Basic Concept of Nuclear Reactor Safety

FTC on REACTOR ENGINEERING

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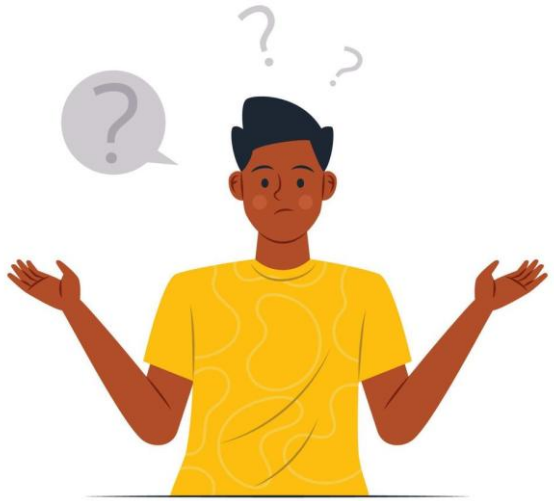
Biodata

- Nama : Rachmat Triharto, M.T.
- Kantor : Instalasi Reaktor Serba Guna G.A. Siwabessy
  Direktorat Pengelolaan Fasilitas Ketenaganukliran
- Jabatan : Pengembang Teknologi Nuklir Muda
- Kompetensi : Keselamatan Reaktor
- Pendidikan:
  - S1 Teknik Elektro, Universitas Diponegoro
  - S2 Teknik Elektro, Universitas Indonesia
- Pelatihan / Training:
  - *Instructor Training Course, Tokaimura-Japan, 2024*

Latar Belakang



- standar keselamatan
- budaya keselamatan

melindungi individu, masyarakat dan lingkungan

Tujuan instruksional

1. peserta memahami tujuan keselamatan nuklir secara umum, tujuan proteksi radiasi, dan tujuan keselamatan secara teknis
2. peserta memahami konsep keselamatan penghalang ganda
3. peserta memahami konsep keselamatan pertahanan berlapis
4. peserta memahami implementasi konsep pertahanan berlapis pada instalasi reaktor nuklir

SAFETY OBJECTIVE

❑General Nuclear Safety Objective:

To protect individuals, society and the environment by establishing and maintaining in nuclear power plants an effective defence against radiological hazard.

❑ Radiation Protection Objective:

To ensure in normal operation that radiation exposure within the plant and due to any release of radioactive material from the plant is as low as reasonably achievable

❑ Technical Safety Objective:

To prevent accidents in nuclear plants; to ensure that radiological consequences would be minor; and to ensure that the likelihood of severe accidents with serious radiological consequences is extremely small.

