard shutdown requests, the Emergency Stop is immune to denial by the city authorities, prioritizing rapid response to potential threats.

  The Emergency Stop button also initiates the rapid insertion of control rods into the reactor core, irrespective of the power supply status or the functionality of the control rod drive mechanism. This immediate insertion of control rods is a failsafe measure designed to swiftly and effectively cease the nuclear fission process, ensuring reactor shutdown even in scenarios where regular control mechanisms may be compromised or non-functional.

- **All Set:** The "All Set" indicator light signifies that all necessary parameters and settings are in the required configuration. When this light illuminate, it indicates that the system has been properly configured and is ready for the commencement of the reactor ignition process. It serves as a comprehensive confirmation that critical conditions, such as pressure, temperature, and control rod positions, are within the prescribed parameters, providing the green light, so to speak, for the initiation of the reactor startup procedure.

CONTROL PANEL: CONTROL RODS

The control panel for the reactor control rods is a focal point. It provides a concise display of the status of control rods, crucial for regulating the reactor's power output.



A visual representation indicates whether each control rod is inserted (controlled power reduction) or withdrawn (increased power). This intuitive interface ensures operators can swiftly and accurately manage the reactor's power levels, maintaining operational stability and safety.

Each fuel load bank has a capacity for 8 control rods. Each control rod is associated with a status light:

- **Green**: Control rod loaded and in optimal operating condition.
- **Gray**: Empty piston, no control rod loaded.
- **Red**: Control rod locked due to exposure to excessively high temperatures.
- **Magenta**: Control rod deformed due to exposure to excessively high temperatures, causing adjustments to be slow or even impossible. Moving the control rods in this

situation may lead to the destruction of the hydraulic system.

- **Yellow**: Control rod in motion.

The center of the indicator represents the control status in relation to all the control rods. It is not possible to move the rods individually, only as a group.

- If the central icon is off (black), it indicates that the hydraulic motor is not active; therefore, the control rods will not move when an adjustment command is executed.

- If the color is green, it indicates that the hydraulic motor is selected and energized, and it will respond to adjustment commands. ***Does not apply to SCRAM, which operates independently, whether power is available or not.***

- If the color is red, it indicates that the hydraulic motor is damaged or does not have sufficient power to operate.

- **Temperature:** This gauge provides real-time data on the temperature overall levels, allowing operators to assess and ensure that the reactor remains within its designated operational temperature range.

- **Efficiency Factor:** This meter is a pivotal component in the control room, dedicated to monitoring the effectiveness of the control rods in absorbing neutrons within the reactor core. This meter quantifies the ratio of neutrons absorbed by the control rods to the total neutrons present in the reactor.

  As control rods are adjusted, their positioning affects the absorption of neutrons, influencing the reactor's power output. The Absorption Efficiency Factor meter provides real-time feedback on the efficacy of this neutron absorption process. A high efficiency factor indicates effective control rod positioning, leading to optimal neutron absorption and power regulation.

CONTROL PANEL: CONTROL RODS | SWITCHES

- **Rod Height:** The control keyboard for the position of control rods serves as a pivotal tool in managing the reactor's power output. Operators utilize this interface to input precise positional commands for control rods. The keyboard allows for incremental adjustments, enabling fine-tuning of rod positions.

  Upon entering desired positions, the control system responds by orchestrating the movement of the control rods accordingly. This meticulous control ensures the reactor's power levels align with operational requirements and safety protocols.

  In essence, the control keyboard acts as a conduit for operator commands, facilitating real-time adjustments to control rod positions and, consequently, the overall power output of the reactor.

- **Motor Speed:** The power control panel of the control rod motor allows for the adjustment of energy supplied to the motor responsible for positioning the control rods within the reactor core. Increasing the power will consequently raise the positioning speed, but it will also accelerate internal motor wear.

  Prolonged use beyond optimal performance levels can lead to irreversible damage. Nevertheless, it may prove beneficial in certain emergency scenarios where rapid adjustment of the control rods is necessary without initiating a scram.

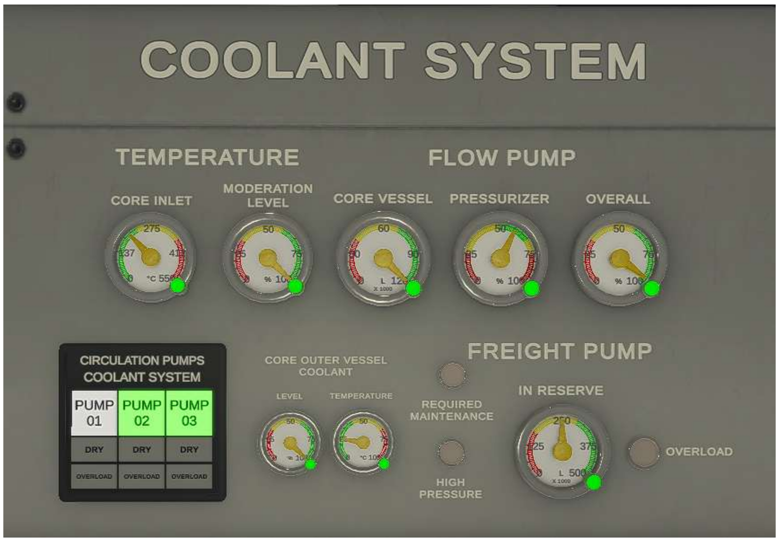
- **Hold**: When the "Hold" button is engaged, it triggers an immediate cessation of any ongoing movement of the control rods. This ensures a prompt response in situations where a rapid halt in reactor power or an emergency shutdown is necessary.

- **Scram**: Emergency Shutdown. In the event of unforeseen emergencies, anomalies, or situations requiring an immediate reactor shutdown, operators can initiate a "Scram" by pressing the associated button. The "Scram" action triggers the swift and full insertion of all control rods into the reactor core. The rapid insertion of control rods enhances neutron absorption, preventing further nuclear fission reactions. This immediate cessation of the chain reaction leads to a rapid reduction in reactor power.

- **Control Bank Activation Panel:** Allows selecting which banks will be active when a movement command is given. It is important to clarify that the control rod groups will move when the operator requests it, only if the bank they belong to is selected and active.

CONTROL PANEL: COOLANT SYSTEM

Within the reactor control room, the control panel for the primary coolant system succinctly presents key volume metrics. It includes the total circuit volume, covering the entire primary coolant pathway. The core vessel volume, encapsulating the reactor core, is also specified.



Additionally, the Pressurizer volume, vital for pressure regulation, is highlighted. This comprehensive data on primary circuit volumes enables operators to monitor and control the system effectively in real-time.

- **Core Inlet Temperature:** Serves as a critical instrument for assessing the temperature of coolant entering the reactor core. This meter provides real-time data on the temperature of the coolant as it enters the core vessel.

  As the reactor operates, nuclear reactions generate heat within the core. The coolant absorbs this heat and circulates through the primary circuit. The Core Inlet Temperature meter precisely measures the temperature of this incoming coolant, offering crucial insights into the thermal conditions at the core's entrance.

  Operators use this information to monitor and control the reactor's temperature, ensuring it remains within safe and efficient operating limits. Deviations from expected temperatures could signify anomalies or require adjustments in the reactor's operational parameters.

- **Moderation Level:** Serves as a pivotal gauge in assessing the moderation status within the reactor's primary circuit. This meter essentially measures the degree to which neutron moderation is occurring. In a nuclear reactor, neutron moderation is the process by which certain materials slow down the fast neutrons generated during fission. This slowing down, or moderation, is crucial for sustaining a controlled nuclear chain reaction.

The Moderation Level meter provides a visual indication of the efficiency of neutron moderation within the reactor. It typically ranges from low to high, with corresponding color codes or numerical values. A low moderation level may suggest insufficient slowing down of neutrons, potentially impacting the reactor's stability. Conversely, a high moderation level indicates effective neutron moderation, contributing to a stable and controlled nuclear reaction.

Operators closely monitor this meter to ensure the reactor operates within the desired moderation parameters, maintaining a balance that optimizes power output while upholding safety standards. Adjustments to the moderation system can be made based on real-time readings from this meter to achieve and sustain the desired neutron moderation level for safe and efficient reactor operation.

- **Core Vessel Volume:** Serves as a critical gauge for tracking the volume within the reactor core vessel. This meter operates by measuring the actual volume of the coolant contained within the core vessel, providing real-time feedback to operators. As the reactor operates, the volume within the core vessel may vary due to factors such as changes in temperature, pressure, or reactor power levels. The Core Vessel Volume meter continuously updates to reflect these variations. In the event of abnormal fluctuations or deviations from the predefined safety parameters, the meter serves as an early warning system, alerting operators to potential issues within the reactor core.

  Operators can use this information to make timely adjustments, ensuring that the coolant volume remains within the designated safe range. The Core Vessel Volume meter, therefore, plays a crucial role in maintaining the stability and safety of the reactor by providing a direct indication of the coolant volume within the core vessel during the operational phases.

- **Pressurizer Volume:** The Pressurizer Volume meter, situated on the primary coolant circuit monitoring panel, operates as a vital gauge for overseeing the volume of the pressurizer. As the pressurizer actively adjusts the pressure to prevent boiling and ensure a controlled environment, the Pressurizer Volume meter provides a visual representation of the pressurizer volume status. Operators can observe fluctuations in real-time, allowing them to gauge the system's responsiveness to changing conditions.

- **Overall Volume:** The Overall Volume meter, situated on the primary coolant circuit monitoring panel, operates as a comprehensive indicator of the total volume within the primary coolant system. It dynamically reflects the cumulative volume encompassing the entire pathway of the primary coolant circuit. This includes the combined volume of the core vessel, pressurizer, and all associated coolant channels.

  As the system functions, the Overall Volume meter provides real-time feedback on the current fluid quantity within the primary circuit. Operators can utilize this information to assess the overall health and status of the coolant system. An increase or decrease in the meter reading may indicate variations in coolant levels, prompting operators to take necessary actions to maintain optimal operating conditions. Essentially, the Overall Volume meter serves as a pivotal tool for monitoring and ensuring the integrity of the primary coolant system in the reactor.

- **Circulation Pumps Coolant System Panel:** The Circulation Pumps Coolant System light panel, situated on the primary coolant monitoring panel, comprises nine lights—three for each circulation pump.

  The first light in each column signifies the presence or absence of the pump. The second light indicates whether the pump is operating under dry conditions, and the third light communicates if the pump is functioning with an overload.

  This configuration offers a concise visual representation of the status of each circulation pump, covering installation status, dry operation, and potential overload conditions for comprehensive monitoring and quick assessment by operators.

- **Core Outer Vessel Coolant Level:** The Core Outer Vessel Coolant Level meter, situated on the primary coolant circuit control panel, operates by monitoring the volume of coolant surrounding the reactor core in the external pool. This pool serves as a protective reservoir, containing any potential minor leaks of radioactivity.

The meter plays a crucial role in safeguarding the core from temperature fluctuations. By continuously assessing the coolant level in the external pool, the system ensures a consistent and adequate thermal environment for the reactor core. This proactive measure not only protects against potential leaks but also contributes to maintaining the stability and integrity of the core, preventing undesirable temperature variations.

- **Core Outer Vessel Coolant Temperature:** The meter provides real-time information on the temperature of this external coolant, offering crucial insights into the environmental conditions surrounding the core. By ensuring the coolant remains within specified temperature ranges, the system helps prevent potential radioactive releases and maintains the core at optimal operating conditions. This monitoring mechanism plays a pivotal role in enhancing the safety and stability of the reactor, mitigating risks associated with temperature variations and contributing to the overall integrity of the containment system.

CONTROL PANEL: COOLANT SYSTEM | SWITCHES

- **RCP | Primary Circuit Coolant Flow Speed panel**

  Is a critical component within the reactor control room, providing precise control over the circulation pumps in the primary circuit. This panel features three distinct control groups, each corresponding to one of the circulation pumps, along with a dedicated regulator for each pump.

  Operators have the capability to set the desired speed for each pump using these regulators.

  - **Control Groups:** Three separate control groups are allocated, each governing a specific circulation pump within the primary circuit. This segmentation allows for individualized control and monitoring of each pump.

  - **Regulators:** Associated with each circulation pump, the regulators enable operators to establish the required speed for optimal coolant flow. Adjusting these regulators affects the pump's performance and, consequently, the overall flow rate in the primary circuit.

  - **Displays:** For every pump, there is a dedicated display indicating both the current speed and the speed requested by the operator. This real-time feedback offers a clear and immediate overview of the pump's performance relative to the operator's instructions.

  - **Significance of Speed Setting:** The speed setting directly influences the flow rate of coolant within the primary circuit. Achieving and maintaining the specified speed is crucial for effective heat transfer and overall reactor efficiency.

- **Fault Indication:** If a circulation pump fails to reach the required speed, it serves as an early warning sign of potential pump damage or malfunction. In such cases, operators can identify the affected pump and take corrective measures to address the issue promptly.

  Operators must regularly monitor the displays and assess whether the actual pump speed aligns with the requested speed. Any deviation may prompt further investigation or troubleshooting to ensure the health of the circulation pumps.

In essence, the RCP | Primary Circuit Coolant Flow Speed panel empowers operators with granular control over circulation pumps, allowing them to regulate coolant flow efficiently. The inclusion of displays and speed regulators not only facilitates precise adjustments but also serves as a diagnostic tool to detect pump issues, ensuring the integrity and reliability of the primary circuit's cooling system.

- **Circulation Pumps Switch panel**

  Is a fundamental control interface within the reactor control room, featuring three switches—one for each circulation pump in the primary circuit. These switches empower operators with the ability to activate or deactivate individual circulation pumps based on operational requirements.

  - **Individual Pump Control:** The panel comprises three distinct switches, each directly linked to a specific circulation pump. This setup allows operators to exercise independent control over the operation of each pump within the primary circuit.

  - **On/Off Functionality:** The switches facilitate a straightforward on/off functionality, enabling operators to either activate or shut down a circulation pump with a simple switch movement. This control mechanism provides a quick and direct means of adjusting the primary circuit's coolant flow.

  - **Operational Flexibility:** The ability to selectively turn pumps on or off offers operational flexibility. For instance, during periods of low energy demand or maintenance activities, operators can choose to deactivate specific pumps while keeping others operational.

- **Emergency Scenarios:** In emergency situations or as part of safety protocols, operators can swiftly deactivate circulation pumps to mitigate potential risks or address specific issues within the primary circuit.

Operators routinely interact with the Circulation Pumps Switch panel to align the operation of circulation pumps with the dynamic needs of the reactor. This includes starting pumps during reactor startup, shutting them down for maintenance, or adjusting pump configurations based on varying operational conditions.

Safety Considerations: The panel is designed with safety in mind, allowing for rapid intervention in case of emergencies or abnormal conditions. The simplicity of the on/off switches facilitates efficient decision-making during critical situations.

- **Primary Circuit Coolant Main Flow Speed**

The Primary Circuit Coolant Main Flow Speed panel serves as a centralized control hub within the reactor control room, overseeing the operation of all installed circulation pumps in the primary circuit. This comprehensive panel features a singular regulator governing the collective speed of all pumps, a display indicating the current speed of all installed pumps, and a separate display reflecting the total circulation power ordered by the operator.

- **Regulator:** The single regulator on the panel allows operators to set the desired overall speed for all installed circulation pumps collectively. Adjusting this regulator influences the combined flow rate of coolant throughout the primary circuit.

- **Pump Speed Display:** The display dedicated to pump speed provides real-time information on the current operating speeds of all installed circulation pumps. This holistic view allows operators to assess the collective performance of the pumps at a glance.

