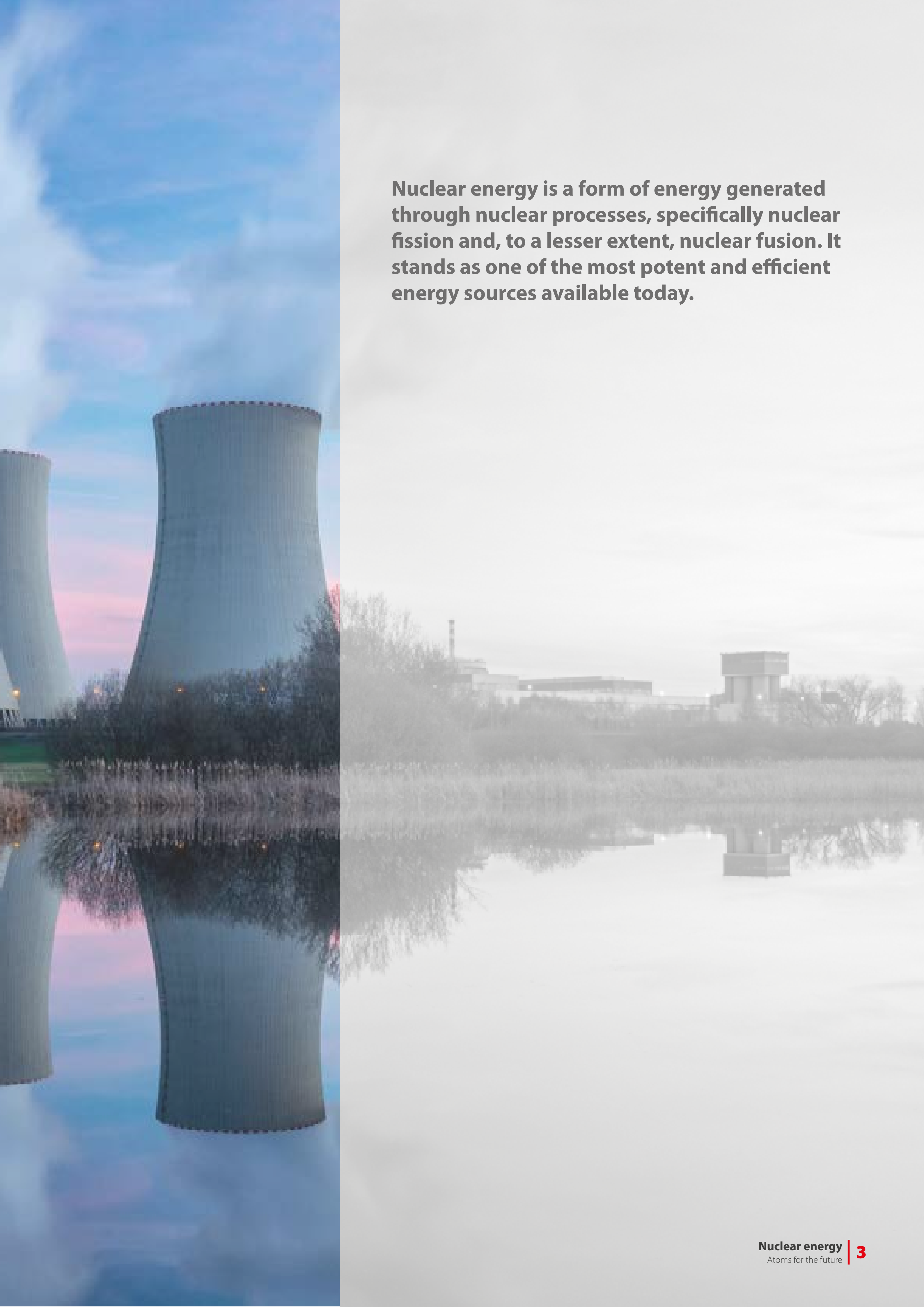
Nuclear Energy

Atoms for the future

By EGA Master



Nuclear energy is a form of energy generated through nuclear processes, specifically nuclear fission and, to a lesser extent, nuclear fusion. It stands as one of the most potent and efficient energy sources available today.

1

INTRODUCTION

IMPORTANCE AND APPLICATIONS

Nuclear energy plays a crucial role in electricity generation worldwide. Nuclear power plants produce large amounts of electricity continuously and reliably, emitting minimal greenhouse gases. This makes them a **significant alternative for reducing fossil fuel dependency and mitigating climate change.**

Beyond electricity generation, nuclear energy finds applications in various fields:

- **Nuclear Medicine:** Used in disease diagnosis and treatment, such as Positron Emission Tomography (PET) and radiation therapy.
- **Industry:** Employed in quality control, medical product sterilization, and generating radioactive isotopes for diverse applications.
- **Scientific Research:** Research nuclear reactors are utilized for material studies, particle physics research, and technology development.
- **Space Propulsion:** Nuclear energy has been considered for long-duration space missions due to its high energy density and autonomy.