Basic Purpose of Nuclear Safety

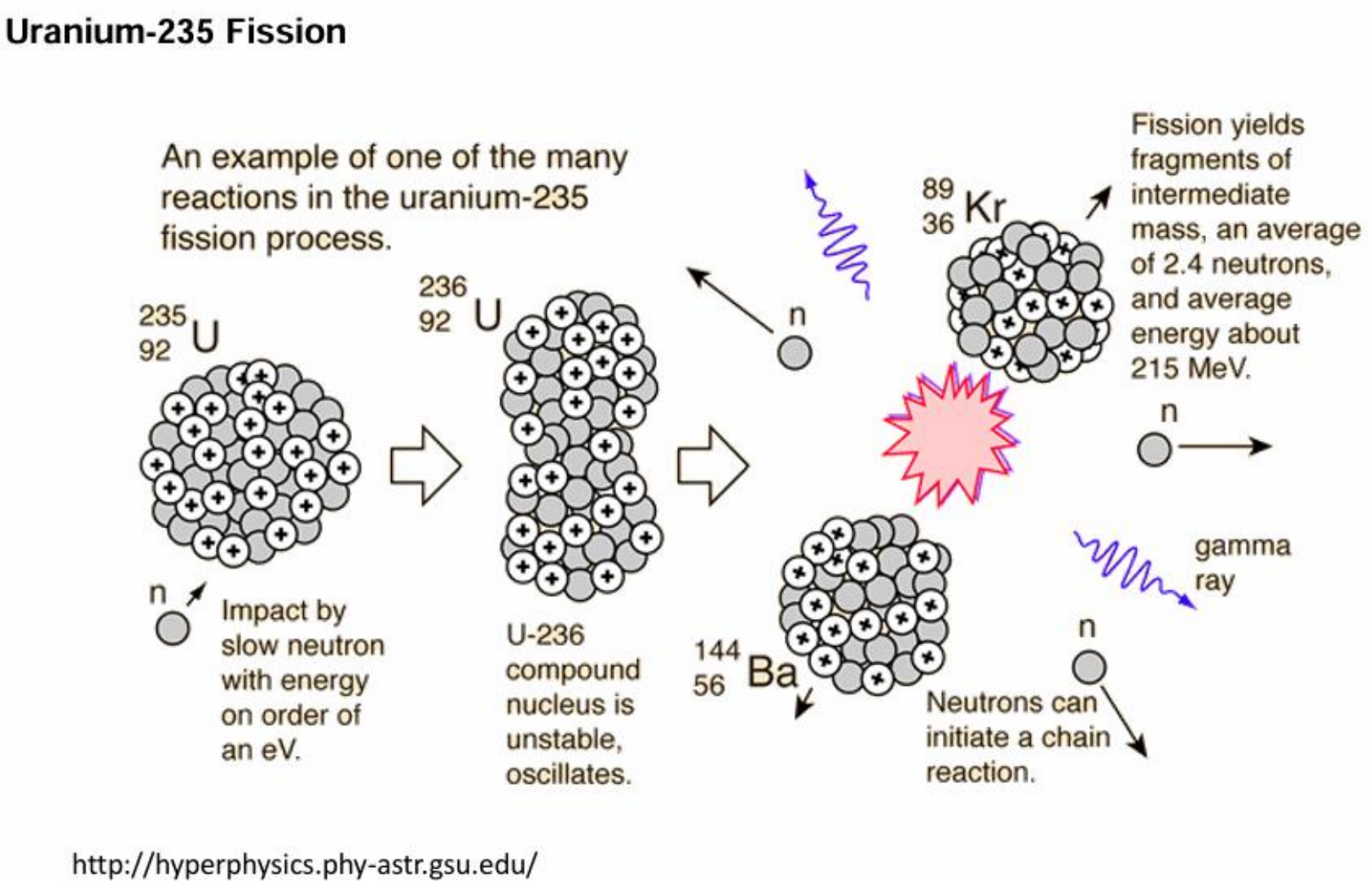
To protect workers, the public and the environment from radiation hazards, through:

➢ Control of radiation exposure to workers and control of the release of radioactive material into the environment.

➢ Limitation of the possibility of incidents that can result in loss of control over the reactor core, chain fission reactions, radioactive sources or other sources of radiation.

➢ Mitigate the consequences of incidents if they occur.

Reaksi fisi



http://hyperphysics.phy-astr.gsu.edu/

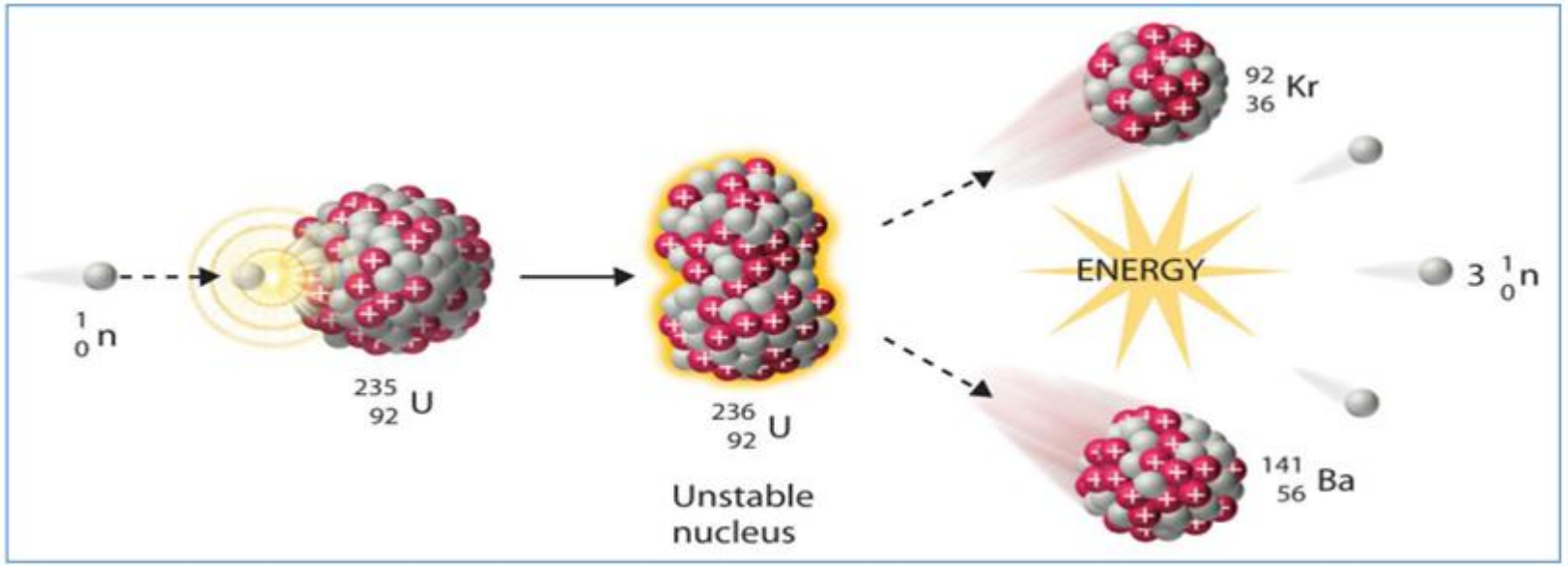
Basic safety functions in a nuclear reactor