- **Total Circulation Power Display:** The display on the panel indicates the total circulation power or the aggregated speed flow capacity ordered by the operator. This display reflects the avg of the speed settings for all installed pumps, providing an overview of the entire primary circuit's flow potential.

Unlike the previous panel that enables individual control over each pump, this panel functions on a global scale, regulating the speed and power of all installed pumps collectively. Operators utilize the regulator to establish the desired overall speed, taking into consideration the reactor's operational requirements and safety parameters.

- **Freight Pump panel**

The Freight Pump panel is a crucial component in the reactor control room, offering operators control over the freight pumps in both the primary and secondary circuits. This panel features three main controls: a switch for activating or deactivating the Freight Pump in the primary circuit, another switch for the Freight Pump in the secondary circuit (or Condenser), and a selector for loading or unloading coolant in the external vessel of the core.

- **External Freight Pump Switch:** This switch controls de activation and deactivation of the Freight Pump that draws water from the external surroundings of the facility and accumulates it in the main external reservoir.

- **Internal Freight Pump Switch:** This switch controls de activation and deactivation of the Freight Pump responsible for transferring water from the external reservoir to the internal reservoir. Subsequently, this water can be utilized to fill the primary circuit.

- **Primary Circuit Freight Pump Switch:** This switch controls the activation and deactivation of the Freight Pump in the primary circuit. When activated, the pump facilitates the movement of coolant within the primary loop, contributing to heat transfer and overall system efficiency.

- **Secondary Circuit (Condenser) Freight Pump Switch:** The second switch pertains to the Freight Pump in the secondary circuit or Condenser. Activating this switch initiates the movement of coolant within the secondary loop, supporting the heat exchange process.

- **Coolant Loading/Unloading Selector:** The selector enables operators to choose between loading and unloading coolant in the external vessel of the core. This functionality is crucial for managing the coolant inventory around the core and ensuring optimal conditions for heat dissipation.

- **Freight Pump Activation**

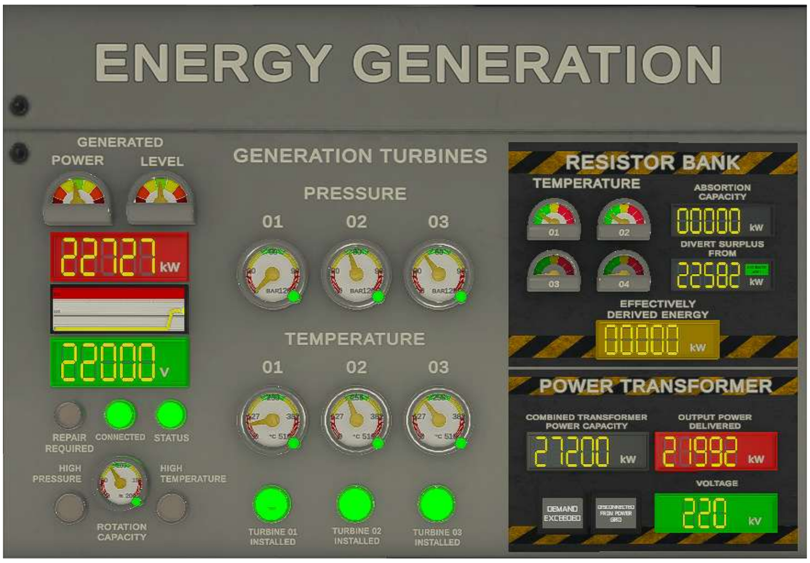
  Operators use the respective switches to activate the Freight Pumps in both the primary and secondary circuits based on operational requirements. This ensures the continuous and controlled flow of coolant for effective heat transfer. The Freight Pump panel provides operators with direct and immediate control over the coolant flow within both primary and secondary circuits.

- **Coolant Loading/Unloading**

  The selector allows operators to choose whether to load or unload coolant in the external vessel of the core. This action is performed in response to operational needs or specific maintenance procedures. The ability to load or unload coolant in the external vessel of the core enhances the flexibility of coolant management, adapting to varying operational scenarios.

In summary, the Freight Pump panel is instrumental in regulating the coolant flow in both primary and secondary circuits, providing operators with essential control switches and selectors to optimize heat transfer and maintain the integrity of the reactor's cooling processes.

CONTROL PANEL: ENERGY GENERATION



The Energy Generation Control Panel, situated in the control room, is a central interface for overseeing and managing various components related to energy production within the reactor facility. This comprehensive panel includes indicators and controls for monitoring the power generated by turbine generators, the status of resistance banks, and the functionality of transformers.

- **Power:** Is a critical gauge that provides a visual representation of the power generated by the turbine in relation to its total capacity. Ranging from 0% to 100%, this meter offers a real-time indication of the efficiency and utilization of the turbine's power generation capabilities. At 0%, the turbine is not producing any power, while at 100%, it is operating at its maximum capacity.

  The Power Meter provides instantaneous feedback on the current power output of the turbine. Operators can observe the position of the indicator on the scale to understand the percentage of the turbine's capacity being utilized at any given moment. Monitoring the meter helps operators optimize power generation, ensuring that the turbine operates within safe and efficient parameters.

- **Level:** Is a crucial indicator that quantifies the power generation of the turbine in proportion to the total energy demand specified by the city. With a scale ranging from 0% to 100%, this meter offers a real-time assessment of the balance between the power generated and the energy requested by the city. A reading of 100% indicates that the turbine is generating the exact amount of energy requested by the city.

The Level Meter provides instantaneous feedback on the alignment between the power generated by the turbine and the energy demand specified by the city. Operators can observe the meter to ensure that the power generation matches the requested energy levels. *Maintaining the Level at 100% ensures that neither excess nor insufficient energy is being generated, contributing to grid stability and efficient energy utilization.*

The Level Meter is closely integrated with overall control strategies, allowing operators to make informed decisions based on the real-time data it provides, ensuring a precise match between power generation and energy demand.

In summary, the Level Meter is a pivotal tool for operators to monitor and optimize power generation, ensuring a harmonious balance between the turbine's output and the energy demand specified by the city. Maintaining the Level at 100% contributes to grid stability, efficient energy utilization, and the overall reliability of the power generation system.

- **Energy Panel (kW):** The display indicating the energy generated by the turbine, expressed in kilowatts (kW), serves as a vital tool for operators to monitor the real-time output of the turbine and assess its contribution to overall energy production. The primary function of the display is to provide a numerical representation of the current energy output generated by the turbine, measured in kilowatts. This value is a direct quantification of the electrical power being produced at any given moment.

  The display offers real-time information on the instantaneous power output of the turbine. It reflects the dynamic nature of power generation, allowing operators to observe fluctuations and variations as they occur.

  Monitoring the kilowatt output is essential for ensuring that the turbine is operating within safe and optimal parameters, contributing to grid stability and meeting energy demand.

- **Energy Panel BUS (kW):** Offers real-time monitoring of the city's energy demand. This allows players to observe fluctuations and patterns in electricity consumption, enabling strategic decision-making in power generation and distribution.

  Efficiently managing the "Energy Panel BUS (kW)" is crucial for maintaining a balance between energy supply and demand. Players must ensure that the generated energy aligns with the city's consumption patterns to avoid shortages or wastage.

- **Energy Panel (V):** The display indicating the energy generated by the turbine, expressed in volts (V), provides crucial information about the electrical potential or voltage produced by the turbine.

  The primary function of the display is to show the voltage output of the turbine. Voltage represents the electrical potential difference generated by the turbine and is a key parameter in understanding the electrical power produced.

  - **Transmission Efficiency:** Higher voltage reduces energy losses during transmission. Ohm's Law states that energy loss in a conductor is proportional to the square of the current and directly proportional to resistance. By maintaining a high voltage, current can be reduced, thereby minimizing energy losses in transmission cables.

  - **Reduction of Energy Losses:** As electricity travels through the transmission and distribution network, energy losses occur due to resistance in the conductors. Higher voltage allows the transmission of the same amount of energy with lower currents, thus decreasing energy losses in the system.

  - **Improvement in Service Quality:** Stable and adequate voltage ensures a consistent quality of electrical supply. Voltage fluctuations can negatively impact electrical and electronic equipment connected to the grid, potentially leading to malfunctions or damage.

Adequate voltage allows for a higher load capacity in the system. This is crucial to meet the growing energy demand, especially during peak times, avoiding supply drops and ensuring reliable service.

- **Energy Panel BUS (V):** Allows players to monitor the city's voltage demand in real-time. This feature enables players to respond promptly to changes in electrical needs and ensures that the power supply meets the specified voltage levels.

  Efficiently managing the "Energy Panel BUS (V)" is crucial for optimizing the power supply. Players need to ensure that the generated voltage matches the diverse requirements of the city to prevent issues such as voltage drops or overloads.

- **RPM Panel:** The RPM display serves as a real-time measurement of the number of revolutions the turbine makes per minute. This data is fundamental for understanding the operational speed of the turbine. Monitoring the RPM is essential for assessing the operational efficiency of the turbine. Changes in speed can indicate adjustments in power output and contribute to optimizing the overall efficiency of the power generation process.

  The RPM display is often instrumental during the synchronization process. It provides visual feedback, allowing players to align the turbine's speed with the desired frequency, ensuring synchronization with the electrical grid.

Keeping an eye on the RPM is crucial for preventing overloading or excessive strain on the turbine. Operators can use this information to make timely adjustments to maintain safe operating conditions.

- **Hertz Panel (Hz):** This display serves as a real-time measurement of the frequency of the electrical output produced by the turbine. Frequency is crucial as it determines the rate at which alternating current oscillates. Is a key indicator of power quality. Consistent frequency ensures that the electrical power supplied to the grid meets the required standards, preventing issues such as equipment malfunctions or power disruptions.

  The Hertz display is crucial during the synchronization process. Players can use this information to fine-tune the turbine's frequency, ensuring accurate synchronization with the grid and enhancing overall operational efficiency.

- **Hertz Panel BUS (Hz):** This display offers real-time information about the frequency of the electrical power demanded by the city. This measurement reflects the required rate at which alternating current oscillates to meet the diverse needs of the city.

  Ensuring that the frequency displayed aligns with the electrical grid's specifications is crucial for maintaining a synchronized and reliable power supply to the city. Maintaining the correct frequency in line with the city's power demand is crucial for overall grid stability and reliability. The Bus Hertz display acts as a key tool for players to ensure that the delivered power meets the dynamic needs of the city.

- **Amperes Panel (A):** This display provides real-time information about the excitation current flowing through the turbine generator. Excitation current is a crucial factor in controlling the magnetic field within the generator and, consequently, the voltage output.

  Voltage Regulation: Adjusting the excitation of the turbine generator impacts the magnitude of the voltage produced. The Amperes display allows players to monitor and control the excitation current, ensuring that the generated voltage aligns with the desired levels for optimal power output.

  The Amperes display serves as a tool for players to exercise control over the generator's excitation. This level of control is essential for adapting to dynamic power demands, maintaining stability, and ensuring the longevity of the turbine generator.

- **Minimum Torque Reached light:** This light serves as an initial checkpoint in the turbine's operation. It indicates when the torque, the rotational force applied to the turbine, has reached the minimum threshold necessary to start the turbine's movement. When the turbine is at rest, it requires a minimum level of torque to overcome inertia and initiate rotation.

  The "Minimum Torque Reached" light acts as a signal to operators that the turbine is ready to start moving and generating power. This prevents issues such as stalling or insufficient force during the initial phases of power generation.

- **Stable RPM light:** This light serves as a confirmation that the turbine has achieved its target operational speed and is maintaining a consistent RPM. This stability is vital for reliable and efficient power generation. The indicator light is an important signal for operators to prepare for the synchronization process. When the RPM is stable, it indicates that the turbine is in a suitable state for synchronization with the electrical grid.

  The "Stable RPM" light prevents the synchronization process from starting prematurely by ensuring that the turbine has settled into a steady rotation. This reduces the risk of synchronization issues caused by RPM fluctuations.

- **Connected light:** This indicator light serves as a visual cue to signify whether the power plant is currently connected to the city's electrical distribution grid. Understanding its operation and significance is crucial for ensuring proper functioning and adherence to safety protocols.

  Importance of Being Connected Before Power Generation

  Before initiating power generation, it is imperative for the power plant to be connected to the electrical grid. Synchronization ensures that the plant's generated electricity aligns with the frequency and phase of the grid, preventing potential disruptions.

  - **Safety and Grid Stability:** Connecting to the grid before generating power is a safety measure to avoid uncontrolled injections of electricity. It helps maintain grid stability by ensuring that the power generated by the plant is in harmony with the overall energy flow.

  - **Prevention of Islanding:** Being connected to the grid prevents the occurrence of "islanding," a situation where a power plant continues to generate electricity even when disconnected from the grid. Islanding can pose safety risks and damage equipment.

Consequences of Not Being Connected

Attempting to generate power without being connected to the grid can lead to electrical imbalances and damage to plant equipment.

- **Grid Instability:** Operating in isolation can create instability in the grid, potentially affecting other connected systems and causing voltage and frequency fluctuations.

- **Safety Hazards:** Uncontrolled injections of power pose safety hazards to both the plant and the broader electrical network. It can lead to overloading, equipment failures, and pose risks to personnel.

- **Generation Turbine Pressure:** The Generation Turbines Pressure meters (one for each turbine), play a crucial role in monitoring and ensuring the optimal performance of the turbines within the power plant.

  Each meter is dedicated to monitoring the pressure levels within the turbines. Pressure is a critical parameter in the steam-driven turbine system, influencing the efficiency and output of the turbines. Operators use the readings from the pressure meters to identify any deviations from standard pressure levels. Adjustments or corrective actions can be taken to maintain the turbines within the desired operational parameters.

- **Generation Turbine Temperature:** The Generation Turbines Temperature meters (one for each turbine), play a crucial role in monitoring and ensuring the optimal performance of the turbines within the power plant.

  Each Generation Turbines Temperature meter is dedicated to monitoring the temperature within a specific turbine. Temperature control is critical for preventing overheating and ensuring the efficiency of the turbines. Operators use temperature readings to assess the thermal conditions of the turbines. Deviations from expected temperatures can prompt operators to make adjustments or take corrective actions to avoid potential issues.

- **Generation Turbine Torque:** Is a critical gauge that measures the torque produced by each turbine. This measurement is expressed as a percentage of the turbine's total capacity. This meter measures the rotational force, or torque, produced by each turbine. Torque is a crucial parameter indicating the amount of rotational force applied by the turbine's blades. The torque reading is expressed as a percentage of the turbine's total capacity.

This provides a relative measure, allowing operators to gauge how close the turbine is to its maximum torque output. The meter serves as an operational efficiency indicator. Monitoring the torque percentage helps operators assess how effectively each turbine is converting steam energy sources into rotational force.

Keeping track of the Generation Turbine Torque ensures that the turbines operate within safe limits. If the torque approaches or exceeds the turbine's maximum capacity, operators can take preventive measures to avoid overloading and potential damage.

- **Resistance Bank Panel | Temperature:** The Temperature Meter for the resistance bank, with one dedicated meter for each bank (ranging from 1 to 4 possible banks), is a critical component in monitoring the thermal conditions of these resistance elements.

  Each Temperature Meter is designed to monitor the temperature of its corresponding resistance bank. Resistance banks are emergency devices used for load control, and the temperature meter provides real-time feedback on the thermal conditions during their operation.

- **Resistance Bank Panel | Absorption Capacity:** The Absorption Capacity display monitors and indicates the current capacity of the resistance banks. It quantifies the amount of electrical energy that can be absorbed by the resistance banks during their operation.