Nuclear energy emerges as a versatile power source with applications ranging from electricity generation to medicine and space exploration. While presenting challenges such as waste management and safety, its significance in transitioning towards a more sustainable and diversified energy matrix is undeniable.

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2
FUNDAMENTAL CONCEPTS

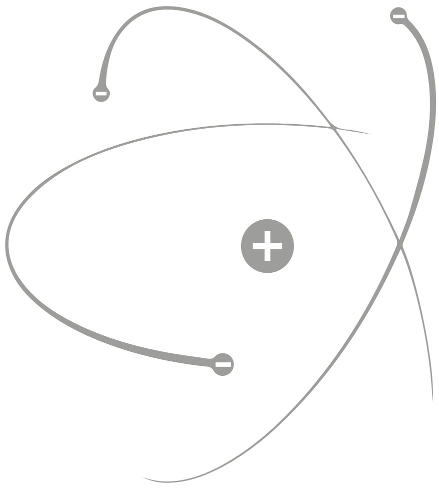
2.1 ATOMS AND NUCLEI

Atoms are the basic units of matter and the fundamental structure of chemical elements. They consist of three primary particles: protons, neutrons, and electrons.

Protons: Positively charged particles located in the nucleus of the atom. The number of protons in the nucleus determines the atomic number of the element and, consequently, its chemical identity.

Neutrons: Electrically neutral particles found in the atom's nucleus alongside protons. The number of neutrons in the nucleus can vary for the same element, resulting in different isotopes of the element.

Electrons: Negatively charged particles that orbit the nucleus in regions known as "shells" or "energy levels." The number of electrons in an atom equals the number of protons in the nucleus, maintaining the atom's electrical neutrality.



2.2 SUBATOMIC PARTICLES: PROTONS AND NEUTRONS

Protons: As mentioned earlier, protons are positively charged (+1) particles located in the atom's nucleus. They have a mass approximately equal to that of a neutron.

Neutrons: Neutrons are neutral particles (without electric charge) residing in the atom's nucleus. They have a mass similar to that of protons. The stability of the atomic nucleus is maintained by the presence of neutrons that balance the repulsive electric charge of the protons.

The combination of protons and neutrons in the nucleus determines the atom's properties, including its atomic weight and nuclear properties. **The interaction between these subatomic particles is crucial for understanding nuclear processes such as fission and fusion, which form the basis of nuclear energy.**

The interaction between these subatomic particles is crucial for understanding nuclear processes such as fission and fusion, which form the basis of nuclear energy

3
NUCLEAR FISSION: DIVISION OF THE NUCLEUS

Nuclear fission is a process in which the nucleus of a heavy atom, such as uranium or plutonium, splits into two or more smaller fragments. This process releases a significant amount of energy in the form of heat and radiation. Below, we explain the nuclear fission process and how energy release occurs.

The energy released in the form of heat is used to generate steam and spin turbines connected to generators, producing electricity