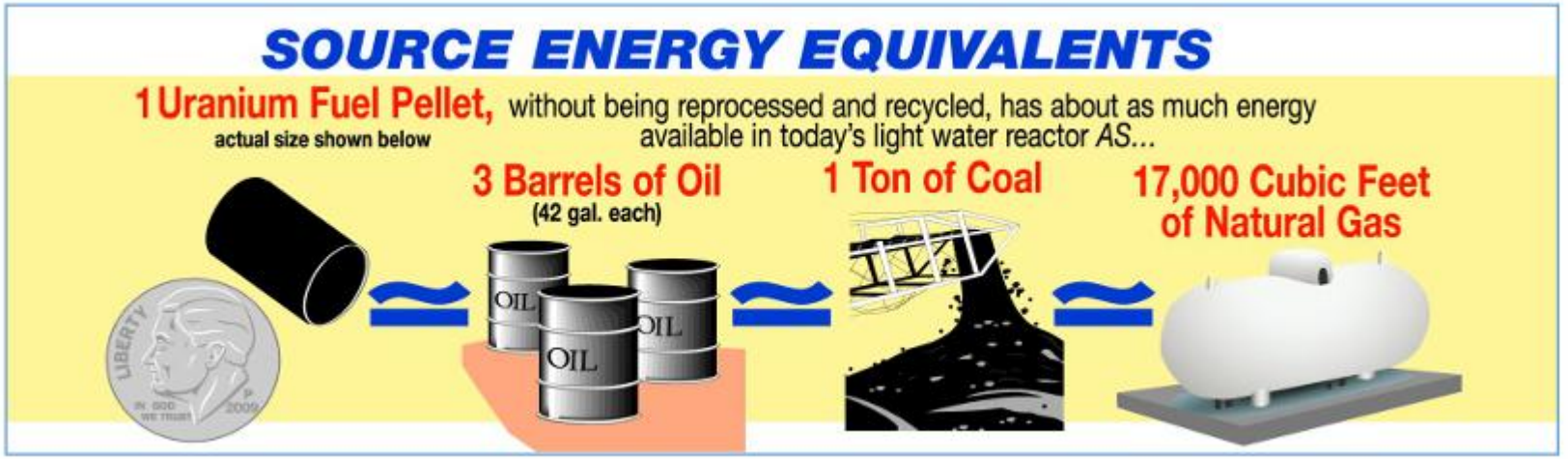
- ➢ to control reactivity
- ➢ to cool the fuel
- ➢ to contain radioactive substances.

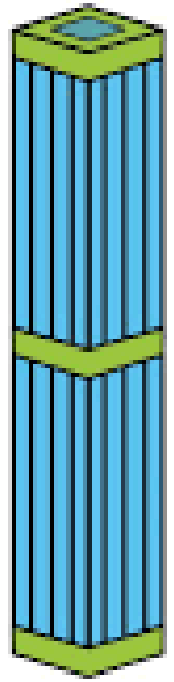
The main safety features of most reactors are inherent:

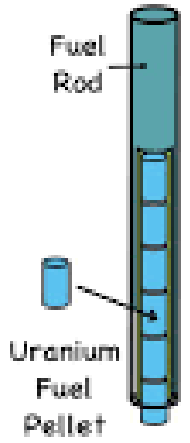
- negative temperature coefficient
- negative void coefficient

Reaksi fisi









Fuel assembly

Fuel assemblies are typically 14 feet long and contain about 200 fuel rods for PWRs and 80-100 fuel rods for BWRs.