  The display offers real-time feedback on the absorption capacity, allowing operators to assess the readiness of the resistance banks to absorb excess energy and prevent overloading of the power system.

- **Resistance Bank Panel | Divert Surplus From:** Is part of an automated system that determines the source from which surplus energy will be diverted for absorption by the resistance banks. It involves a decision-making process based on real-time data. The display is linked to the total energy generation of the power plant. It considers the overall electrical output of the plant as a reference point for determining surplus energy that needs to be absorbed.

The automated system, guided by the "Divert Surplus From" display, optimizes the activation and use of resistance banks.

- **Resistance Bank Panel | Effectively Derived Energy:** Monitors and presents the cumulative amount of electrical energy that has been effectively derived and absorbed by the resistance banks. This information reflects the actual utilization of the resistance banks during their operation.

  Monitoring effectively derived energy helps operators evaluate the performance and efficiency of the resistance banks in emergency load control. The display assists in preventing overloading by providing real-time insights into the actual energy absorption by the resistance banks. This information is crucial for ensuring the safety and reliability of the power generation system.

- **Power Transformer Panel | Combined Transformer Power Capacity:** The display quantifies and presents the total energy transformation capacity of all connected transformers combined. This value is expressed in kilowatts (kW) and represents the cumulative capability of the transformers to convert electrical energy.

  The display helps operators gauge the plant's readiness to respond to varying grid demands. It provides insights into the total capacity available for adapting to fluctuations in energy consumption. Understanding the total energy transformation capacity allows operators to optimize the distribution of electrical energy across the grid efficiently.

- **Power Transformer Panel | Output Power Delivered:** presents the cumulative amount of electrical energy that has been transformed by the transformers and effectively delivered to the electrical grid. This information reflects the actual energy contribution to the grid. The display offers real-time feedback on the total output power delivered, allowing operators to assess the overall performance and contribution of the transformers in supplying electrical energy to the grid.

  Monitoring the output power delivered is crucial for evaluating the transformers' effectiveness in supplying electrical energy to the grid and meeting the demand. And assists in preventing overloading by providing real-time insights into the transformers' contribution to the grid. This information is essential for ensuring the safety and reliability of the power generation system.

- **Power Transformer Panel | Demand Exceeded:** Serves as a visual signal, illuminating when the total energy delivered to the city surpasses the current demand. The "Exceeded Demand" indicator monitors the real-time demand for electrical energy within the city. It compares the total energy delivered to the city with the current demand. When the delivered energy exceeds the demand, the indicator light is activated.

    - Potential Grid Stress: The indicator warns operators that the electrical grid may be experiencing stress due to an excess of supplied energy compared to the current demand.

    - Adjustment Needed: It prompts operators to assess the situation and consider adjustments to the energy delivery to align with the actual demand, preventing potential issues such as overloading or grid instability.

- **Power Transformer Panel | Disconnected From Power Grid:** Serves as a visual signal that the power plant is not currently connected to the electrical distribution grid. The indicator light illuminates when the power plant is not connected to the electrical distribution grid. This status indicates that the plant is operating in isolation from the broader power network.

    Operator Interpretation

    The illuminated "Disconnected from Power Grid" indicator visually confirms to operators that the power plant is not currently integrated with the broader electrical distribution system.

    Importance of Disconnected Indicator

    - Grid Synchronization: The indicator is crucial for ensuring that the power plant is aware of its disconnected status, preventing attempts to generate power without being synchronized with the grid.

- Safety and Operational Integrity: Operating in isolation from the power grid is a deliberate state, and the indicator helps maintain safety by preventing uncontrolled injections of power and ensuring operational integrity.

CONTROL PANEL: ENERGY GENERATION | SWITCHES

- **Turbines Bypass Valves:** The Turbines Bypass Valves panel is a critical component consisting of three regulators (one for each turbine). Each regulator is equipped with a display to show the current degree of valve opening and the degree of opening requested by the operator.

  The regulator controls the hydraulic motor of the valve, adjusting its opening to achieve the desired degree. Each valve performs a bypass between the evaporators and the condenser, preventing steam from passing through the turbine.

  - *Bypass Functionality:* The Turbines Bypass Valves are designed to provide a bypass route for steam, allowing it to skip the turbines and flow directly from the evaporators to the condenser. The regulators on the panel control the degree of opening of the bypass valves. The degree of opening is a measure of how much the valve allows steam to bypass the turbines.

    The operator can use the displays to monitor and adjust the degree of opening based on the operational requirements of the power plant. This control allows for dynamic management of the steam flow.

  - *Utilizing the Bypass:* Opening the bypass valves is a strategic choice made by operators to regulate the flow of steam in the power plant. It provides a means to control and manage the overall energy output. By adjusting the bypass valves, operators can control the load on the turbines and manage the power output of the plant. This is particularly useful during fluctuations in demand or operational changes.

- *Preventing Turbine Stress:* Opening the bypass valves helps prevent unnecessary stress on the turbines during periods when full power generation is not required. It allows for a more gradual adjustment to varying power demands. The bypass valves also play a role in regulating the temperature of the steam. By controlling the flow, operators can optimize the temperature conditions within the power plant.

- *Efficiency Considerations:* Strategically using the bypass valves contributes to the overall efficiency of the power plant. It ensures that the turbines operate under conditions that maximize their performance and lifespan.

- *Emergency Scenarios:* In certain emergency scenarios or abnormal conditions, opening the bypass valves may be a safety measure to redirect steam away from the turbines and prevent potential damage.

- **Bypass Valve Link switch:** When the switch is set to ON, it enables the adjustment of all valves simultaneously using the regulators. Conversely, when set to OFF, each regulator modifies only the valve it is associated with.

  Link ON (Switch ON):

  - Simultaneous Control: With the Link switch ON, all regulators have a collective impact on every valve. Adjustments made by any regulator will affect all valves at the same time.
  - Global Valve Adjustment: This setting provides a synchronized approach, allowing for global adjustments to all valves. It is useful when a coordinated response is needed across the entire valve system.

  Link OFF (Switch OFF):

  - Individual Valve Control: When the Link switch is OFF, each regulator operates independently, affecting only the specific valve it is connected to.

  - Isolated Valve Adjustment: This setting allows operators to make isolated adjustments to individual valves without impacting the others. It provides a more granular level of control, offering precision in regulating specific valves.

Practical Implications:

- Emergency Response: The Link ON setting can be useful in emergency scenarios where a swift and coordinated response is needed to control or redirect steam flow across all valves simultaneously.

- Fine-Tuning Operations: The Link OFF setting is beneficial during regular operations or maintenance when operators may need to fine-tune specific valves without affecting the entire system.

In summary, the Turbines Bypass Valves panel, with its regulators and displays, plays a crucial role in the strategic management of steam flow within the power plant. By opening the bypass valves, operators can control load, regulate temperature, and optimize the overall efficiency and performance of the turbines in response to varying operational conditions.

- **Compensator:** A power compensator serves the purpose of stabilizing energy generation by addressing variations in torque that may occur in a generator turbine. The normal torque fluctuations in a generator turbine can lead to fluctuations in the generated power output. When the compensator is active, the turbine controller adjusts the generated energy to maintain stability.

  It's important to note that the compensator should only be activated when the turbine is operating within its specified operational ranges. Activating the compensator outside these ranges could potentially impede the stabilization of the turbine rather than assisting it.

- **Resistor Bank Switches:** The Resistor Bank Switches panel is a crucial component that contains four switches, each responsible for connecting or disconnecting resistor banks. Resistor banks, when connected, are available to receive energy derived from the power generating turbines.

Resistor banks are specialized devices designed to absorb and dissipate electrical energy. They serve as emergency load control mechanisms in the power plant. When a switch is in the "Connect" position, it establishes the electrical connection for the respective resistor bank, making it available to receive energy derived from the turbines.

During normal operation or when emergency load control is not required, operators may choose to disconnect the resistor banks using the switches. This prevents unnecessary energy absorption by the resistors.

Emergency Load Control

In situations where there is excess electrical energy generated by the turbines and the grid cannot absorb it, operators can connect the resistor banks to absorb and dissipate the excess energy, preventing overloading.

Connecting resistor banks provides a means of load balancing in the power plant. It helps stabilize the electrical grid by absorbing surplus energy and preventing disruptions.

The resistor banks serve as a protective mechanism for the power generation equipment. By absorbing excess energy, they prevent potential damage to turbines and associated components.

- **Derivation Percentage Panel:** The Derivation Percentage Panel is a critical component that includes both an automatic mode switch and a manual regulator for controlling the percentage of energy to be derived to the resistor banks.
    - **Automatic Mode:** The panel features a switch that allow operators to toggle between automatic and manual modes. When in automatic mode, the system calculates the energy that should be derived to the resistor banks based on the current demand of the city.
        - Demand Sensing: In automatic mode, the panel is designed to sense the demand from the city and dynamically adjust the percentage of energy derivation to the resistor banks to meet the load requirements.

- Efficient Load Control: Automatic mode ensures efficient load control by automatically managing the energy derivation process, responding to variations in the city's power demand without requiring constant manual adjustments.

- **Manual Mode:** When the automatic mode is deactivated, operators can manually control the energy derivation percentage using a regulator on the panel. The regulator allows adjustments from 0% to 100%.

  - Operator Flexibility: Manual mode provides operators with flexibility in determining the proportion of energy that should be directed to the resistor banks. This manual control is valuable for fine-tuning energy distribution based on operator insights.

  - Immediate Adjustments: Operators can make immediate adjustments to the energy derivation percentage in manual mode, responding to specific operational requirements or emergency scenarios.

The Derivation Percentage Panel is integrated into the broader control system of the power plant. It collaborates with other panels and components to ensure a coordinated response to variations in power demand and emergency load control. Operators play a key role in deciding whether to operate in automatic or manual mode based on the plant's operational goals, load conditions, and the need for emergency load control.

- **Turbine Trip Emergency Button:** The Turbine Trip Emergency Button serves as a safety mechanism by initiating a rapid opening of the ventilation valves on the turbines.

  - This action redirects steam away from the turbines, directing it to the secondary condenser. The sole purpose of the secondary condenser, in this context, is to absorb steam during emergency situations.

  - Simultaneously, the Turbine Trip Emergency Button triggers the opening of the circuit breaker in the turbine's electrical system to disconnect the turbine from the electrical grid for safety measures.

- **Synchronoscope Panel:** the Synchronoscope Panel is a critical tool for synchronizing the turbine with the electrical grid. Here's an explanation of each component and its functionality:

  - **Synchronoscope Display:** The primary display that shows the current frequency and phase of the turbine in comparison to the electrical grid. It provides real-time feedback on the synchronization process.

  - **RPM Raise Button:** Increases the turbine's rotational speed. Press when the turbine needs to match the Hertz grid's frequency during synchronization. Used to raise the RPM for alignment.

  - **RPM Lower Button:** Decreases the turbine's rotational speed. Press when adjustments are needed to lower the turbine's RPM during the synchronization process, to match Hertz grid's frequency.

  - **Circuit Breaker Open Button:** Opens the circuit breaker, disconnecting the turbine from the grid. Press when isolating the turbine from the grid, such as during maintenance or troubleshooting.

  - **Circuit Breaker Close Button:** Closes the circuit breaker, connecting the turbine to the grid. Press when re-establishing the connection between the turbine and the grid after maintenance or isolation.

  - **Voltage Raise Button (Field Excitation):** Increases the excitation voltage, influencing the generator's output voltage. Press when adjusting the turbine's voltage output during synchronization to match the grid's voltage.

  - **Voltage Lower Button (Field Excitation):** Decreases the excitation voltage. Press when adjustments are needed to lower the turbine's voltage output during synchronization.

- **Circuit Breaker Open light:** When the circuit breaker is open (**red** color), it signifies that the electrical connection between the generator (or turbine) and the electrical grid is interrupted. This state can be due to various reasons, such as maintenance, repairs, or a manual action to disconnect the unit from the electrical system.

  When the circuit breaker is closed (indicated by a **green** light), it signifies that the electrical connection between the generator (or turbine) and the electrical grid is established.

  This state indicates a normal operational condition where the unit is connected to the grid, allowing the flow of electrical power. The green light signals proper functioning, and the closure of the circuit breaker is necessary for the unit to actively contribute to the electrical grid.

- **Synchronized light:** The synchronization process involves matching the frequency and phase of the generator's output with that of the electrical grid. The synchroscope is a device used to visualize and assist in achieving this synchronization. When the generator's frequency and phase align precisely with the grid, the synchroscope needle reaches the 0 position.

  Simultaneously, the "Synchronized" light illuminates, indicating that the synchronization process is successful, and the generator is ready to be connected to the grid.

These functions collectively allow operators to synchronize the turbine with precision, ensuring a smooth and controlled integration with the electrical grid.

CONTROL PANEL: INTERNAL SUPPLY

The Internal Plant Supply Control Panel is a centralized interface that allows operators to manage and monitor essential internal power supply components within the facility.

This panel provides control over generators, emergency batteries, and facilitates oversight of internal power consumption.

The panel enables operators to control various generator groups within the plant. Generators are crucial for ensuring a stable and reliable power supply, especially in the event of grid outages. Operators can start, stop, or adjust the output of each generator based on the plant's energy needs.

Emergency batteries play a critical role in providing backup power during unexpected power outages or emergency situations. The control panel allows operators to monitor the status of the batteries, including their charge level and overall health. In the case of an outage, operators can initiate the use of emergency batteries to maintain essential systems until primary power sources are restored.

The panel provides real-time data on the internal power consumption of the plant. Operators can verify the current consumption levels and assess the load on the internal electrical system. Additionally, control features enable adjustments to internal power distribution, optimizing the use of available resources and ensuring efficient energy utilization.

The control panel facilitates load balancing by allowing operators to distribute power from generators and emergency batteries based on the priority of different plant systems. This ensures that critical operations receive power priority during times of high demand or power constraints.

- **Starting lights:** The starting lights associated with each of the two installable generator sets serve as visual indicators to convey the status of the generator during the startup process. Specifically, these lights illuminate or blink when the generator is in the process of starting up.

Initialization and Pre-Start Phase: When the "Starting" light is illuminated or blinking, it signals that the generator is in the initialization and pre-start phase. During this stage, various systems within the generator are being prepared for operation, and the engine is being ready for ignition.

Fuel System Priming: The blinking "Starting" light may coincide with the fuel system priming process. This involves ensuring that the fuel lines are filled with fuel, ready to supply the engine when the ignition sequence begins. The blinking light provides a visual cue that this essential pre-start step is in progress.

Engine Ignition: As the "Starting" light blinks, it signifies that the engine ignition sequence is underway. Igniters or glow plugs are activated to initiate combustion within the engine. The blinking light serves as a visual confirmation that the generator is in the active phase of starting its engine.

The "Starting" light typically ceases to blink and remains steady once the generator has successfully completed the startup sequence. This signals that the generator is now in normal operating mode and is ready to provide electrical power.

- **Power:** The Power display, expressed in kilowatts (kW), provides a real-time indication of the electrical power being generated by the active generator sets within the system. Real-Time Power Output:

  The Power display in kW represents the actual electrical power output of the active generator set at any given moment. It is a dynamic and real-time measurement that reflects instantaneous energy production.

  The Power display is instrumental in responding to changes in electrical demand. Operators can adjust the output of the generator sets based on the varying load requirements, ensuring that the system meets the demand without compromising stability.