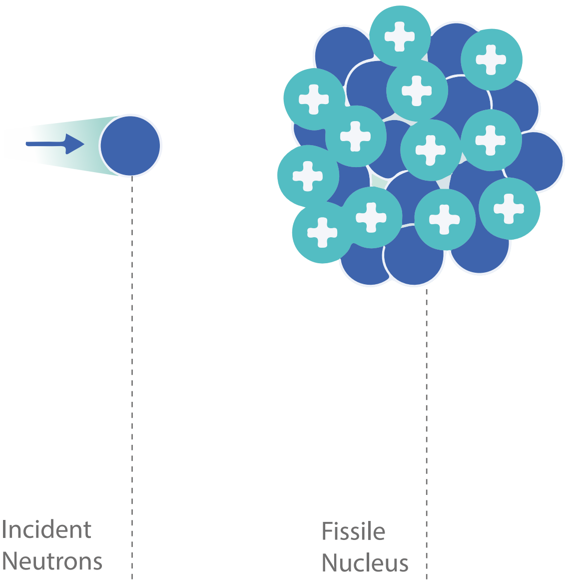
3.1 NUCLEAR FISSION PROCESS

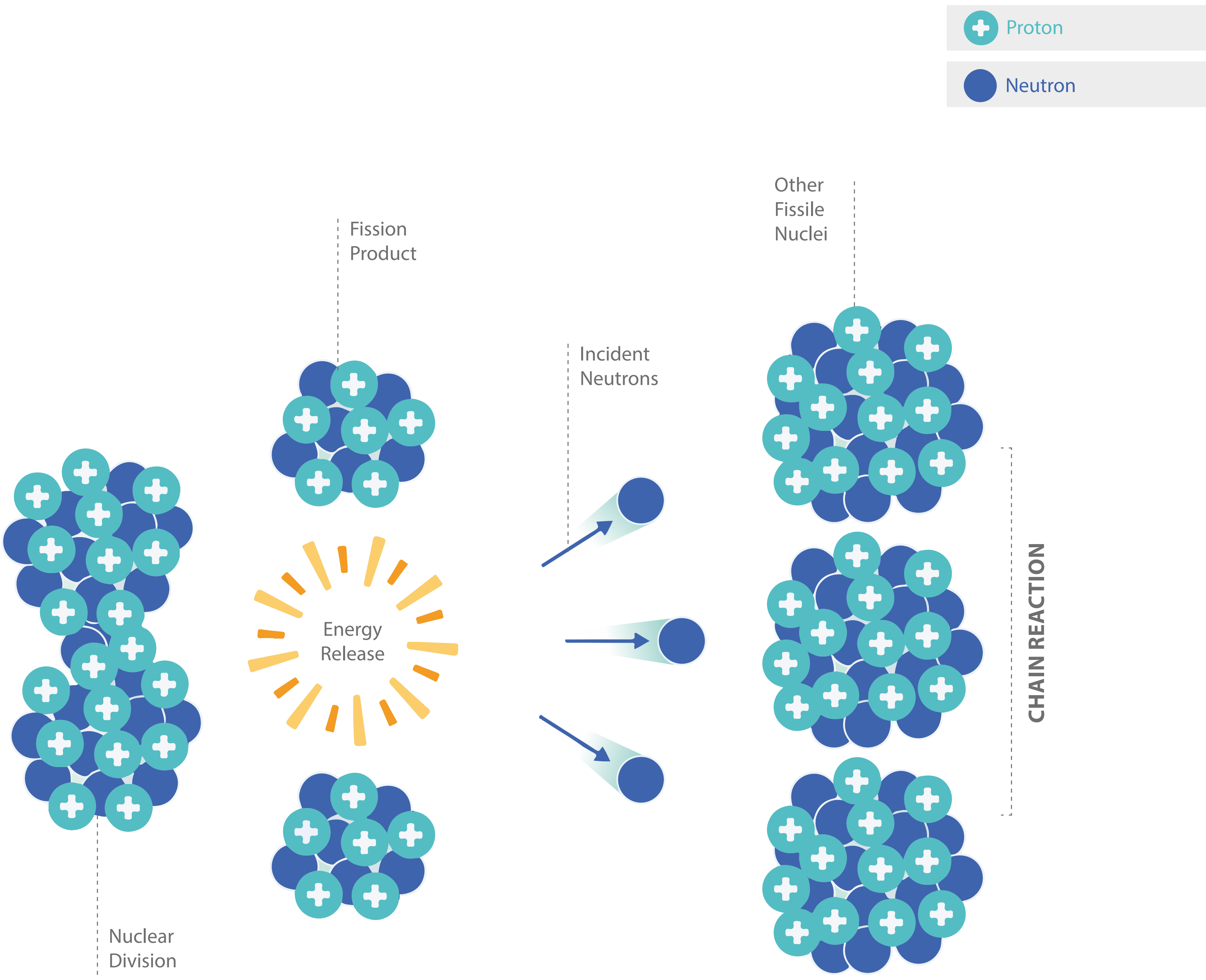
- **Neutron Incident:** For nuclear fission to occur, the nucleus of an atom must be struck by a neutron. This incident neutron is absorbed by the nucleus, causing it to become unstable.
- **Nucleus Division:** Neutron absorption makes the nucleus unstable, leading it to break into two or more smaller fragments, known as fission products. This process releases additional neutrons and a large amount of energy in the form of heat.
- **Neutron Emission:** During nuclear fission, several additional neutrons are released. These neutrons can be absorbed by other nearby atom nuclei, causing them to also split in a process known as a chain reaction.

3.2 ENERGY RELEASE

The energy release during nuclear fission occurs due to the conversion of mass into energy, in accordance with Einstein's famous equation, $E=mc^2$. During fission, the mass of the fission products is slightly less than the mass of the original nucleus before fission.

This small mass difference translates into a tremendous amount of energy according to Einstein's equation. The energy released in the form of heat is used to generate steam and spin turbines connected to generators, producing electricity in nuclear power plants.




Proton
Neutron
Fission
Product
Other
Fissile
Nuclei
Incident
Neutrons
Energy
Release
CHAIN REACTION
Nuclear
Division

4
CHAIN REACTION

The chain reaction is a pivotal phenomenon in the nuclear fission process, where the neutrons released during the fission of an atomic nucleus lead to the fission of other nuclei in a continuous cycle. This section elucidates the role of neutrons in this reaction and how the dynamics of a chain reaction unfold:

4.1 NEUTRONS AND THEIR ROLE

Neutron Generation: During nuclear fission, several neutrons are released as reaction products. These neutrons are essential for initiating new nuclear reactions.