Nuclear Reactor Safety

Potential Hazards in Nuclear Energy Utilization:

➢Chain Fission Reactions produce Ionizing Radiation; so a Radiation Shield is needed.

➢Fission Reaction produces a highly radioactive Fission Product (Material); so it needs a tight containment (leakproof).

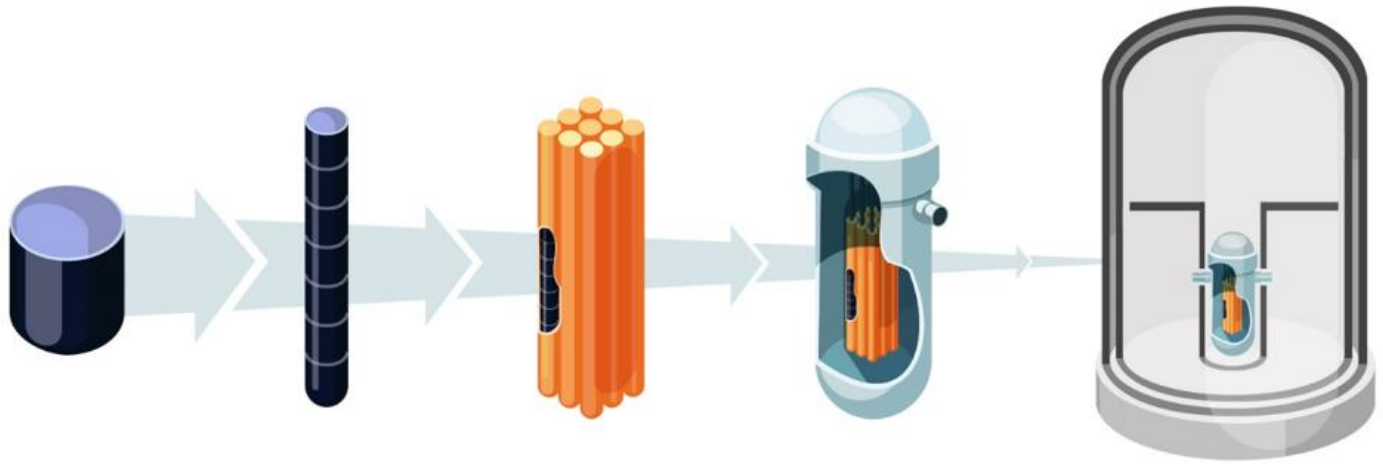
➢Fission Reaction is a very dynamic process and the energy released can increase extremely quickly; so a controller is needed

➢The effects of a fission reaction do not necessarily disappear after the fission stops; because radioactive material decays for a long time and requires cooling.

Safety approach

Diperlukan beberapa pendekatan:

- Multiple barriers (penghalang ganda)
- Defence In Depth (Pertahanan Berlapis)