  Anomalies or faults in a generator set can be identified through the Power display. Sudden drops or fluctuations in the displayed power may indicate issues with a specific generator, prompting operators to investigate and address potential problems promptly.

- **% Fuel / Hour:** Is a crucial component of the generator control system, providing valuable information about the average fuel consumption of the generator sets over the course of one hour.

  Calculates and represents the percentage of fuel consumed by the generator sets within a specific one-hour period. It serves as an indicator of the efficiency of fuel utilization during that timeframe.

  The display provides real-time tracking of fuel consumption trends, allowing operators to assess how efficiently the generator sets are utilizing fuel resources. This information is essential for optimizing operational strategies and minimizing overall fuel costs.

- **Consuming (Batteries):** The Consuming meter measures and indicates the rate at which electrical power is being drawn from the emergency batteries. This is critical during situations where the primary power source is unavailable, and the emergency batteries become the primary source of power for the plant.

  The meter provides real-time data, allowing operators to monitor the current consumption of electrical power from the emergency batteries. Continuous monitoring of the Consuming meter provides insights into the health and capacity of the emergency batteries.

  Operators can observe how the batteries respond to different loads and assess their ability to meet the plant's power demands during emergencies.

- **Batteries Capacity:** The Batteries Capacity display represents the cumulative kW capacity of all installed batteries within the system. It indicates the maximum amount of electrical power that the batteries can collectively store and supply during periods of demand or emergencies.

  This display is dynamic and reflects the current status of the overall capacity of the installed batteries. It takes into consideration the gradual changes in capacity, such as losses due to dragging, providing operators with real-time information on the available energy storage.

As batteries undergo dragging, their overall capacity diminishes over time. The Batteries Capacity display incorporates this loss into its calculation, offering operators an accurate representation of the remaining effective capacity for the entire battery bank.

- **Total Energy Generated:** The display accumulates and shows the total amount of electrical energy generated by the generator sets and emergency batteries over a specific period. It provides a comprehensive view of the overall energy production, considering contributions from both sources. Operators use the Total Energy Generated display for real-time tracking of the plant's overall energy output. It offers insights into the efficiency and performance of the entire power generation system over the selected timeframe.

- **Batteries / Charge:** The Battery Load Meter is a vital instrument that visually represents the overall charge level of the entire rack of emergency batteries. This meter employs a needle to showcase the charge status, ranging from 0% (no charge) to 100% (full charge). The meter provides a consolidated view of the charge level for the entire rack of emergency batteries.

- **Discharging % / Hour:** The display calculates and presents the average rate at which the battery rack is discharging its stored energy over the course of one hour. This metric is expressed as a percentage, representing the proportion of the total battery capacity consumed during that time frame.

  Operators use the Discharging % / Hour display for real-time monitoring of the battery rack's energy consumption trends. It offers immediate feedback on how efficiently the emergency batteries are discharging their stored energy based on the current operational demands.

CONTROL PANEL: INTERNAL SUPPLY | SWITCHES

- **External Energy Supplier**

  This switch allows connecting the plant to the external power provider to supply the internal energy requirement. Electricity consumption must be paid daily on a day-to-day basis. Invoices can be consulted in the tablet's Bank app.

- **Generator Group Mode Selector**

  1. **Manual Mode:** In Manual Mode, the operator has direct control over the generator group's operation. In emergency situations, the Manual mode ensures that the operator has immediate control over the generator's startup and shutdown. This can be crucial for responding rapidly to unforeseen events or quickly addressing power demand fluctuations.

     - *Start Operation:* The operator initiates the generator by pressing the "Start" button. This action activates the generator and begins the power generation process.

     - *Stop Operation:* To cease generator operation, the operator presses the "Stop" button. This action halts the generator, bringing it to a complete stop.

  2. **Automatic Mode:** In Automatic Mode, the generator group operates based on internal plant requirements and predefined criteria. The mode offers a more hands-free approach, and the system manages the generator's status without continuous manual intervention.

     - *Automatic Startup:* The generator automatically starts when specific conditions or internal demands within the plant necessitate additional power. These conditions might include high energy demand, unexpected power loss, or other triggers configured in the system.

- *Automatic Shutdown:* Similarly, the generator automatically shuts down when the plant's internal systems determine that additional power is no longer required. This could be in response to decreased demand or the availability of alternative power sources.

- **Emergency Battery Rack Mode Selector**

The Emergency Battery Rack Mode Selector is a crucial component that allows operators to choose between manual and automatic modes for the emergency battery rack.

1. **Manual Mode:** In Manual Mode, operators have direct control over the emergency battery rack's operation.

- *Use Mode:* The operator selects the "Use" mode, making the battery rack available for immediate use to supply internal power within the plant. In this mode, the batteries are ready to provide energy whenever needed.

- *Charge Mode:* If the operator switches to "Charge" mode, the battery rack is configured to solely charge the batteries. While in Charge mode, the batteries do not supply energy to the plant but focus on recharging for future use.

2. **Automatic Mode:** In Automatic Mode, the emergency battery rack operates based on dynamic plant conditions and energy demand. The mode allows the system to manage the battery rack's status automatically, optimizing charging and discharging based on real-time requirements.

- *Automatic Charging:* The battery rack automatically enters charging mode when the system detects a need for replenishing the battery capacity. This ensures that the batteries are maintained at optimal levels to respond to potential power outages or high demand periods.

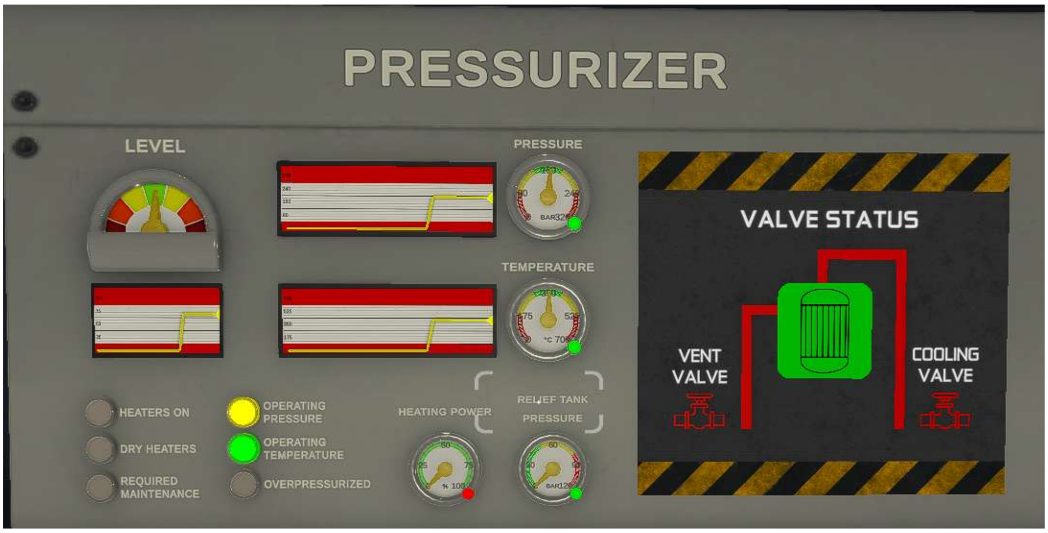
- *Automatic Power Supply:* In response to increased energy demand or specific triggers within the plant, the battery rack automatically switches to "Use" mode, supplying power internally. This occurs without manual intervention, contributing to seamless and responsive energy management.

- **Seamless Energy Transition**

  The Automatic mode facilitates a seamless transition between charging and supplying power based on plant requirements. This adaptability contributes to uninterrupted energy supply and efficient energy management during varying operational scenarios.

CONTROL PANEL: PRESSURIZER

The Pressurizer Control Panel is a critical component located in the control room, responsible for managing and regulating the pressurized water reactor (PWR) system's pressurizer.



The Pressurizer Control Panel allows operators to monitor and control the pressure inside the pressurizer vessel. Maintaining the correct pressure is essential for the safe and efficient operation of the nuclear reactor.

- **Level:** The primary purpose of the Level Meter is to offer a visual representation of the coolant level inside the pressurizer, allowing operators to monitor and maintain the proper volume of coolant. The Level Meter includes a scale with gradations that helps operators interpret the coolant level. This scale is divided into different zones to provide a clear indication of whether the coolant volume is within the desired range.

  - *Midpoint (**Green Zone**):* The midpoint of the scale, often represented by a green zone, signifies the optimal coolant level. If the needle aligns with this midpoint, it indicates that the pressurizer contains the correct volume of coolant for normal operation.

  - ***High** and **Low** Zones:* The scale extends beyond the midpoint, featuring high and low zones. If the needle moves towards the high zone, it suggests an excess of coolant, while movement towards the low zone indicates a potential deficit.

  The Level Meter provides operators with immediate visual feedback on the pressurizer's coolant level. This enables quick assessments and timely interventions to ensure that the reactor operates within safe parameters.

Changes in the pressurizer conditions, such as temperature adjustments or alterations in pressure, may influence the coolant volume. The Level Meter responds dynamically to these changes, keeping operators informed about the evolving status of the pressurizer.

- **Pressure:** The primary purpose of the Pressure Gauge is to provide operators with a visual indication of the pressure conditions inside the pressurizer. Monitoring pressure is crucial for maintaining the safe and efficient operation of the pressurized water reactor system. The gauge responds dynamically to changes in pressurizer conditions. Adjustments to temperature, coolant volume, or reactor power can influence pressure, and the gauge provides immediate feedback on these changes.

- **Temperature:** The primary purpose of the Temperature Gauge is to offer operators a visual representation of the temperature conditions within the pressurizer. Monitoring temperature is essential for ensuring the safe and efficient operation of the pressurized water reactor system. The Temperature Gauge responds dynamically to changes in pressurizer conditions. Variations in reactor power, coolant volume, or external factors can influence temperature, and the gauge provides immediate feedback on these changes.

- **Heating Power:** The primary purpose of the Heating Power Meter is to offer operators a visual representation of the power generated by the internal heaters in the pressurizer. Monitoring heating power is essential for controlling the temperature and pressure conditions within the pressurized water reactor system.

  Heating power is directly linked to temperature control within the pressurizer. The Heating Power Meter is integrated into the overall control systems, working in tandem with temperature and pressure indicators to ensure coordinated responses for maintaining optimal reactor conditions.

  Operators can adjust the heating power based on the desired temperature conditions. The Heating Power Meter provides operators with a clear indication of the power level, enabling them to make real-time adjustments to meet operational requirements.

- **Pressurizer Indicator Lights**

  - **Heaters On**: Activates when the internal heaters within the pressurizer are actively heating. It confirms that the heating system is operational and working to maintain the desired temperature within the pressurizer.

    The "Heaters On" light assures operators that the pressurizer's heating elements are engaged and contributing to the controlled environment necessary for reactor operation.

  - **Dry Heaters**: Activates when there is a risk of the heaters operating without adequate coolant. It signals a potential issue where the heating elements might be at risk of overheating due to insufficient coolant coverage.

    This warning is critical, prompting operators to address the coolant levels promptly to prevent damage to the heating elements and maintain safe pressurizer conditions.

  - **Required Maintenance:** Signals that the pressurizer is due for scheduled maintenance. It may be triggered based on operating hours, cycles, or other predefined criteria to ensure the ongoing reliability of the pressurizer system.

    This indicator prompts operators to schedule and perform necessary maintenance tasks, preventing potential issues and ensuring the continued efficient operation of the pressurizer.

  - **Operating Pressure Reached:** When the pressure inside the pressurizer reaches the desired operating level, the "Operating Pressure Reached" light illuminates. It indicates that the pressurizer has achieved the intended pressure conditions for normal reactor operation.

    This light assures operators that the pressurizer is functioning within the specified pressure range, contributing to stable reactor conditions.

- **Operating Temperature Reached:** Activates when the temperature within the pressurizer reaches the desired operating level. It signals that the heating system has effectively achieved the required temperature conditions.

  This light provides confirmation to operators that the pressurizer has attained the necessary temperature for optimal reactor performance.

- **Overpressurized:** Activates when the pressure inside the pressurizer exceeds safe operational limits. It signals a critical situation where immediate corrective actions are necessary to avoid potential safety hazards.

  This warning is a crucial safety feature, alerting operators to intervene promptly and implement measures to bring the pressurizer back to within acceptable pressure levels.

In summary, the pressurizer indicator lights play a vital role in providing real-time feedback to operators, ensuring the safe and efficient operation of the pressurized water reactor system. Each light serves a specific purpose, from confirming normal operation to signaling potential issues that require immediate attention or scheduled maintenance.

- **Pressurizer Control Panel Diagram**

  The Pressurizer Control Panel features a graphical representation of the pressurizer system, including two essential connections: the Vent Valve for releasing steam and pressure, and the Spray Valve for injecting coolant to cool the pressurizer.

  The color scheme is used to indicate the status of each valve:

  - Red Color: Valve Closed
  - Yellow Color: Valve in Transition
  - Green Color: Valve Open

The color changes in real-time based on the operational status of each valve. Operators can observe the graphical representation to assess whether the valves are closed, in transition, or fully open.

As operators manipulate the valves or as the system responds to changing conditions, the colors on the diagram dynamically update to reflect the status of each valve.

CONTROL PANEL: PRESSURIZER | SWITCHES

- **Heaters switch:** The Pressurizer Internal Heaters Switch is a critical component on the control panel, allowing operators to control the activation or deactivation of the internal heaters within the pressurizer vessel. The switch serves as a manual control mechanism to turn the internal heaters of the pressurizer on or off.

    - **ON** Position: When the switch is moved to the ON position, it signals the system to activate the internal heaters within the pressurizer. Heating Power: The internal heaters start generating heat, contributing to an increase in temperature within the pressurizer vessel.

    - **OFF** Position: Moving the switch to the OFF position instructs the system to deactivate the internal heaters. Heating Power Cessation: The internal heaters cease generating heat, allowing the pressurizer to cool down if necessary.

  The switch provides operators with direct control over the heating function, allowing them to adjust the temperature conditions within the pressurizer based on operational requirements. The activation of heaters helps in maintaining the desired temperature within the pressurizer, a crucial factor for ensuring stable reactor conditions. Turning off the heaters allows for natural cooling or other cooling mechanisms to take effect, regulating the temperature as needed.

- **Thermostat switch:** A thermostat operates within the pressurizer to regulate the water temperature. However, it's important to note that the thermostat solely monitors the temperature and doesn't directly control or measure pressure or volume within the pressurizer. When the water temperature reaches a predetermined level, the thermostat detects this change and triggers a control mechanism to maintain the operating temperature. *It's crucial to emphasize that the thermostat's role is limited to temperature regulation; it does not directly influence pressure or volume.*

- **Heating Power Selector:** The regulator acts as a control mechanism to adjust the power output of the internal heaters within the pressurizer. Features a range of power settings that operators can adjust, influencing the amount of heat generated by the internal heaters.

  Operators can make real-time adjustments to the heating power, responding to changes in operational demands, temperature requirements, or emergency scenarios.

  The power regulator is integrated into the overall control systems of the pressurized water reactor, ensuring coordination with temperature, pressure, and safety systems.

- **Vent Valve Selector:** The Pressurizer Steam Vent Valve Control Panel is a critical component in the control system, enabling operators to manage the steam vent valve on the pressurizer. The panel features a selector with three positions:

  - **Open**: Selecting the Open position activates the hydraulic motor associated with the steam vent valve. The hydraulic motor works to open the steam vent valve, allowing the controlled release of steam and pressure from the pressurizer. <u>This position is utilized when controlled venting of steam is required to manage pressure within the pressurizer</u>.