Neutron Velocity: The velocity of the liberated neutrons can vary. Fast neutrons are less likely to be absorbed by other nuclei, whereas slow neutrons have a higher probability of absorption.

Neutron Capture: When a neutron is absorbed by another nucleus, it can induce the fission of that nucleus. This process releases more neutrons and energy, leading to a chain reaction.

The neutrons released during the fission of an atomic nucleus lead to the fission of other nuclei in a continuous cycle

4.2 DYNAMICS OF A CHAIN REACTION

- **Initiation of the Reaction:** An incident neutron impacts an atomic nucleus, causing its fission and releasing several additional neutrons.
- **Propagation of the Reaction:** The released neutrons collide with nearby nuclei, causing their fission and releasing more neutrons. This process continues in a repetitive cycle.
- **Control of the Reaction:** To maintain the reaction under control, neutron-absorbing materials, such as control rods, are utilized. These can absorb neutrons and regulate the reaction rate.
- **Pace of the Reaction:** The pace of the chain reaction is determined by the number of neutrons produced, the rate at which they are released, and the likelihood of their absorption by other nuclei.
- **Reactor Stability:** A nuclear reactor must be maintained in a critical state, where the number of neutrons produced remains constant. If there are too many neutrons, the reaction accelerates, leading to a hazardous situation known as "supercritical."

A nuclear reactor must be maintained in a critical state, where the number of neutrons produced remains constant

5

NUCLEAR POWER PLANTS

Nuclear power plants are facilities designed to generate electricity using the energy released in the nuclear fission process. This section elucidates the basic operation of a nuclear power plant, the fuel materials employed, and the role of the nuclear reactor in electricity generation:

Uranium is the most commonly used fuel material in nuclear power plants

5.1 BASIC OPERATION

Controlled Nuclear Fission: The core of a nuclear power plant is the nuclear reactor, where controlled nuclear fission takes place. Within the reactor, nuclear fuel rods are placed in a moderating medium, such as water or graphite. When the neutrons released during fission collide with other nuclei, a controlled chain reaction occurs.

Heat Generation: Significant heat is released during nuclear fission. This heat is utilized to heat circulating water in a primary cooling system, converting it into high-pressure steam.

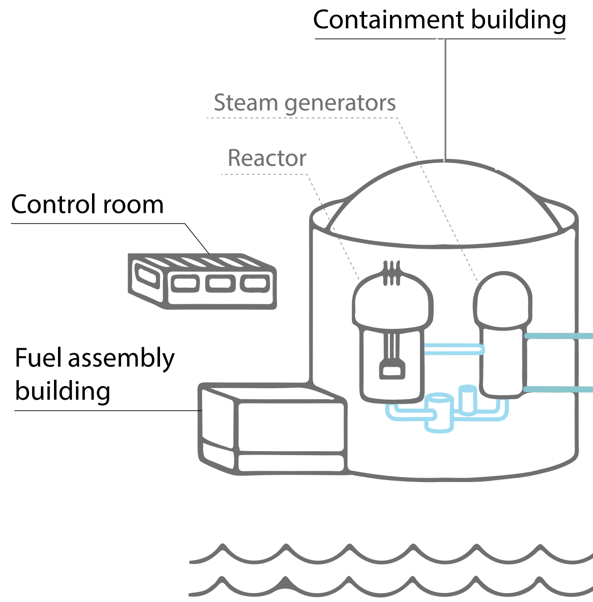
Turbine and Generator: The high-pressure steam produced in the primary cooling system is directed towards a turbine connected to an electrical generator. As the steam rotates the turbine blades, the generator converts this mechanical energy into electricity.

Condensation and Recirculation: After passing through the turbine, the steam is cooled and condensed in a secondary cooling system. The condensed water is recirculated back to the primary cooling system to initiate the cycle anew.

5.2 FUEL MATERIALS: URANIUM AND PLUTONIUM

Uranium: Uranium is the most commonly used fuel material in nuclear power plants. The uranium-235 isotope is particularly useful for nuclear fission due to its ability to capture neutrons and split into smaller fragments.