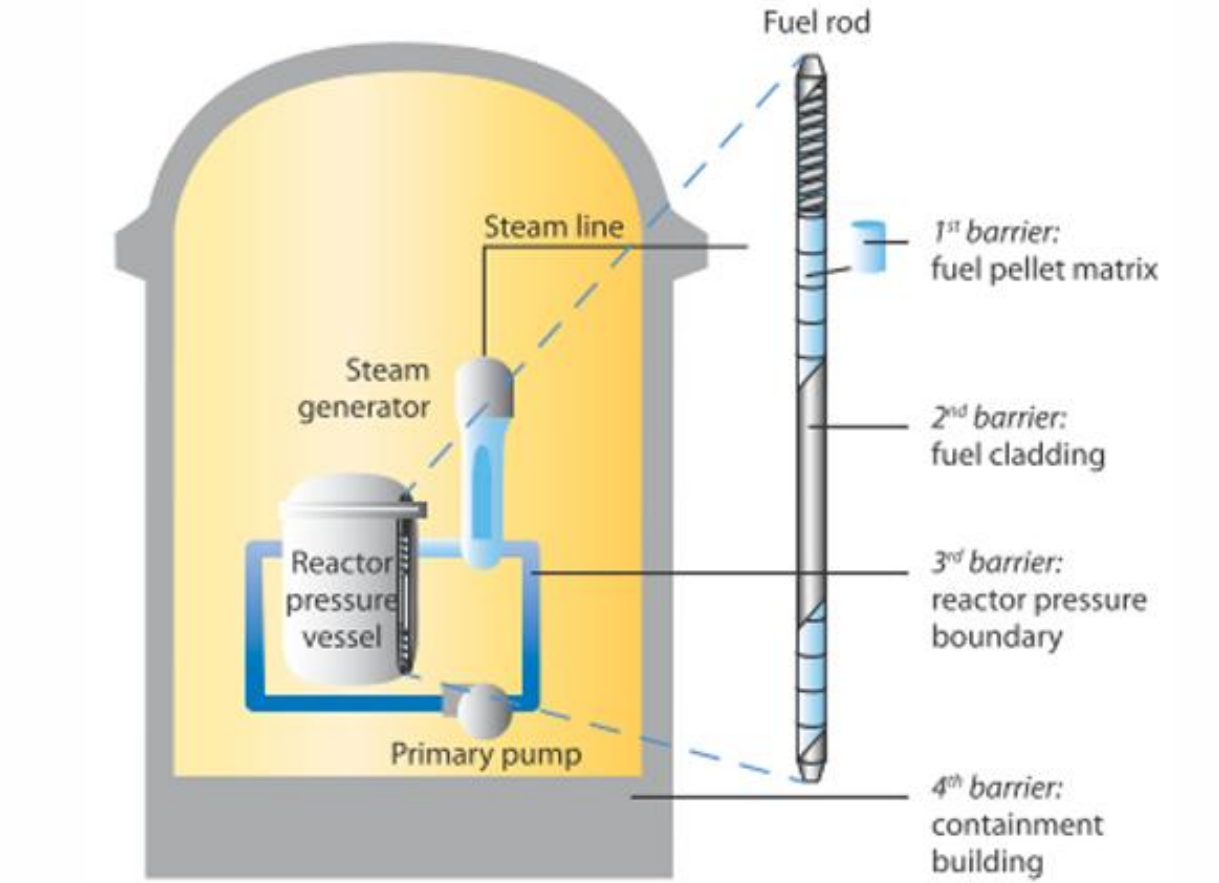


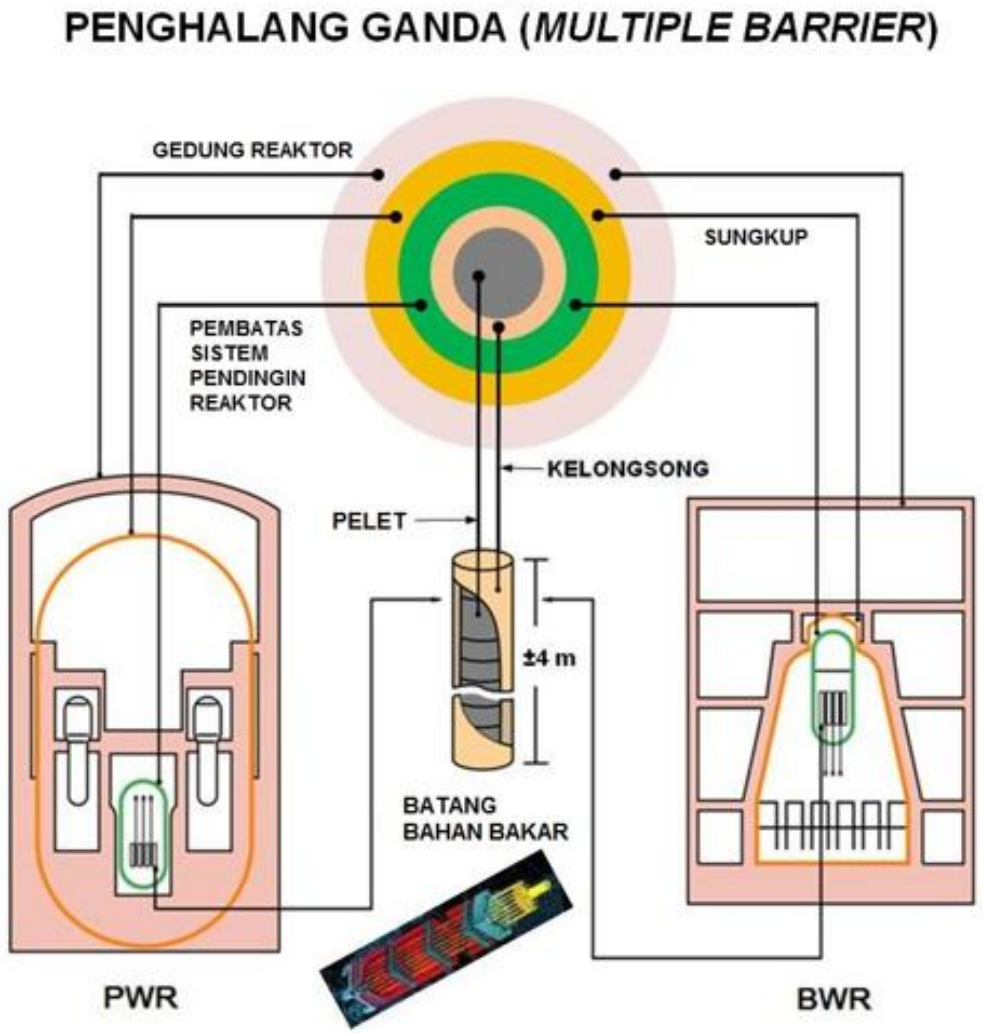
Multiple Barriers

Secara sederhana, pengungkungan bahan radioaktif dicapai dengan menempatkan beberapa penghalang secara fisik. Desainnya bisa berbeda tergantung pada aktifitas bahan radioaktif dan kemungkinan penyimpangan dari operasi normal yang dapat menyebabkan kegagalan beberapa penghalang.

Agar dapat mengeliminasi kejadian terlepasnya bahan radioaktif dari dalam sebuah reaktor nuklir, setiap lapis penghalang harus dijaga keutuhannya dalam kondisi apapun dengan cara menurunkan temperatur maupun tekanan di dalam masing-masing struktur penghalang ganda agar setiap penghalang tidak mengalami kelebihan tekanan (over-pressure) dan kelebihan temperatur (over-temperature).

Multiple Barriers





Gambar 1: Konsep Penghalang Ganda pada PLTN

Fuel matrix

material that contains the nuclear fuel and retains the fission products

The fuel matrix typically consists of small, cylindrical pellets made from enriched uranium dioxide (UO_2)