  - **Close**: Choosing the Close position triggers the hydraulic motor linked to the steam vent valve. The hydraulic motor functions to close the steam vent valve, restricting the release of steam and pressure. <u>This position is employed to cease venting and maintain desired pressure levels within the pressurizer.</u>

  - **Off:** Opting for the Off position deactivates the hydraulic motor associated with the steam vent valve. The hydraulic motor stops, halting any ongoing opening or closing activity of the steam vent valve. <u>This position is chosen when it is necessary to keep the steam vent valve in a stable, non-operational state.</u>

The selector provides operators with direct control over the hydraulic motor of the steam vent valve, allowing them to initiate specific actions based on operational requirements. Operators can swiftly respond to changing conditions within the pressurizer, adjusting the steam vent valve as needed.

- **Cooling Valve Selector:** The Pressurizer Spray (or cooling) Valve Control Panel is a critical component in the control system, allowing operators to manage the spray valve off the pressurizer. The panel features a selector with three positions:

    - **Open:** Selecting the Open position activates the hydraulic motor associated with the spray valve. The hydraulic motor works to open the spray valve, allowing the injection of coolant into the pressurizer for the purpose of cooling. This position is utilized when controlled cooling is required to manage temperature levels within the pressurizer.

    - **Close:** Choosing the Close position triggers the hydraulic motor linked to the spray valve. The hydraulic motor functions to close the spray valve, stopping the injection of coolant. This position is employed to cease cooling and maintain desired temperature levels within the pressurizer.

    - **Off:** Opting for the Off position deactivates the hydraulic motor associated with the spray valve. The hydraulic motor stops, halting any ongoing opening or closing activity of the spray valve. This position is chosen when it is necessary to keep the spray valve in a stable, non-operational state.

The selector provides operators with direct control over the hydraulic motor of the spray valve, allowing them to initiate specific actions based on operational requirements. Operators can swiftly respond to changing conditions within the pressurizer, adjusting the spray valve as needed for temperature control.

CONTROL PANEL: STEAM GENERATOR

The Steam Generators panel, situated in the control room, is a critical interface that provides comprehensive control over the steam generation process within the nuclear reactor.

This panel plays a pivotal role in managing the transfer of heat from the primary coolant to the secondary side, eventually producing steam to drive the turbines.

- **Temperature:** The meter provides operators with real-time readings of the temperature within each steam generator. This information is crucial for ensuring that the operating temperature remains within the specified safe and efficient range.

  The Temperature meter serves as an early warning system by indicating any deviations from the normal temperature range. If the temperature surpasses or falls below the predetermined thresholds, alarms may be triggered to alert operators of potential issues.

  As there are three separate meters corresponding to each steam generator, operators can individually monitor the temperature of each unit. This granularity is essential for identifying specific issues within a particular steam generator and taking targeted corrective actions.
- **Pressure:** The Pressure meter provides operators with real-time readings of the pressure levels within each steam generator. This information is essential for ensuring that the pressure remains within the designated safe operational range.

Maintaining optimal pressure is crucial for the safe and efficient operation of steam generators. The Pressure meter serves as a critical parameter for safety control, alerting operators to any deviations from the recommended pressure levels.

With three separate meters corresponding to each steam generator, operators can individually monitor the pressure levels of each unit. This granularity is crucial for identifying specific issues within a particular steam generator and taking targeted corrective actions.

- **Level:** The Level meter provides real-time readings of the coolant volume within each steam generator. It is designed to measure the level of water, ensuring that an adequate amount of coolant is maintained to facilitate the steam generation process.

  Maintaining the coolant at the optimum level is essential for the safe and efficient operation of steam generators. The Level meter helps operators ensure that the coolant volume remains within the designated safe operational range.

  With three separate meters corresponding to each steam generator, operators can individually monitor the coolant levels of each unit. This granularity is crucial for identifying specific issues within a particular steam generator and taking targeted corrective actions.

- **Thermal Balance | Steam-Water Flow Balance:** Refers to the balance between the steam generated in the steam generator and the steam exiting the system. This equilibrium ensures that the steam produced aligns with the water returning from the condenser, sustaining a consistent and efficient cycle.

  - **Steam Generated:** It is the steam generation factor of the evaporator, used to compare with the steam outlet and coolant inlet factors to determine internal equilibrium.

    The amount of steam generated is directly proportional to the reactor's power output. To increase the steam generation, one of the following actions must be taken:

- Increase Reactor Power: Boosting the reactor's power raises the heat transferred to the coolant, which in turn increases the rate of steam production.

- Increase Circulation Pump Speed: Increasing the speed of the circulation pump enhances the flow rate of the coolant through the reactor core. This results in more efficient heat transfer and subsequently higher steam generation.

Adjustments to reactor power or pump speed must be made gradually and with careful monitoring to maintain operational safety and efficiency. Overloading the system can lead to overheating or an imbalance in the steam-water flow cycle, potentially compromising the reactor's stability.

- **Steam Outlet:** It is the steam propulsion factor toward the turbines, used to compare with the steam generated and coolant inlet factors to determine internal equilibrium.

The amount of steam discharged from the evaporator is directly influenced by two key factors:

- Internal Pressure: Higher internal pressure increases the driving force that pushes the steam through the system, thereby raising the amount of steam expelled.

- Opening of the Main Steam Control Valves: The degree to which the Main Steam Control Valves are open determines the flow rate of steam leaving the evaporator. Wider valve openings allow for greater steam discharge.

How to increase the amount of steam expelled:

- Increase the internal pressure within the evaporator by adjusting operational parameters, such as reactor power or heat input.

- Ensure that the Main Steam Control Valves are opened to the appropriate degree to handle the desired flow rate.

Increasing pressure must be carefully managed to prevent system instability or over-pressurization, which could trigger safety mechanisms such as the pressure relief valve.

Valve adjustments should be gradual and monitored in real time to avoid abrupt changes in the steam-water balance.

- **Coolant Inlet:** It is the coolant return factor from the condenser, used to compare with the steam generated and steam outlet factors to determine internal equilibrium. If the factor is very low or zero, check whether there is sufficient power in the circulation pump or if the evaporator pressure is too high, preventing coolant return.

  The amount of coolant returning to the evaporator is influenced by two primary factors:

  - Internal Pressure of the Evaporator: Higher internal pressure can reduce the pressure differential between the evaporator and the condenser, making it more difficult for coolant to return efficiently.

  - Circulation Pump Speed of the Condenser: Faster pump speeds increase the flow rate of coolant back into the evaporator, facilitating a more robust return cycle.

  How to increase the volume of coolant returning to the evaporator:

  - Increase the speed of the condenser circulation pumps to boost the coolant flow rate.

  - Reduce the internal pressure of the evaporator if it is excessively high and restrict coolant reentry. Adjusting operational parameters or venting excess steam may help achieve this.

  Maintaining an optimal balance between pressure and pump speed is critical to ensuring efficient coolant return and stable system operation. Excessively high internal pressure not only impedes coolant return but also increases the risk of triggering safety systems such as the pressure relief valve.

Adjustments should be performed gradually and under careful monitoring to avoid introducing system instabilities.

Important: Maintaining this balance is essential for the safe and efficient operation of the reactor. However, in situations where the pressure inside the steam generator is very high, the water may not return in sufficient quantities due to the reduced pressure difference between the condenser and the generator. ***This imbalance can lead to a reduction in reactor efficiency and even jeopardize its operation if not properly controlled.***

The balance gauges provide a quick understanding of whether the current equilibrium situation will cause the evaporator to empty or become overpressurized.

- If the needle moves to the left, it means the evaporator is receiving more water than it can evaporate or expel, leading to an increase in the coolant level inside the evaporator. Conversely,

- If the needle moves to the right, the evaporator is generating more steam than it can recover, resulting in a decrease in its coolant volume.

The reactor's control system continuously monitors these variables and adjusts operational conditions to ensure that water and steam flow remain balanced, minimizing risks and optimizing energy generation.

CONTROL PANEL: STEAM GENERATOR – SWITCHES

- **Switches:** The panel houses individual switches corresponding to each circulation pump in the secondary circuit. These switches control the activation or deactivation of the pumps. When the operator activates a switch (turning it from "off" to "on"), the associated circulation pump starts operating.

    - Activating the pumps is crucial for maintaining a continuous flow of coolant within the secondary circuit, ensuring efficient heat transfer and preventing overheating. If needed, the operator can deactivate a pump by switching it from "on" to "off".

    - Deactivating pumps might be necessary for maintenance, troubleshooting, or adjusting the system's operational parameters.

  In emergency scenarios or when rapid shutdown is required, the switches can be turned off collectively to shut down all circulation pumps simultaneously. Emergency shutdowns may be implemented in response to critical situations to prevent potential damage or hazards.

- **Secondary Circuit Coolant Flow Speed:** Is a critical component in controlling the speed of circulation pumps within the secondary circuit of the nuclear reactor. The panel features a regulator responsible for controlling the speed of all circulation pumps in the secondary circuit. The regulator is equipped with a dedicated display that provides real-time information on the average speed of all pumps and the total speed requested.

    - **Average Speed Display**: The display on the regulator indicates the average speed of all circulation pumps currently in operation within the secondary circuit. This information allows operators to assess the overall performance of the circulation system immediately.

- **Total Requested Speed Display:** The regulator also displays the total speed requested for all circulation pumps combined. This value represents the collective speed that the system is expected to achieve, considering the demands of the operational conditions or specific requirements.

- **Speed Adjustment:** The operator can use the regulator to adjust the speed of all circulation pumps collectively. Turning the regulator dial or adjusting the control settings allows for precise control over the coolant flow speed within the secondary circuit.

The regulator is designed to operate within the safety parameters of the nuclear reactor. Adjustments made through the regulator are subject to safety limits to prevent potential issues such as overheating or system instability.

Operators continuously monitor the regulator's display to ensure that the average speed aligns with the desired operational parameters and that the total requested speed meets the reactor's current demands.

- **Individual Secondary Circuit Coolant Flow Speed:** Are essential components for controlling the speed of individual circulation pumps within the secondary circuit of the nuclear reactor. Each regulator is dedicated to controlling the speed of an individual circulation pump within the secondary circuit. The presence of three regulators corresponds to the three circulation pumps in the system.

  - Each regulator is equipped with a display that provides real-time information on the speed of the associated pump. The display shows the current speed of the specific pump, allowing operators to monitor its performance.

  - Additionally, the display features an average speed reading that represents the collective speed of all three pumps combined. This average speed value is calculated based on the individual speeds of each pump, providing an overview of the overall system performance.

Each regulator allows operators to adjust the speed of the associated circulation pump independently. Fine-tuning the speed of individual pumps is crucial for maintaining balance and efficiency within the secondary circuit.

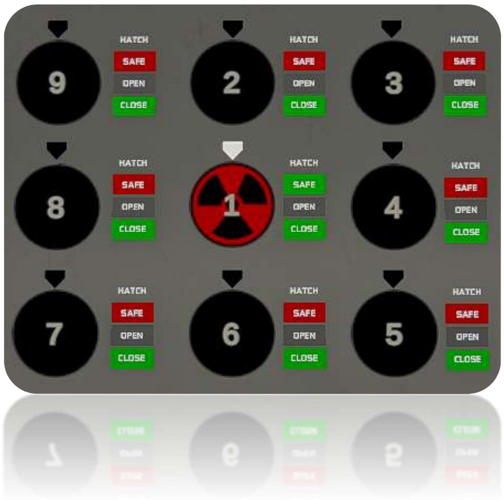
- **Pressure Relief Valve Controls:** This control activates the evaporator's manual relief valve to release excess steam and reduce internal pressure. The relief valve is a critical safety component, manually operated to prevent overpressure conditions that could compromise the integrity of the evaporator or other connected systems.

  When the operator identifies that the internal pressure of the evaporator is approaching or exceeding safe limits, the relief valve can be opened manually to discharge steam into a designated containment or vent system. This action helps reduce pressure and protects the equipment from potential damage caused by overpressurization.

  Important: The operator must monitor system conditions carefully while using the relief valve, as improper or excessive use can lead to unstable pressure levels. Regular activation may indicate a failure in primary pressure control mechanisms, which should be investigated and resolved to maintain safe reactor operation.

CONTROL PANEL: REACTOR FUEL

The Fuel Control Panel in the control room is a vital component for managing the nuclear reactor's fuel system. This panel provides the operator with a comprehensive interface to monitor, control, and ensure the proper functioning of the reactor's fuel configuration.



The Fuel Control Panel serves as a central hub for managing the reactor's fuel system, ensuring operational efficiency, safety, and adherence to protocol throughout the fuel transfer and placement processes.

The reactor core is equipped with **9 fuel-loading bays**, each designed with an integrated safety system that allows fuel blocks to be inserted or removed even while the reactor is active. These bays play a crucial role in managing the reactor's energy production and ensuring operational safety.

Fuel Bay Representation

On the control panel, each fuel bay is represented by a circular icon with a number in its center:

- **Black Icon:** Indicates the bay is empty, with no fuel block loaded.
- **Red or Yellow Icon:** Indicates the bay contains a fuel block.

A **white arrow-shaped indicator** is used to show which bay is currently selected to receive operator commands. **It is important to confirm the selected bay** before executing any action, such as opening a hatch or moving a fuel block.

Each fuel bay is divided into two distinct sections:

- **Upper Section (Safe Zone):** Known as the expulsion or safety zone, this is where fuel blocks can be safely introduced or stored without being actively used for energy generation.
- **Lower Section (Decomposition Zone):** In this section, the fuel block is actively utilized to generate energy.

Hatch Indicators: Open / Close / Secure

Each fuel bay hatch is equipped with three indicators that provide information about its current state:

- **Open**: Indicates that the hatch is open, allowing access between the Safe Zone and the Decomposition Zone. In this state, fuel block movement is not possible, as the hatch must be closed to ensure proper operation and safety.
- **Close**: Indicates that the hatch is closed, but the area is not yet fully sealed. This is a transitional state that allows for safe movement of fuel blocks between zones.
- **Secure**: Indicates that the hatch is closed, and the piston is in the upper position, fully sealing the exchange area. In this state, it is considered safe to open the hatch, as the sealed compartment prevents coolant or other materials from contaminating the safety zone during operations.

Operational Notes

The **Secure** state is critical for maintaining safety during fuel handling. Operators must confirm that the hatch is in the **Secure** state before initiating any action that requires opening the hatch. Failing to do so can compromise the integrity of the system and lead to operational risks.

By monitoring these indicators, operators can ensure proper procedures are followed during reactor core operations, minimizing potential hazards and maintaining system integrity.

Fuel Block Movement

To move a fuel block between the **Safe Zone** and the **Decomposition Zone**, the bay's **hatch must be closed**. This is a fundamental safety protocol to prevent accidental exposure or contamination.

- **Hatch Opening Requirements:** The external vessel containing the core, which is submerged in coolant, must either be emptied or have its coolant level below the designated safety threshold. This precaution prevents coolant from entering the safety compartments when the hatch is opened.

- **Hatch Closing Requirement:** The hatch must remain securely closed during any movement of fuel blocks to ensure the integrity of the process and avoid risks such as coolant leaks or uncontrolled reactions.

By following these safety measures, operators can efficiently manage fuel handling while maintaining the stability and safety of the reactor system.

CONTROL PANEL: REACTOR FUEL | SWITCHES

Each switch and its corresponding indicator on the panel are designed to provide detailed and safe control over the operations within the reactor, ensuring that fuel handling and reactor components are managed in accordance with established safety protocols.