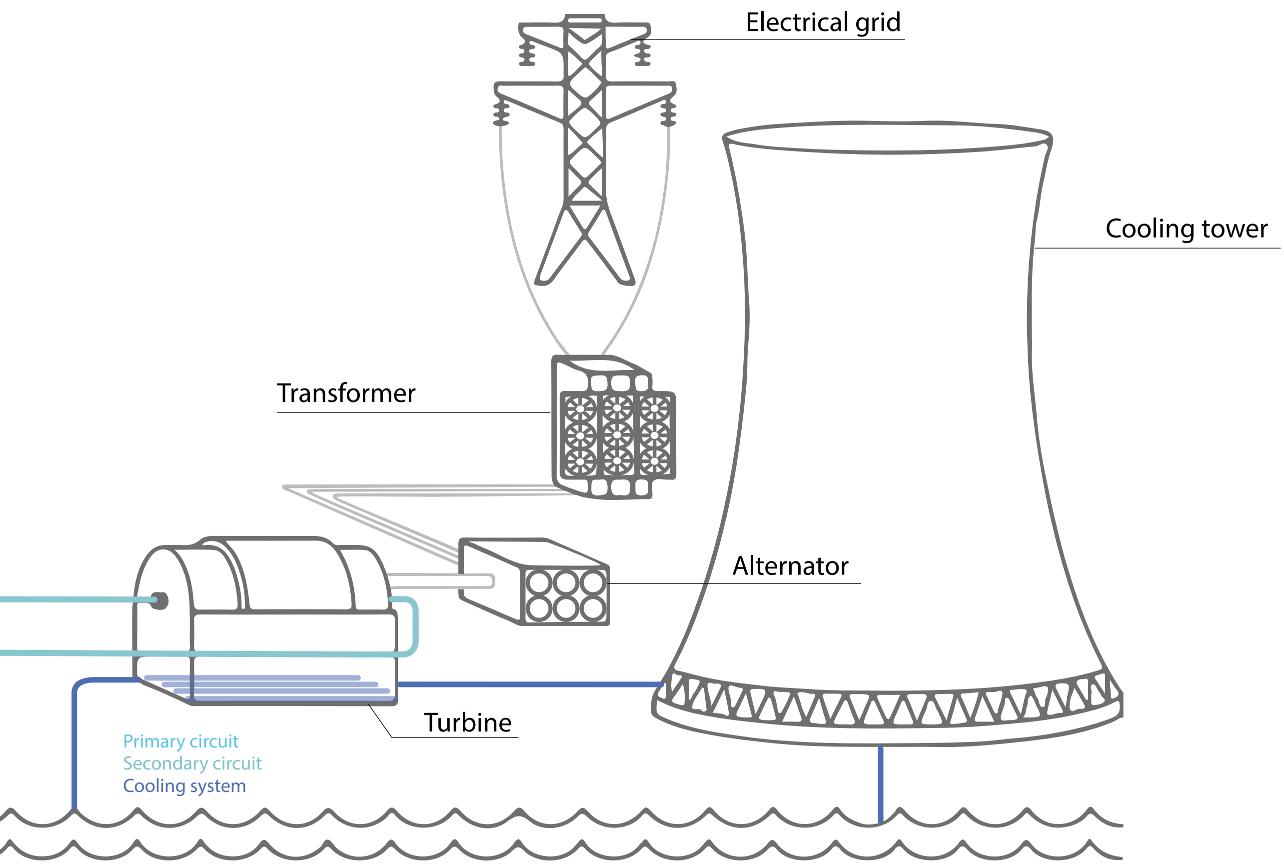
Plutonium: Plutonium can also be utilized as fuel in nuclear power plants. It is artificially produced from uranium-238 in a nuclear reactor through neutron capture. Plutonium-239 is a fissionable isotope that can replace uranium-235 as fuel in certain reactor types.



5.3 NUCLEAR REACTOR AND ELECTRICITY GENERATION

The nuclear reactor is the heart of a nuclear power plant, where nuclear fission is controlled to generate heat and, consequently, electricity. Nuclear reactors can vary in design and technology, but they all share the use of fuel materials, moderators, and cooling systems to maintain controlled fission and generate electricity safely and efficiently.

The nuclear reactor is the heart of a nuclear power plant, where nuclear fission is controlled



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NUCLEAR ENERGY CONTROL

The control of nuclear energy is paramount to ensuring the safety and stability of nuclear reactors. This section delineates the safety systems employed in nuclear power plants, as well as the pivotal role of control rods in regulating the nuclear reaction:

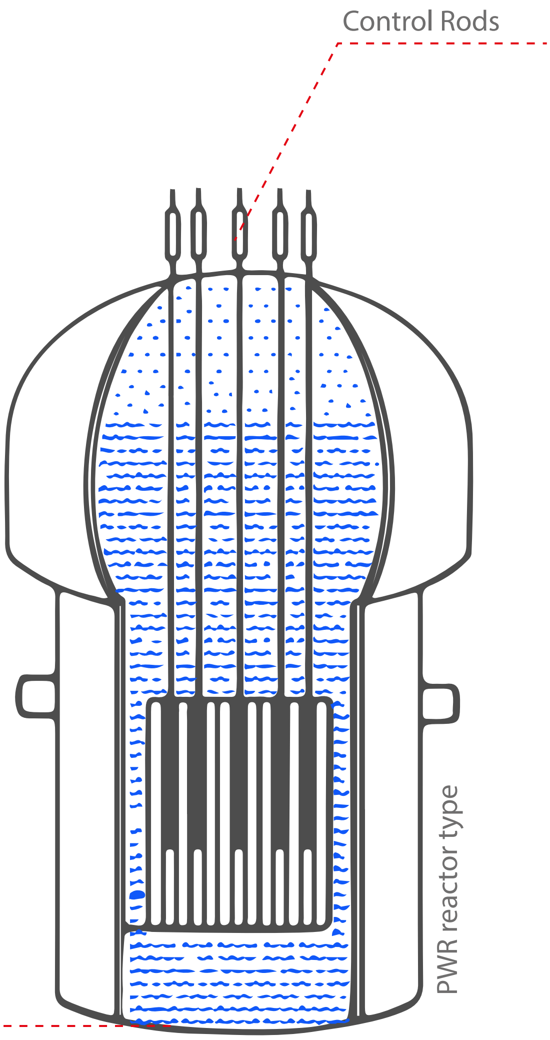
6.1 SAFETY SYSTEMS

Reactor Containment: Nuclear power plants are designed with robust containment structures capable of withstanding adverse events, such as earthquakes, tsunamis, or internal failures, to prevent the release of radioactive material into the environment.

Cooling Systems: The primary and secondary cooling systems in nuclear power plants help maintain the reactor temperature under control, preventing overheating and the potential for unintended nuclear meltdowns.

Automatic Control Systems: Nuclear reactors are equipped with automatic control systems that continuously monitor reactor conditions and can take corrective actions in case of deviations beyond established limits.

Radiation Protection: Radiological protection measures are implemented to ensure the safety of workers and the public near the nuclear power plant, including the use of shielding, radiation monitoring, and safety protocols.



The reactor power is controlled using control rods, lowering the turbine demand, and varying the concentration of boric acid in the primary circuit. Boron is an effective absorber of neutrons released during fission.

6.2 CONTROL RODS AND REACTION REGULATION

Control rods are pivotal devices for regulating the nuclear reaction in a nuclear reactor. These rods are made of neutron-absorbing materials, such as boron or cadmium, and are used to control the neutron population within the reactor. Their primary functions are:

- **Neutron Absorption:** Control rods can be inserted or withdrawn from the reactor core to control the number of neutrons available for nuclear fission. When control rods are fully inserted, they absorb a greater number of neutrons, thereby reducing the speed of the nuclear reaction.

- **Power Regulation:** By adjusting the position of the control rods, the reactor power can be regulated. By increasing or decreasing the neutron population in the reactor, the chain reaction speed, and hence the heat generated, can be controlled.

- **Emergency Safety:** In case of emergencies or power outages, control rods can be rapidly inserted into the reactor core to halt the nuclear reaction and prevent core overheating, which could lead to a severe accident.

Control rods are pivotal devices for regulating the nuclear reaction in a nuclear reactor

7

NUCLEAR POWER PLANT MAINTENANCE

Maintenance of nuclear power plants is paramount to ensuring their safety, reliability, and operational efficiency. This guide provides an overview of the key practices and procedures involved in maintaining these critical nuclear energy facilities.

Maintenance of nuclear power plants is paramount to ensuring their safety, reliability, and operational efficiency

7.1 MAINTENANCE PLANNING

Risk Assessment: Conduct a comprehensive risk assessment associated with the plant's operations, identifying critical areas that require prioritized focus in maintenance activities.

Development of Preventive Maintenance Programs: Establish preventive maintenance programs that include regular inspections, equipment testing, and scheduled component replacement to prevent unexpected failures.

Scheduled Outages Planning: Schedule planned outages, known as refueling outages, to perform maintenance activities requiring the temporary cessation of plant operation.

7.2 MAINTENANCE EXECUTION

Regular Inspections and Testing: Perform regular visual inspections and operational tests on equipment and systems to detect potential issues and ensure optimal performance.

Corrective and Predictive Maintenance: Implement corrective maintenance actions to address identified issues during inspections and utilize predictive techniques, such as vibration analysis, to anticipate potential failures.

Change Management: Manage any changes to the plant's design, operation, or maintenance through a formal change control process, carefully assessing risks and obtaining necessary approvals prior to implementation.

7.3 STAFF TRAINING

Continuous Training: Provide regular training to maintenance staff to ensure they are familiar with safety procedures and protocols, as well as the specific technologies and equipment used in the plant.