Ceramic Material

highly stable and capable of retaining fission products

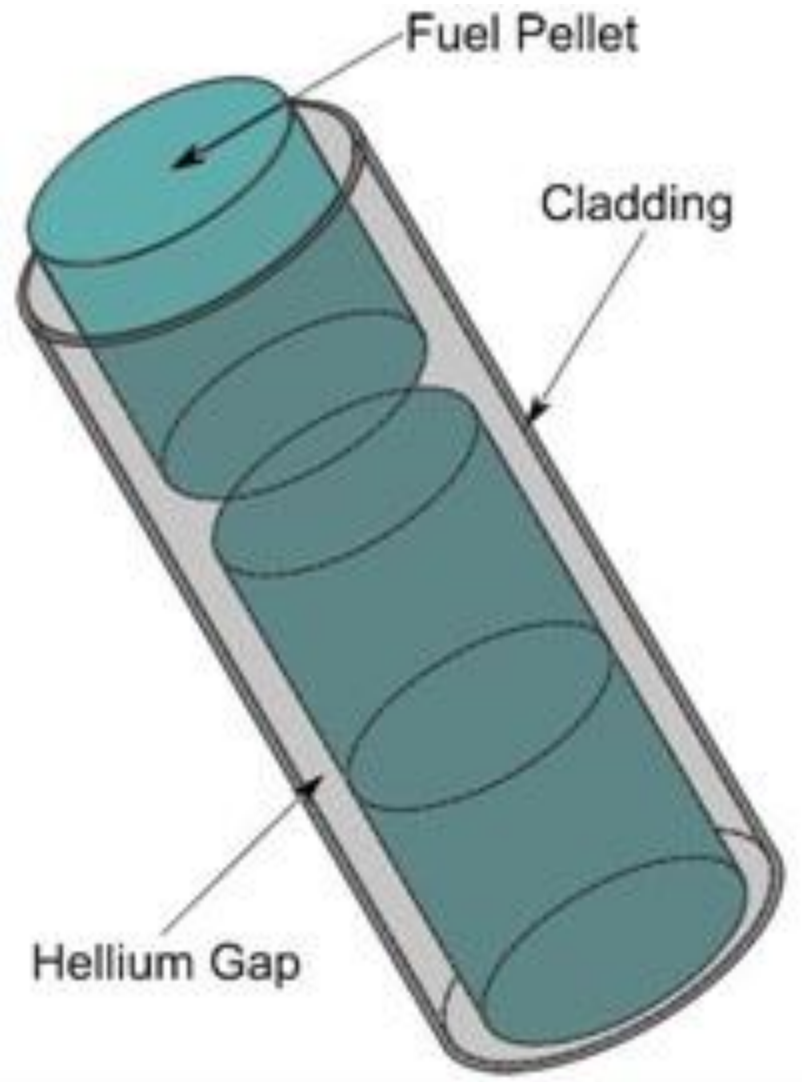
Fuel Cladding

- zirconium alloys
- low absorption of neutrons
- excellent corrosion resistance

The cladding is a thin-walled tube that encases the nuclear fuel pellets, providing a barrier between the radioactive fuel and the reactor coolant.

provides mechanical support to the fuel pellets, ensuring they remain properly aligned and spaced within the fuel rod