Panel Switches and Indicators

- **Unload Fuel / Isolate Bay:** This switch moves the fuel block from the Decomposition Zone (lower section) to the Safe Zone (upper section) within the selected bay. It effectively isolates the fuel block from the energy-generating process, ensuring that it is safely stored for future use or maintenance. The Isolate Bay action also temporarily disables the bay for fuel handling.

- **Load Fuel / Unisolate Bay:** This switch moves the fuel block from the Safe Zone (upper section) to the Decomposition Zone (lower section) within the selected bay. It allows the fuel block to be activated and used for energy generation. The Unisolate Bay action re-enables the bay for normal operation, making it part of the reactor's energy production cycle.

- **Open Hatch:** This switch opens the hatch of the selected fuel bay.

- **Close Hatch:** This switch closes the hatch of the selected fuel bay.

- **Display Danger:** This indicator lights up when an attempt is made to perform an action that violates safety protocols, such as opening the hatch when it is not in the Secure state or moving fuel blocks without proper safeguards. This warning alerts the operator to a potential safety hazard and signals that corrective action must be taken to proceed safely.

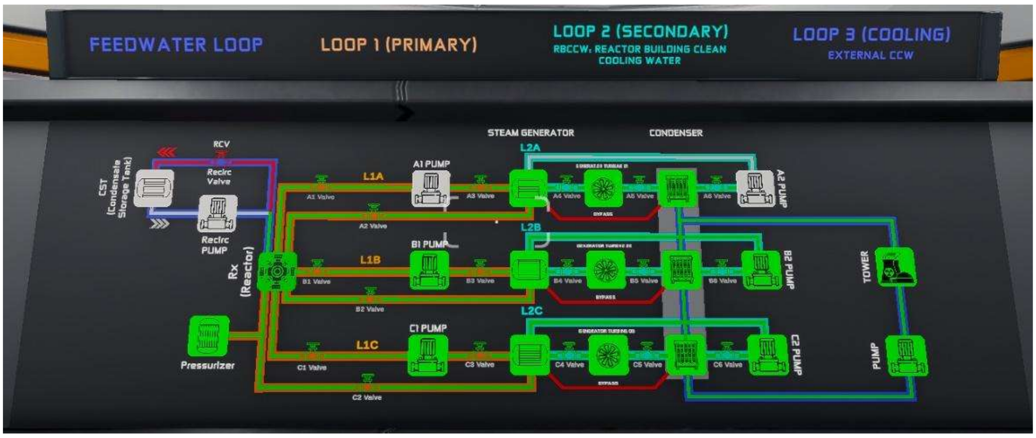
- **Display Safe to Open:** This indicator lights up when the external coolant level is below the safety threshold for the hatches. In this condition, it is considered safe to open the hatch, as the sealed compartments are protected from coolant contamination. This indicator ensures that the operator only opens the hatch when the system is in a safe state to do so.

- **Switch Apply to All:** This switch allows the operator to apply the selected action (e.g., open hatch, move fuel) to all bays, not just the selected one. This feature enables the operator to quickly perform the same action across multiple bays simultaneously.

- **Core Loading Bay numeric keypad:** This numeric keypad allows the operator to select a specific fuel bay, which will then receive the actions indicated by the other switches. By entering the corresponding number, the operator determines which bay will be affected by commands such as opening or closing the hatch, loading or unloading fuel.

CONTROL PANEL: VALVES

The Control Room Valve Panel serves as a comprehensive interface within the control room, providing operators with a visual representation of the reactor's valve system.



This panel includes a graphical display illustrating all the connections within the reactor, the location of each valve, and their current status—indicated by color-coded markers.

Valve Action Selectors

The Valve Action Selectors play a crucial role in the control and operation of individual valves within the reactor system. Each valve is equipped with a selector that allows operators to choose between three actions: Open, Close, or Off.

Understanding the functions and importance of these selectors is essential for maintaining the integrity and safety of the hydraulic motors associated with the valves.

- Selecting the **Open** position activates the hydraulic motor linked to the valve. The hydraulic motor engages, initiating the process of opening the valve to allow the flow of coolant, steam, or other substances. This action is used when controlled opening of the valve is required for normal system operation.

- Choosing the **Close** position triggers the hydraulic motor associated with the valve. The hydraulic motor functions to close the valve, restricting the flow of coolant, steam, or other substances. This action is employed to cease flow through the valve, maintaining desired operational conditions within the reactor.

- Opting for the **Off** position deactivates the hydraulic motor associated with the valve. The hydraulic motor stops, halting any ongoing opening or closing activity of the valve. This position is crucial for preventing continuous strain on the hydraulic motor, preserving its integrity during periods of inactivity.

Importance of Maintaining the Selector in Off

Keeping the selector in the Off position is essential to protect the hydraulic motor from unnecessary wear and tear. Continuous activation of the motor, particularly when not required, can lead to premature failure.

- Hydraulic motors require energy to operate. By keeping the selector in Off, operators conserve energy and contribute to the overall efficiency of the reactor system.

- Activating the hydraulic motor on a valve that is *stuck or damaged* poses a significant risk. Forcing the motor under such conditions can exacerbate the issue, potentially causing further damage to the valve or the motor itself.

Forcing a hydraulic motor on a malfunctioning valve without proper assessment can lead to safety hazards and compromise the integrity of the entire system.

Manual Override

In the event of a power failure or if the hydraulic motor is unable to operate, the operator may need to manually override the system. This involves going to the physical location of the valve, activating the bypass to disconnect the motor, and manually adjusting the valve (if it is not stuck or damaged).

REACTOR OPERATION MODES

The mode selector facilitates the determination of the reactor's operational state, offering three distinct modes: Shutdown, Nominal Operation, and Maximum Operation. Each mode configures the system's actions, including those of the Automation Operator (AO), alarm settings, event processes, and statistical tracking.

- **Shutdown Mode:** When transitioning to Shutdown Mode, ongoing operational tasks executed by AO, such as monitoring the Pressurizer or Control Rods, are promptly halted.

  Low productivity alarms deactivate, preventing the initiation of new events. It's crucial to note that the mandatory daily service level persists. If the plant remains idle for over two consecutive days, there's a risk of the operating license being revoked. To avoid this, it is necessary to notify the city in advance that a stop will be made.

  Removal of fuel from the core is only permitted in Shutdown Mode.

- **Nominal Mode:** Nominal Mode represents the standard operational state, defining alarm thresholds, expected operational ranges, AO activities, statistical data, and event handling.

  If AO is managing control rods, it ensures the reactor stays within designated operating ranges.

  Nominal Mode also serves as the startup mode for the reactor.

- **Maximum Mode:** The alarm threshold undergoes modification between Nominal and Maximum levels, with the latter allowing for a greater tolerance outside operational limits.

If AO is controlling control rods, the reactor is maintained slightly outside operating ranges, and an emergency shutdown is not initiated until critical values are reached in the general situation.

Initiating the reactor in Maximum Mode is prohibited.

AUDIT AND COMPLIANCE PROCEDURE

When the Audit Control System of the National Atomic Energy Commission is activated for a visit to the nuclear reactor plant, meticulous checks are conducted to ensure adherence to operational and safety standards.

Here's a detailed breakdown of the audit procedure:

- **Verification of Operational Range:** If the reactor is active, must operate within the specified range outlined in its active mode.

- **Backup Fuel Availability:** Adequate backup fuels must be readily available for use in case of any unforeseen circumstances.

- **Contamination and Safety Suit Checks:** No areas within the plant should exhibit contamination, and safety suits should be free from damage or compromise.

- **Component Integrity Assessment:** Components' integrity is rigorously evaluated, and any level below 90% is considered non-compliant. Below 50% is deemed critical non-compliance.

- **Component Wear Analysis:** Wear and tear of components are scrutinized, with wear below 50% deemed acceptable. Exceeding 90% is considered a critical non-compliance.

- **Identification of Destroyed Components:** No components within the reactor system should be in a destroyed state.

This process is integral to maintaining the plant's integrity and ensuring the highest level of compliance.

Non-Compliance Consequences

A "Non-Compliance Consequence" refers to the repercussions or penalties that arise when the nuclear reactor plant fails to meet specified standards, regulations, or safety protocols during an audit or inspection. These consequences are applied based on the severity and nature of the identified non-compliance.

- **Important Non-Compliances:** These are deviations from operational or safety standards that are significant but not critical. Examples include components not meeting integrity criteria. The consequence involves the deduction of Prestige Points, impacting the overall performance rating of the plant. The deduction severity depends on the type of component found in violation.

- **Critical Non-Compliances:** Critical non-compliances are more severe deviations that pose a significant risk to operational safety. Examples include components with extremely low integrity or high wear. The consequence for each critical non-compliance is the forfeiture of half of the operating license. This is a substantial penalty, emphasizing the gravity of the violation.

In summary, Non-Compliance Consequences serve as a mechanism to enforce adherence to established standards and regulations within the nuclear reactor plant. They act as a deterrent to ensure that operators maintain the highest levels of safety, operational integrity, and overall compliance. The severity of the consequences reflects the importance of maintaining a secure and efficient nuclear facility.

Rewards for Compliance

Refer to the positive outcomes or incentives provided to the operator of the nuclear reactor plant when the facility successfully adheres to operational, safety, and regulatory standards during an audit or inspection. These rewards are designed to encourage and acknowledge the plant's commitment to maintaining high levels of safety, integrity, and overall compliance.

- **No Major Breaches:** If the audit reveals that the plant has not committed any significant breaches of operational or safety standards, the operator is rewarded with bonus Prestige Points. Prestige Points are a form of recognition and performance measurement that contribute to the overall reputation and standing of the nuclear reactor plant.

- **Special Prizes:** In addition to Prestige Points, the operator may receive special prizes as a tangible reward for achieving and maintaining compliance. These prizes can be stored in the plant's display cabinets or exchanged for additional Prestige Points. The value of these prizes increases for each day that passes after the audit, providing an incentive for sustained excellence and ongoing commitment to compliance.

This comprehensive audit and compliance procedure not only ensures the plant's continued safe operation but also incentivizes operators to uphold the highest standards, fostering a culture of excellence and responsibility within the nuclear reactor facility.

In essence, "Rewards for Compliance" serve as a positive reinforcement mechanism, fostering a culture of responsibility and excellence within the nuclear reactor facility. By recognizing and incentivizing compliance, operators are motivated to continuously uphold the highest standards, ensuring the safe and efficient operation of the plant.

MAINTENANCE AND REPAIRS

To assess the overall condition of the plant, respond to maintenance prompts from the Operational Assistant (OA), or address indications of damaged components in the control room, follow these procedures:

- **Request a Preventive Maintenance Report:**

  Direct OA to generate a preventive maintenance report. OA will navigate through the plant, conducting a thorough analysis of the current situation.

- **Review Maintenance Tasks:**

  Once OA completes the report, check the "Maintenance Tasks" section for a detailed list of elements requiring repairs.

- **Plant Shutdowns for Maintenance:**

  Certain components may necessitate a plant shutdown for repair. The maintenance task app will provide information on time, cost, and the need for a prior shutdown.

- **Scheduled Maintenance Shutdowns:**

  The OA's report indicates the wear percentage of plant components. It is advisable to perform maintenance tasks on these components before the wear percentage reaches 100%.

What happens at 100% Wear or Beyond?

While not mandatory, exceeding 100% wear increases the risk of damage or failure. It is strongly recommended to perform the maintenance in such cases.

Smoke or Fire from a Component

If a component starts emitting smoke or catches fire, irreversible damage may have occurred. Depending on the component and location, automatic fire sprinklers will activate. Request a maintenance report from the OA. If repairable, it will appear in the maintenance task list. If irreparable, discard the component using the machinery app.

Insufficient Prestige Points for Repairs

If lacking sufficient prestige points for repairs, consider requesting a loan from the city bank. Access the banking app via the maintenance app to apply for a loan.

Alternatively, sell machines and components; the selling price will be adjusted based on the overall condition of the component. Prizes obtained from successful audits can also be sold.

Manual repairs by the plant operator

If you want to repair something manually, keep the following in mind:

- You can repair non-energized cables with the clamp. If energized, the clamp must have resistors. If the cable is inaccessible, you won't be able to repair it (ask AO to do it).
- If a resistance block in the resistance bank burns out, you can change it as long as the bank is offline.
- You can repair tubes and containers (evaporators, pressurizer, condenser, etc.) with the welder. If the damage is unreachable, you won't be able to repair it (ask AO to do it).

- If the motor that moves the control rods is damaged and it is an emergency, you can get on the crane and operate it manually to move the rods.
- The crane cannot be used manually to move fuel blocks.

PROCEDURE: STARTUP

The reactor startup protocol is a structured set of steps and procedures designed to safely and systematically initiate nuclear reactor operations. This protocol is crucial to ensure system integrity, plant safety, and compliance with established regulations.

- **Verify Power Availability:** Ensure an adequate power supply in the supply room for reactor startup. Check the condition and fuel levels of the emergency generators and ensure the emergency battery rack is fully charged. Reliable power sources are critical for initiating reactor startup. The availability of energy ensures a smooth transition into the startup phase, with emergency backup systems ready for activation if needed.

- **Energize Control Room Panels:** Power up the control room panels to initiate the control systems. Activating the control room panels is the initial step in establishing communication with and control over various reactor components.

- **Set the reactor mode to *Nominal*.**

- **Coolant Range Verification:** Check that the coolant in both the primary and secondary circuits is within operational ranges. Make necessary adjustments if the coolant is outside acceptable limits. Proper coolant conditions are essential for effective heat transfer and system stability. Verification and adjustments ensure a safe and controlled environment.

- **Pressurizer Check:** Verify that the Pressurizer contains an appropriate volume of coolant within operational parameters. Adjust if the Pressurizer volume is outside the designated range. Pressurizer plays a crucial role in maintaining pressure and preventing vapor formation. Monitoring and adjusting its coolant volume is a safety measure.

- **Pressurizer Heater Activation:** Turn on the Pressurizer heaters to achieve the operational temperature and pressure (360°C and 160 BAR). Heating the Pressurizer is necessary to reach the required operational conditions for initiating controlled reactor startup.

- **Primary Circuit Loop 3 Pump Activation:** Start the circulation pump for loop 3 of the primary circuit at low power (25%). Gradual activation of circulation pumps ensures a controlled and steady increase in coolant flow throughout the system.

- **Secondary Circuit Loop 3 Pump Activation:** Activate the circulation pump for loop 3 of the secondary circuit at low power (25%). Gradual activation of circulation pumps ensures a controlled and steady increase in coolant flow throughout the system.

- **Condenser Cooling Pump Activation:** Start the cooling pump for the Condenser cooling circuit at low power (10%). Gradual activation of circulation pumps ensures a controlled and steady increase in coolant flow throughout the system.

- **Control Rod Insertion:** Insert control rods into the core at 100%. Control rods insertion is a safety measure to regulate reactor power during startup and prevent an uncontrolled chain reaction.

- **City Communication and Permission:** Communicate with the city authorities to request permission for reactor startup. Wait for the city's response and the specified time for initiation. Coordination with the city is crucial to align reactor startup with citywide energy demand and safety regulations.

- **Fuel Block Insertion:** Insert the fuel block into the reactor, considering the approved startup time provided by the city. Controlled fuel block insertion is timed to align with the approved schedule and city energy demand.

- **Critical Mass Achievement:** Wait until the reactor reaches critical mass, signaling the completion of the startup protocol. Critical mass achievement indicates that the reactor has reached a stable and controlled state, ready for normal operation.