Drills and Training Exercises: Conduct periodic drills and training exercises to familiarize staff with emergency procedures and prepare them to effectively respond in crisis situations.

7.4 COMPLIANCE WITH REGULATIONS AND STANDARDS

Regulatory Compliance: Ensure all maintenance activities comply with regulatory and normative requirements established by competent authorities in nuclear safety.

Audits and Assessments: Conduct internal audits and periodic evaluations to ensure compliance with safety and quality standards in all maintenance operations.

7.5 CONTINUOUS EVALUATION AND IMPROVEMENT

Results Analysis: Analyze the results of maintenance activities and reported incidents to identify areas for improvement and opportunities for process optimization.

Implementation of Improvements: Implement corrective actions and improvements based on analysis findings, aiming to optimize maintenance processes and promote safety and efficiency in plant operation.

The maintenance staff must be familiar with the safety procedures and protocols, as well as the specific technologies and equipment

8
EGA GROUP SOLUTIONS

8.1 ANTIDROP® TOOL

The ANTIDROP® tool is essential in the maintenance of nuclear power plants to ensure the safety of personnel working at elevated heights. By preventing accidental falls from dangerous heights, such as those found in the plant's structures, the anti-drop tool significantly reduces the risk of severe or even fatal injuries.

This not only protects the physical integrity of the workers but also ensures the safe and efficient continuity of maintenance operations, thereby contributing to the overall safety of the nuclear facility.

At EGA Master we are aware of this, a whole range of ANTIDROP® products and solutions that have been designed to control and prevent object dropping when working at height.

These products have been designed to allow a comfortable, productive, and efficient use of tools while assuring workers' and equipment safety against object dropping.

On the one hand, we offer belts and retractable lanyard with carabiner.

8.1.1 Belts and wrist bands

They are designed to fit the worker´s body, to enable user freedom and provide maximum tool fixing points, and to make internal hooks safely to retain tools while the operator is climbing or moving location

8.1.2 Lanyards

They are designed for maximum safety and to give an optimum working freedom. The many systems provide all the necessary solutions for a safe and comfortable use at heights, and at the same time, they ensure a better shock absorption.

ANTIDROP® products and solutions have been designed to control and prevent object dropping when working at height

8.1.3 Premium tools for industrial use

On the other hand, we offer different ranges of ANTIDROP® premium tools for industrial use: non-sparking, insulated 1000V, ESD, non-magnetic. These have attached a thermo-shrink system and retention ring, following DROPS recommendations. Such system is much effective and safe, and also it avoids damages on the properties of the tool.

It is true that most of the tools can be turned in ANTIDROP®, we discourage to put sleeves oneself. It is not economic nor safe, since one must put it registering temperature, time, diameter of sleeve and length of sleeve. And then, TEST it.

If the tests succeed, then for that code the design parameters are settled, and the rest of ANTIDROP® tool units of that code are manufactured according to these parameters.

Without having made TESTS to the design parameters, they can never assure that the outcome will perform properly in the first fall. They can't assure safety; if they make the tests, it will cost them much more than buying complete ANTIDROP® tools.

8.2 TOOL CONTROL SYSTEM

Tool control systems are crucial in the maintenance of nuclear power plants as they ensure traceability and safety of the tools used. Moreover, they facilitate the prevention of losses and detection of missing tools, reducing the risk of accidents and ensuring the integrity of critical equipment in nuclear facilities.

Therefore, we have also developed different tool control systems, essential in many applications, especially in cases where "lost" or forgotten tools increase risks and decrease safety.

As a solution, we offer an exclusive and customized tool control system, preventing the misplacement or loss of these tools.

8.2.1 EGAWARE Software

EGA Master offers an exclusive and customized tool control system solution, preventing the misplacement or loss of tools.

The EGAWARE software allows tracking which tool each user picks up or returns:

A. The user logs in with their username and password.

B. The operator takes the tool they will work with.

C. The operator scans the barcode.

D. The software detects that the tool has been taken.

E. The operator returns the tool and scans the barcode again.

F. The software detects that the tool has been returned.

The EGAWARE software allows tracking which tool each user picks up or returns

8.2.2 Smart opening system for drawers

Avoid mistakes in the tool selection, increasing efficiency and therefore, productivity.

Each door is assigned a radio frequency card that is passed through the RFID reader of each roller cabinet allowing the opening and locking of the drawers.

Laser technology that detects errors such as a drawer that has not been completely closed.

LEDs in the drawers facilitate the visual recognition of the status of each drawer (open / locked).