In summary, the reactor startup protocol is essential for conducting nuclear operations safely, efficiently, and in compliance with regulatory and safety standards. Ensures the plant operates within safe parameters, avoiding risk to personnel, the plant, and the environment. Establishes controlled initial conditions for critical variables such as temperature, pressure, and coolant flow.

PROCEDURE: STABILIZATION

In the dynamic environment of nuclear reactor simulation, the Stabilization Protocol is a crucial series of steps designed to achieve and maintain a stable and controlled operational state. Each step is strategically crafted to address specific components and variables, ensuring optimal performance and safety.

1. **Steam Generators Monitoring:** After reaching critical mass, the priority is to assess and regulate temperature and pressure within the steam generators. Ensuring the generators operate within the designated temperature range is pivotal for efficient steam production and subsequent electricity generation. Adjust control rods as needed and primary circuit pump speed to attain operational temperature in the steam generators.

    - **Steam Generators Monitoring Procedure:** After achieving critical mass, the Steam Generators Monitoring step plays a crucial role in maintaining optimal conditions for efficient steam production and electricity generation. The procedure involves meticulous assessment and adjustment of key parameters within the steam generators.

        - **Assessment of Steam Generator Conditions:** Evaluate the temperature and pressure within the steam generators. Purpose: Ensure the generators are operating within the specified temperature range for efficient steam production.

        - **Control Rod Adjustment:** Fine-tune the positioning of control rods. Purpose: Regulate the nuclear reaction within the core, controlling the heat generated and influencing the temperature in the steam generators.

        - **Primary Circuit Pump Speed Adjustment:** Modify the speed of the primary circuit pump. Purpose: Control the flow of coolant within the primary circuit, influencing the transfer of heat to the steam generators.

        - **Temperature Regulation in Steam Generators:** Adjust control rods and primary circuit pump speed to attain the operational temperature in the steam generators. Purpose: Achieve and maintain the required temperature for optimal steam production, a critical factor in subsequent electricity generation.

- **Execution Guidelines:**

  Use monitoring instruments and displays to assess temperature and pressure levels within the steam generators.

  - Gradually adjust the control rods to influence the nuclear reaction, aiming for the desired temperature.

  - Fine-tune the speed of the primary circuit pump to control the circulation of coolant and manage heat transfer to the steam generators.

  - Continuously monitor the temperature in the steam generators, making incremental adjustments as needed to reach the operational range.

  This step ensures that the steam generators operate under conditions that maximize steam production efficiency. Proper adjustment of control rods and pump speed contributes to temperature regulation and, consequently, optimal electricity generation.

2. **Evaporators and Turbines Optimization:** Following steam generator stability, attention shifts to evaporators and turbines. Achieving and maintaining optimal temperature and pressure in evaporators is crucial for turbine efficiency and overall system performance. Fine-tune control rods and primary circuit pump speed to regulate pressure within the turbines.

- **Evaporators and Turbines Optimization Procedure:**

  After ensuring the stability of steam generators, the focus shifts to optimizing the performance of evaporators and turbines. This step involves achieving and maintaining ideal temperature and pressure in evaporators, a critical factor for turbine efficiency and overall system performance.

  - **Assessment of Evaporator Conditions:** Evaluate the temperature and pressure within the evaporators.

Purpose: Ensure optimal conditions for efficient heat exchange and steam generation.

- **Control Rod Adjustment for Evaporators:** Fine-tune the positioning of control rods Purpose: Regulate the nuclear reaction within the core to control the heat supplied to the evaporators.

- **Primary Circuit Pump Speed Adjustment for Evaporators:** Modify the speed of the primary circuit pump. Purpose: Control the flow of coolant within the primary circuit to manage heat transfer to the evaporators.

- **Pressure Regulation within the Turbines:** Adjust control rods and primary circuit pump speed to regulate pressure within the turbines. Purpose: Achieve and maintain the required pressure for optimal turbine efficiency.

- **Execution Guidelines:**

  Utilize monitoring instruments and displays to assess temperature and pressure levels within the evaporators.

  - Gradually adjust the control rods to influence the nuclear reaction, controlling the heat supplied to the evaporators.

  - Fine-tune the speed of the primary circuit pump to manage the flow of coolant and optimize heat transfer to the evaporators.

  - Continuously monitor pressure levels within the turbines, making adjustments to achieve and maintain optimal conditions.

  This step ensures that evaporators operate under conditions that facilitate efficient heat exchange and steam generation. Proper adjustment of control rods and pump speed contributes to the regulation of pressure within the turbines, optimizing their performance.

3. **Condenser and Secondary Circuit Control:** Ensuring the proper functioning of the condenser becomes the focus, addressing

potential challenges related to coolant temperature. Preventing excessive cooling of the coolant returning to the evaporator is essential for maintaining momentum and system efficiency. Activate the condenser vacuum pump, regulate the cooling pump, and adjust secondary circuit pumps as needed.

- **Condenser and Secondary Circuit Control Procedure:**

  The third step involves focusing on the proper functioning of the condenser, addressing challenges related to coolant temperature. It is crucial to prevent excessive cooling of the coolant returning to the evaporator to maintain momentum and system efficiency. The procedure includes activating the condenser vacuum pump, regulating the cooling pump, and adjusting secondary circuit pumps as needed.

  - **Condenser Functionality Assessment:** Evaluate the current state and functionality of the condenser. Purpose: Identify any potential issues or challenges related to coolant temperature and overall condenser performance.

  - **Coolant Temperature Monitoring:** Monitor the temperature of the coolant returning to the evaporator. Purpose: Prevent excessive cooling that could impact system momentum and efficiency.

  - **Activation of the Condenser Vacuum Pump:** Activate the condenser vacuum pump. Purpose: Create the necessary vacuum conditions within the condenser for optimal heat exchange.

  - **Regulation of the Cooling Pump:** Adjust the speed or operation of the cooling pump. Purpose: Control the flow of coolant within the condenser to prevent overcooling.

  - **Adjustment of Secondary Circuit Pumps:** Fine-tune the speed or operation of secondary circuit pumps. Purpose: Ensure proper circulation of coolant within the secondary circuit, maintaining the desired temperature.

- **Execution Guidelines:**

- Use monitoring instruments and displays to assess the condenser's current state and coolant temperature.

- Continuously monitor the temperature of the coolant returning to the evaporator to prevent excessive cooling.

- Activate the condenser vacuum pump to establish the required vacuum conditions.

- Regulate the cooling pump to control the flow of coolant within the condenser.

- Adjust secondary circuit pumps as needed to maintain optimal coolant circulation.

This step ensures the effective functioning of the condenser, addressing challenges related to coolant temperature. Proper adjustment of pumps contributes to maintaining momentum and optimizing overall system efficiency.

4. **Turbine Power Generation Stability:** The final stage involves stabilizing the electricity generation from the turbines. A stabilized turbine ensures consistent and reliable power output. Monitor and adjust parameters as necessary until the turbine's electricity generation stabilizes.

- **Turbine Power Generation Stability Procedure:**

  In the fourth step, the focus shifts to stabilizing electricity generation from the turbines. A stable turbine is essential for consistent and reliable power output. This procedure involves monitoring and adjusting parameters until the turbine's electricity generation stabilizes.

  - **Turbine Functionality Assessment:** Assess the current functionality and performance of the turbines. Purpose: Identify any fluctuations or irregularities in electricity generation.

  - **Electricity Generation Monitoring:** Continuously monitor the electricity generation levels from the turbines. Purpose:

Track variations in power output and identify any instability.

- **Parameter Adjustment for Stability:** Adjust relevant parameters to achieve stable electricity generation. Purpose: Fine-tune settings to minimize fluctuations and ensure a consistent power output: Control Rod Adjustment, Primary Circuit Pump Speed Adjustment, Activation of the Condenser Vacuum Pump, Regulation of the Cooling Pump, Adjustment of Secondary Circuit Pumps

- **Continuous Monitoring and Adjustment:** Implement real-time monitoring and make necessary adjustments. Purpose: Respond to any dynamic changes in system conditions to maintain stable electricity generation.

- **Execution Guidelines:**

  - Utilize monitoring instruments and displays to assess the current state and performance of the turbines.

  - Continuously track electricity generation levels to detect any fluctuations or instability.

  - Adjust relevant parameters, such as control rods and pump speeds, to achieve stable electricity generation.

  - Implement real-time monitoring to respond promptly to any changes that may affect turbine stability.

This step aims to ensure the stability of electricity generation from the turbines, contributing to a reliable power output. Continuous monitoring and adjustment are crucial to adapt to dynamic conditions and maintain consistent performance.

PROCEDURE: SHUTDOWN

The Shutdown Protocol is a crucial set of steps in the simulation game, designed to deactivate the nuclear reactor safely and effectively. Each step serves a specific purpose, emphasizing both controlled and emergency shutdown scenarios.

- **Set Reactor Mode to Shutdown:** This initial step establishes the reactor's operational mode as Shutdown. Ensures a deliberate transition to a state where controlled deactivation can take place.

- **Insert Control Rods to 100%:** Fully insert the control rods into the core. Reduces the reactivity of the core, initiating the process of deactivating the fission reactions.

  - ***IN CASE OF EMERGENCY****: If the insertion of control rods encounters difficulties or becomes impractical, an alternative method is available for reactor operators. The operational use of the operative crane can be employed to exert the force needed for the insertion of control rods. This dynamic approach adds an extra layer of strategic decision-making, offering players a nuanced gameplay experience where adaptability and resourcefulness are key in navigating unexpected challenges during the shutdown process.*

- **Set Maximum Cooling Turbine Speed (Condenser):** Adjust the cooling turbine speed in the condenser to its maximum. Enhances cooling efficiency during the shutdown process, preventing overheating.

- **Set Maximum Primary Circuit Circulation Turbine Speed:** Adjust the turbine speed in the primary circuit circulation to its maximum. Promotes efficient circulation, aiding in the gradual reduction of reactor activity.

- **Activate Primary Circuit Loading Pump:** Initiate the pump responsible for loading the primary circuit. Supports controlled shutdown by managing coolant flow within the primary circuit.

- **Open Primary Circuit Draining Valve:** Open the draining valve for the primary circuit. Facilitates controlled coolant drainage during shutdown; caution required in emergencies.

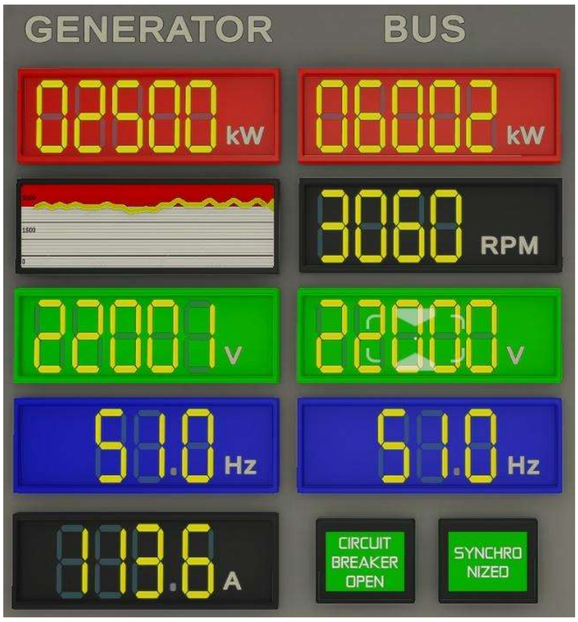
- ***IN CASE OF EMERGENCY**: Last two steps are applicable for controlled shutdowns; careful assessment of coolant levels is essential before draining in emergencies.*

- **Extract Fuel Block after Residual Temperature:** Remove the fuel block from the core once the residual temperature is below 50°C. Safely removes the heat source, preventing unnecessary heating during the shutdown process. The external core pool must be empty.

  - ***IN CASE OF EMERGENCY:** In the event of an uncontrolled shutdown scenario, it is strongly recommended to open the core and turbine ventilation valves. This precautionary measure aims to manage pressure and temperature levels effectively, mitigating potential complications that may arise during the shutdown process. Implementing this strategic step can contribute to maintaining optimal conditions and ensuring a safer reactor shutdown.*

Executing the Shutdown Protocol ensures a systematic and secure deactivation of the simulated nuclear reactor, considering both controlled and emergency scenarios for enhanced gameplay experience.

PROCEDURE: SYNCHRONIZING WITH ELECTRICAL GRID



The synchronization procedure is a crucial set of steps designed to ensure a seamless and secure connection between the turbine and the electrical grid. Its primary purpose is to align the turbine's operational parameters, such as frequency and voltage, with the grid's specifications.

This alignment is essential for the safe and efficient transfer of electrical power from the turbine to the grid.

Grid Stability: Synchronization prevents disruptions and ensures the stability of the electrical grid. Aligning the turbine with the grid's frequency and voltage parameters avoids fluctuations and maintains a consistent power supply.

Equipment Safety: Following the synchronization procedure helps in preventing overloads and mechanical stress on the turbine. It ensures that the turbine operates within safe limits, enhancing the longevity of equipment.

Efficient Power Transfer: Synchronization optimizes the efficiency of power transfer from the turbine to the grid. It allows for a smooth integration of the turbine's output with the existing electrical infrastructure, minimizing the risk of grid instabilities.

Prevention of Voltage Fluctuations: Proper synchronization helps in preventing voltage fluctuations, which could lead to equipment malfunctions and power quality issues. This is crucial for maintaining a reliable and high-quality electrical supply.

Optimal Power Generation: Synchronization ensures that the turbine operates at its optimal conditions, maximizing power generation efficiency. This is essential for meeting the energy demands of the electrical grid and supporting a reliable power supply to consumers.

Grid Connection: The synchronization procedure facilitates the controlled connection of the turbine to the electrical grid. This controlled connection prevents sudden power surges or imbalances, contributing to the overall reliability of the electrical system.

Synchronizing

When synchronizing with the Synchroscope in Nucleares, the procedure involves precise adjustments to ensure synchronization with the target RPM (Revolutions Per Minute), set at 3060 in this game.

- Fine-tuning with the Admin Valve: As the RPM approaches 3060, finely adjusts the admin valve while monitoring the synchroscope. At 3059 RPM, the synchroscope needle will indicate a deviation by turning left, and at 3061 RPM, it will turn right. The magnitude of the needle's movement corresponds to the difference between the actual RPM and the target RPM.

- Timing is Key: The skill lies in precisely hitting 3060 RPM when the needle is aligned at the top position. This ensures synchronization with the grid at the optimal moment.

- Catching the Needle: If the needle moves slowly through the top position, indicating a slight deviation, you can stabilize it by closing the main breaker. This action effectively locks the RPM to 3060, establishing synchronization with the grid.

When the main breaker is closed at the top position, the needle on the synchroscope indeed stops moving, indicating a near-perfect synchronization. However, it's important to note that while the needle stops, the turbine will quickly adjust to match the 3060 RPM target. This rapid adjustment, known as a "jump" to 3060 RPM, is generally acceptable and signifies a successful synchronization. However, if the RPM overshoots the target, such as reaching 3080 RPM before closing the breaker, and then abruptly syncing, it puts unnecessary strain on the turbine components. This abrupt change can lead to increased wear and tear, potentially shortening the lifespan of the equipment. This aspect underscores the importance of proper care and maintenance of machinery, particularly in nuclear facilities where precision and equipment longevity are paramount.

Warning

Closing the breaker at any position other than the top can have severe consequences. It can cause damage to the transformer or generator and trigger a turbine trip. If the main breaker is closed with a significant difference between the turbine's current RPM and the target RPM of 3060, the turbine may fail to perform the rapid adjustment, or "jump," necessary for synchronization. This situation can lead to catastrophic consequences for the machine.