The smart opening system for drawers avoids mistakes in the tool selection

8.3 TITANIUM TOOLS

Due to titanium's non-magnetic property and its low cross-sectional area for neutron absorption, it allows minimizing the risk of interference with sensitive detection and measurement equipment used in nuclear facilities. This ensures that titanium tools are **safe and effective for use in radioactive environments, thereby contributing to safety and efficiency in the maintenance operations of nuclear power plants.**

At EGA Master, we have developed a range of Titanium 6Al-4V tools. This alloy is the best currently available for critical and special applications that require high mechanical capacity, combined with features that other alloys cannot achieve, such as being non-magnetic, etc.

Among the tools that make up our extensive range of non-magnetic Titanium tools are:

- Adjustable, open-end, hexagonal, and double offset ring wrenches
- Torque wrenches
- Pliers and pincers
- Socket wrenches
- Screwdrivers
- Sockets bits
- Cutting tools and hammers

Titanium tools allow minimizing the risk of interference with sensitive detection and measurement equipment used in nuclear facilities

8.4 CONTROLLED TIGHTENING

Controlled tightening in nuclear power plant maintenance ensures the integrity of critical equipment by applying precise and controlled torque, avoiding damage and preventing radioactive leaks. It contributes to maintaining a safe and reliable work environment by complying with the highest safety standards, ensuring optimal operation of nuclear systems.

At EGA Master Group, we have developed extensive expertise in the field of controlled tightening, allowing us to create a wide range of torque wrenches, dynamometric screwdrivers, torque calibration machines, and adapters.

Among the types of controlled tightening tools we manufacture are:

- Torque wrenches
    - Analogic reversible
    - Digital checking QC
    - With Wireless data communication
    - With angle and torque measurement
    - Interchangeable heads
    - Battery-on
    - Hydraulic
- Angle adapters and meters
- Torque multipliers
- Dynamometric screwdrivers and nutrunners

8.4.1 EGATORK Control system

Nuclear reactors are characterized by a high presence of valves, turbines, pressurizers, and cooling systems. **The amount of energy generated, heat produced, and thermal contrasts result in wear on the bolted joints that make the operation of these structures possible. Ensuring the safety of the fastening in such structures**

Controlled tightening in nuclear power plant maintenance ensures the integrity of critical equipment by applying precise and controlled torque

is essential, preventing leaks and thereby avoiding high-impact catastrophes in the environment.

Controlled tightening in nuclear power plant maintenance ensures the integrity of critical equipment by applying precise and controlled torque.

Therefore, from the EGA group we have developed the **EGATORK CONTROL SYSTEM, a remote tightening torque management system, based on software and wireless automated tools, with the aim of:**

- Ensuring the quality of the assemblies
- Get absolute traceability and subsequent certification
- Optimizing production and improving safety

The EGATORK CONTROL SYSTEM is a remote tightening torque management system, based on software and wireless automated tools

8.5 INOX RANGE

Stainless steel tools are essential in the maintenance of nuclear power plants due to their unique properties that make them suitable for demanding nuclear environments.

It is highly resistant to corrosion, which is crucial in environments where corrosive chemicals and water can be found, ensuring tool durability and structural integrity over time.

At EGA Master, we manufacture a wide range of industrial tools in 420 stainless steel. This type of 420 stainless steel has mechanical characteristics very similar to carbon steel, allowing the manufacture of tools whose mechanical characteristics approach industrial use tools, granting more durability due to the tool's use.

They can also withstand thousands of sterilization processes.

Among the tools that make up our extensive range of 420 INOX tools are:

- Adjustable, open-end, hexagonal, and double offset ring wrenches
- Torque wrenches
- Pliers and pincers
- Socket wrenches
- Screwdrivers
- Socket bits

8.6 CUSTOMIZED SETS AND TOOL PERSONALIZATION

Our extensive experience in the most demanding industries and our capacity for industrial equipment and tool customization has earned the trust of many relevant companies in their sector.

We offer solutions to meet the specific needs of each client, either by customizing solutions or manufacturing tools according to customer requirements.

The stainless steel is highly resistant to corrosion, which is crucial in environments where corrosive chemicals and water can be found

In this way, if EGA Master's standard sets do not fit the customer's requirements, they can indicate their tool selection, and we will manufacture the trays.

We customize the design of each Foam tray, whether for roller cabinets, tool boxes, cases, or toolkits.

Another service we provide is **LASER ENGRAVING of tools with the client's logo or company name, to improve traceability and reduce costly losses.**

8.7 SAFETY TRAINING

Safety training in nuclear power plants is crucial to ensure the protection of personnel, surrounding communities, and the environment.

It provides workers with the knowledge and skills needed to identify and effectively manage risks associated with nuclear operations, including accident prevention.

Thanks to our experience in the nuclear energy industry and a well-trained team, we offer training in the safe use of tools in nuclear plants.

We offer advice and seminars on the safe use of tools integrated into solutions aimed at the nuclear industry:

- Antidrop®
- Controlled tightening
- Non-magnetic Titanium
- INOX

9
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