When the RPM difference is substantial, the turbine cannot efficiently synchronize with the grid. As a result, it struggles to match the required RPM, causing stress on the turbine components and the grid itself. This scenario poses significant risks to the integrity of the turbine and other connected equipment.

Preparation

Ensure that the turbine has reached the operational RPM and is stable. Synchronization involves aligning the turbine's rotational speed with the frequency of the electrical grid.

1. Starting the synchronization process when the turbine is stable helps prevent mechanical stress, reduces the risk of equipment damage, and ensures the longevity of turbine components.

2. Verify that the BUS (connection to the electrical grid) and GEN (generator turbine operational) lights are on.

    a. The BUS light indicates that the turbine is physically connected to the electrical grid. Verifying its illumination ensures that the necessary link between the turbine and the grid is established.

    b. The GEN light signals that the generator turbine is in operational mode. It confirms that the turbine is ready to generate electrical power. Synchronization should only proceed when the turbine is operational to avoid potential issues during the process.

Observation of the Synchronoscope

Observe the synchronoscope's speed lights. They should be rotating either to the left (slow synchronization) or to the right (fast synchronization).

1. Press the "RPM Raise" and "RPM Lower" buttons on the synchronoscope, until the synchronoscope's light remains fixed at position 0.

2. Confirm that the synchronization light has turned on, indicating that the turbine is synchronized with the electrical grid.

Parameter Verification

Once synchronized, check the *Hertz* and *Voltage* on the panel. The electrical grid operates at a specific frequency. To synchronize with the grid, the turbine's rotational speed, measured in RPM, must match this frequency. Adjusting the RPM allows operators to fine-tune the turbine's speed for synchronization.

If it's necessary to increase the *Hertz*, press "RPM Raise" button. If it's necessary to decrease them, press "RPM Lower" button.

Maintaining voltage stability is crucial for the overall stability of the electrical grid. The "Field Excitation Voltage Raise" button increases the magnetic field strength in the generator, raising the voltage output. Conversely, the "Field Excitation Voltage Lower" button decreases the field strength, lowering the voltage.

These adjustments help keep the turbine's voltage in sync with the grid, contributing to stable power delivery. Overvoltage or undervoltage conditions can lead to equipment damage and power quality issues.

If it´s necessary to increase the *Voltage*, press "Field Excitation Voltage Raise" button. If it´s necessary to decrease the *Voltage*, press "Field Excitation Voltage Lower" button.

Secure Connection to the Grid

1. When all parameters are synchronized, press "*Circuit Breaker Close*" to connect the turbine to the electrical grid. The circuit breaker acts as a switch that allows or interrupts the flow of electricity between the turbine and the grid. Closing the circuit breaker enables the seamless integration of the turbine into the electrical grid, ensuring a controlled and stable connection.

2. The turbine is now ready to deliver power safely and efficiently. With the circuit breaker closed, the turbine is seamlessly integrated into the electrical grid. The compatibility achieved during synchronization allows for the safe and reliable transfer of electrical power between the turbine and the grid.

In summary, pressing "Circuit Breaker Close" when all parameters are synchronized is a critical step to safely and effectively integrate the turbine with the electrical grid. It ensures a controlled connection, prevents power disturbances, and supports the overall stability and reliability of the power generation system.

PROCEDURE: FUEL LOADING

To safely load a fuel block into the reactor core, follow these steps:

1. **Verify Coolant Level:** Check that the coolant level in the external vessel is below the safe threshold. If the level is too high, use the water pump to lower it until it is within the acceptable range. This ensures that opening the hatch will not introduce coolant into the safety compartment.
2. **Select the Fuel Bay:** Use the **numeric keypad** on the control panel to select the bay where the fuel block will be loaded. Confirm the selected bay by checking the white arrow indicator on the panel.
3. **Isolate the Bay:** Execute the **Isolate Bay** command. This will move the safety piston upward, ensuring that the safety zone is sealed and ready for fuel handling.
4. **Open the Hatch:** Use the **Open Hatch** command to unlock and open the hatch of the selected bay. This allows access to the safe zone for fuel loading.
5. **Load the Fuel Block:** Open the **Operational Actions App** on your tablet and select the command to load a fuel block. The system will place the block into the safety zone of the selected bay.
6. **Close the Hatch:** Once the fuel block is loaded, use the **Close Hatch** command to secure the bay. This step ensures that the compartment is sealed for safe operation.
7. **Unisolate the Bay:** Execute the **Unisolate Bay** command to lower the safety piston, moving the fuel block from the safe zone to the decomposition zone. At this point, the block's seal will break, and nuclear fission will commence, generating energy.

Important Notes:

- Always verify the coolant level before opening any hatch to prevent contamination or operational hazards.
- Confirm the selected bay before issuing commands to avoid accidental operations on the wrong compartment.
- Once the fuel block enters the decomposition zone, it becomes active and contributes to the reactor's energy generation. Handle these steps with precision to ensure the reactor operates efficiently and safely.

PROCEDURE: FUEL UNLOADING

To safely remove or dispose of a spent fuel block from the reactor core, follow these steps:

1. **Verify Coolant Level:** Ensure the coolant level in the external vessel is below the safe threshold. If the level is too high, use the water pump to reduce it until it is within the acceptable range. This prevents coolant from entering the safety compartment when the hatch is opened.
2. **Select the Fuel Bay:** Use the **numeric keypad** on the control panel to select the bay from which the fuel block will be removed. Verify the selection by checking the white arrow indicator on the panel.
3. **Isolate the Bay:** Execute the **Isolate Bay** command. This will move the safety piston upward, transporting the fuel block from the decomposition zone to the safe zone.
4. **Open the Hatch:** Use the **Open Hatch** command to unlock and open the hatch of the selected bay. This provides access to the safe zone for fuel removal.
5. **Remove the Fuel Block:** Open the **Operational Actions App** on your tablet and select the command to remove the fuel block. The system will transfer the block out of the bay for proper disposal or storage.
6. **Close the Hatch:** After the block is removed, use the **Close Hatch** command to securely seal the bay. This step prepares the compartment for future operations.
7. **Unisolate the Bay (if necessary):** If the bay remains in active use, execute the **Unisolate Bay** command to lower the safety piston back to the decomposition zone. Otherwise, keep the bay isolated until required.

Additional Conditions for Fuel Unloading

To safely move a fuel block from the decomposition zone to the safe zone, the following conditions must be met:

1. **Temperature Below Safe Extraction Threshold:** The fuel block must have a temperature lower than the **safe extraction temperature**, typically set at **300°C**. If the block exceeds this temperature, the unloading procedure cannot proceed until it cools to an acceptable level.

2. **Block Integrity:** If the fuel block has been exposed to extreme temperatures well beyond operational limits, it may become **deformed**. A deformed block cannot be moved due to the risk of structural failure or mechanical damage to the bay.
3. **Maintenance Required for Deformed Blocks:** In cases where a block is deformed, unloading is only possible after shutting down the reactor and performing maintenance tasks.

Important Notes:

- Ensure the external coolant level is within the safe range before opening any hatch to avoid contamination or operational risks.
- Always confirm the selected bay before issuing commands to prevent accidental operations on the wrong compartment.
- Proper handling and disposal of spent fuel blocks are critical for reactor safety and efficiency. Ensure all procedures comply with operational safety standards.

OPERATIONAL ASSISTANT

The Operational Assistant (AO) is prepared to always assist the operator of the nuclear plant. It is an autonomous unit of help and operational assistance:

- Status report and warnings.
- General maintenance analysis.
- Maintenance and repair tasks.
- Assistance in operational protocols.
- Verification, adjustment, and control of operating parameters (on demand).

AO can be controlled through the operating Tablet of the plant operator, and from this tablet it will be possible to know the location of AO, the battery level, the command it is executing and the active operational tasks.

To activate the working tablet, press the [TAB] key at any time.

About AO autonomy

The Operating Assistant uses a rechargeable battery to be able to move freely through the plant. Although the battery is long-lasting, and has between 8 and 10 hours of autonomy, it will require resting in the charging bay to recharge. During the reload time, AO will not respond to any commands.

Status report and warnings

During plant operation, situations may arise that will require the immediate attention of the Plant Operator. If this were the case, AO will automatically intervene to warn or suggest the best plan of action.

General maintenance analysis

One of the main tasks of AO is the analysis of the situation of the plant. By starting the "Preventive Maintenance Analysis" command, AO will walk through the entire plant and analyze each component. At the end, it will prepare the maintenance report, with the details of each element analyzed. The maintenance report is the main tool of the Plant Operator to plan maintenance and repair tasks.

Maintenance and repair tasks

Daily maintenance tasks are crucial for safe operation. Based on the maintenance report generated by AO, the Plant Operator will be able to plan and order maintenance tasks. When initiating the "Start Maintenance Tasks" command, AO will perform the necessary tasks on each selected item.

Assistance in operational protocols

If necessary, the Plant Operator may request assistance to receive help or carry out the main protocols of plant operation:

- Help with Active Alarms
- Reactor start-up protocol
- Stabilization Protocol

Verification, adjustment, and control of operating parameters

Although AO does not have permission to take full control of the reactor, it can verify and control some subsystems, such as the Pressurizer or stabilization through Control Rods. Operational skills are not an initial part of AO and must be acquired separately through Prestige Points.

The Operating Assistant can execute up to two or more operating tasks simultaneously, but if he receives another type of command from the Plant Operator, all operational control tasks will be suspended and will once again be the responsibility of the Plant Operator.

TABLET OPERATIONS

To enhance your control and management experience, you have access to a tablet within the game. This tablet features various applications designed to assist you in efficiently operating and maintaining your nuclear power plant.

- **Operating Assistant:** Use this app to control the Operational Assistant (AO), overseeing its tasks and activities.

- **Maintenance Report:** Check the results of maintenance reports generated by the AO to stay informed about the plant's condition.

- **Objectives:** View active objectives and review historical records of achieved and failed objectives.

- **Select Maintenance Tasks:** Choose maintenance tasks for the AO based on the previously generated maintenance report.

- **Supplies and Spare Parts:** Purchase plant supplies, spare parts, and consumables to keep your plant running smoothly.

- **Logistics and Deliveries:** Monitor logistics status and delivery times for purchased supplies and spare parts.

- **Service Compliance:** Check the level of service compliance, view historical data, and ensure optimal plant performance.

- **Machines and Upgrades:** Explore installed machines, make decisions to sell, remove, or upgrade them to enhance efficiency.

- **Marketplace:** Access the marketplace to buy new machines and equipment for your power plant.

- **Wiki:** Utilize the internal wiki for valuable in-game information and tips.

- **Status:** Keep track of real-time status updates on key reactor variables.

- **Help:** Access the in-game help section to find assistance and guidance.

- **Bank:** Visit the virtual bank to request loans and manage your financial resources.

- **Audits:** Access detailed audit reports to ensure the plant's compliance with safety and operational standards.

- **Alarms Calibration:** Customize alarm ranges according to your preferences using this configurator.

Ensure to make the most of these applications on your tablet to run a successful and efficient nuclear power plant.

CORE FUSION SEQUENCE

In the event of a core fusion, a countdown timer will appear on the screen. Upon reaching zero, the core fusion process will be complete. Players will then face a critical decision with two options: attempting to halt the fusion or escaping via the train.

Countdown Initiation

When the core fusion is triggered, a countdown timer is displayed, indicating the time remaining until the fusion process concludes.

Decision Point

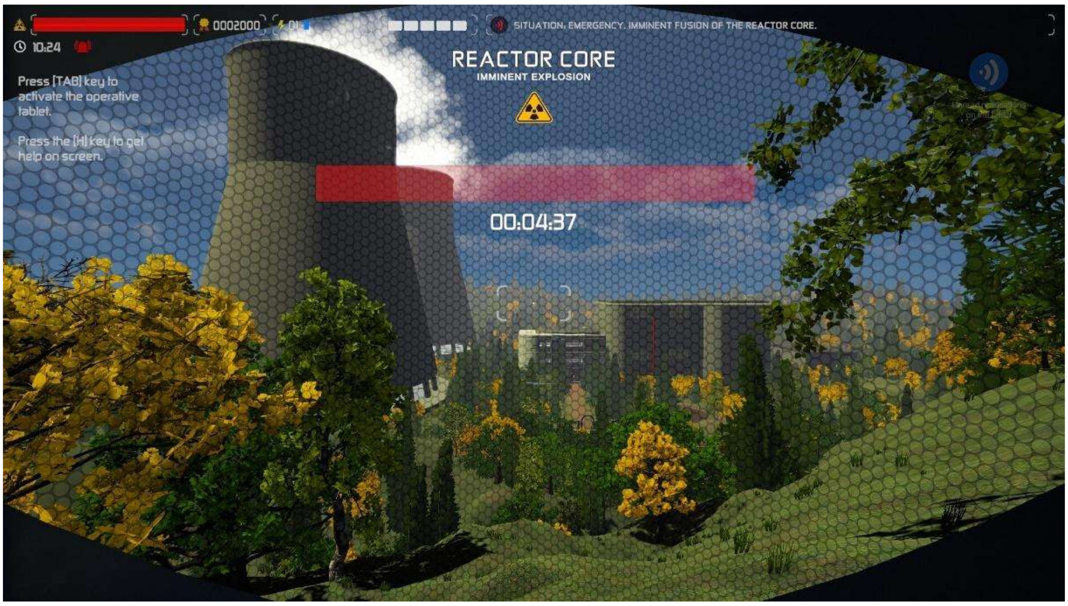
As the countdown progresses, players must decide between two options:

1. *Attempt to Halt Fusion:* Choosing this option involves engaging in a challenging mini-game or series of tasks to reverse the fusion process. Success results in a prestige point reward and a bonus for all repairs conducted during the fusion event.

2. *Escape via Train:* Opting to escape via the train initiates a new game with 50% of the player's points, experience, and level. This choice allows for a fresh start but with reduced progress.

HALTING FUSION

If the player chooses to attempt to halt the fusion, they will face a mini-game that challenges their skills. Successful completion of the mini-game results in a reversal of the fusion process.



To successfully complete the mini game during the core fission sequence, players must achieve at least two out of the following three achievements:

1. **Manual Control Rod Insertion:** Successfully introducing all control rods manually using the operational crane, with a minimum number of control rods remaining undamaged.

   Players must manually operate the crane to introduce all control rods into the core. The challenge lies in ensuring precision and minimizing damage to the control rods during the insertion process.

2. **Fuel Block Extraction and Storage:** Accomplishing the extraction of the fuel block and securely storing it in a final disposal capsule.

3. **Actual Fuel Temperature Reduction:** Successfully reducing the actual temperature of the fuel during the fission sequence.

Meeting the requirements of at least two out of the three achievements demonstrates the player's proficiency in managing critical aspects of the core fission sequence. It ensures a successful outcome in the mini-game, contributing to the prevention of catastrophic consequences.

Points and Prestige Reward

Successfully reversing the fusion not only prevents catastrophic consequences but also rewards the player with prestige points and a bonus for all repairs conducted during the fusion event.

ESCAPE VIA TRAIN

Opting to escape via the train concludes the current game, and the player can start anew in the next round. However, they begin with 50% of their accumulated points, experience, and level.

Fresh Start or Prestige Points

Players must weigh the risk and reward of their decision. Choosing to escape via the train provides a chance to start over with a fresh perspective with 50% of the player's points, experience, and level. This choice allows for a fresh start but with reduced progress.

In summary, the core fusion sequence introduces a critical moment in the game where players must decide between attempting to halt the fusion for prestige points and repair bonuses or escaping via the train for a new beginning with reduced progress.