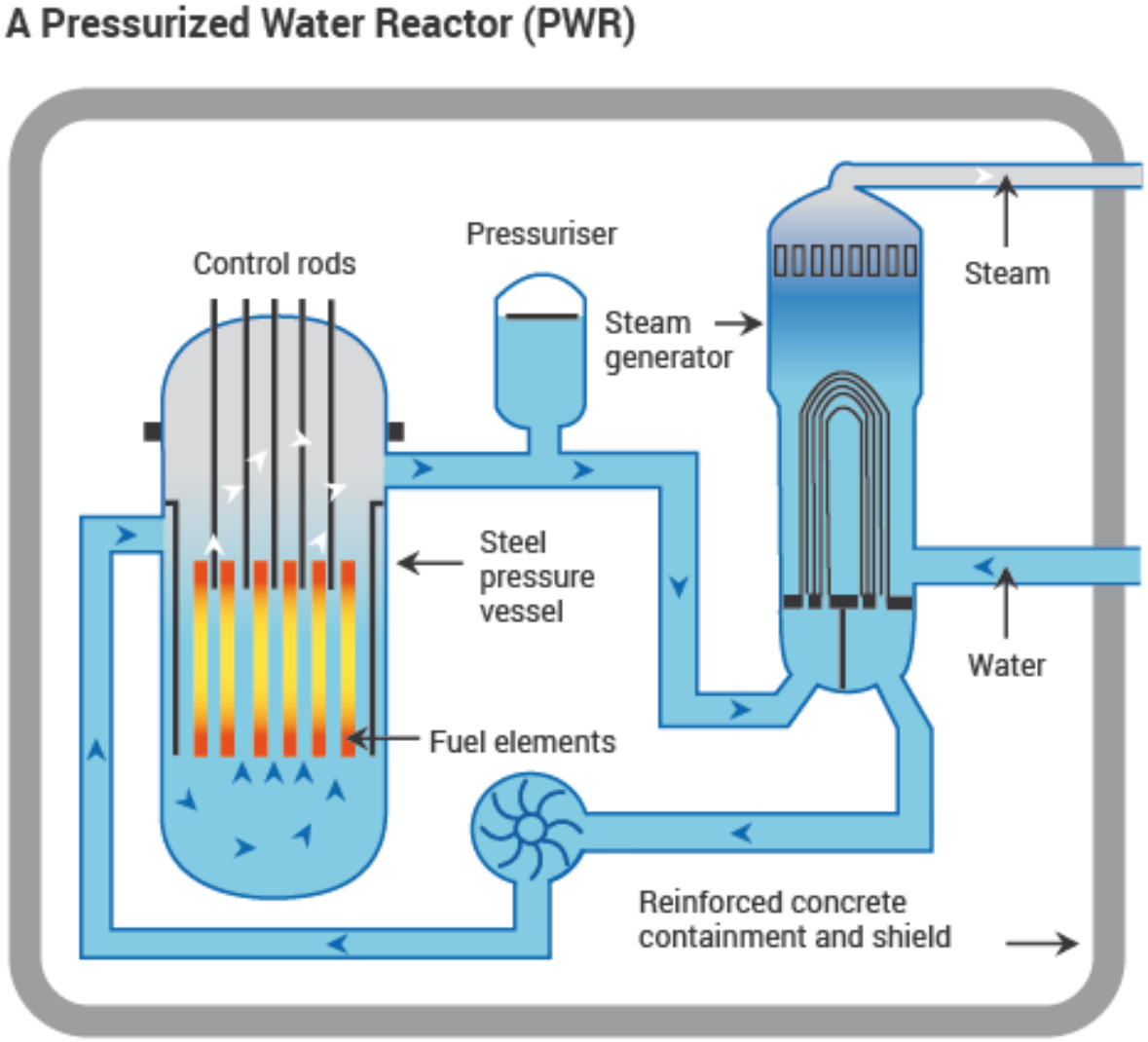
efficient heat transfer



Reactor Coolant System (RCS)

- Reactor Pressure Vessel (RPV)
- Coolant
- Primary Coolant Loop
- Pressurizer
- Pumps
- Heat Exchangers

- Heat Removal
- Temperature Regulation
- Pressure Maintenance
- Barrier to Radioactive Release



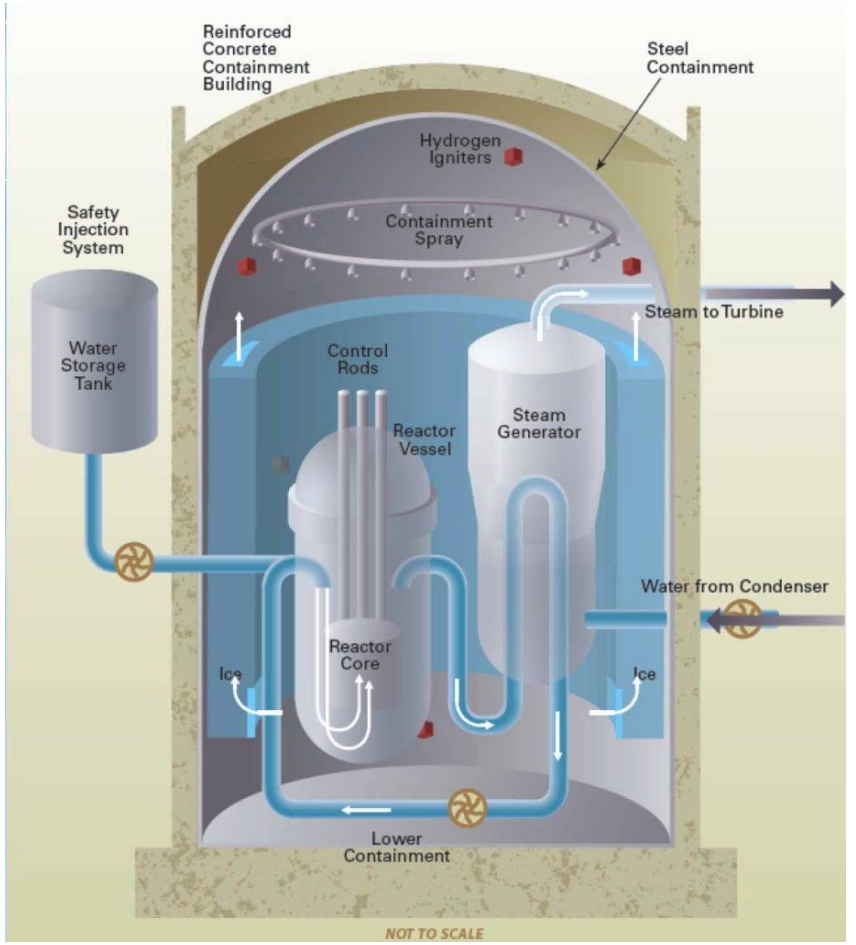
Containment Building

robust, airtight structure

prevent the release of radioactive materials

made of thick, reinforced concrete or steel

- Seismic activity
- Extreme weather conditions
- Aircraft crashes
- External explosions



- Cooling systems to prevent overheating
- Pressure suppression systems to prevent over-pressurization
- Air filtration systems to remove radioactive particles from the air

Question?

Defense in Depth

Penempatan level yang berbeda secara bertingkat dari peralatan/perlengkapan dan prosedur dengan tujuan menjaga keefektifan penghalang ganda fisik yang berada di antara bahan radioaktif dan pekerja, publik, atau lingkungan, baik pada kondisi operasi normal, kejadian operasional terantisipasi, bahkan kondisi kecelakaan pada instalasi nuklir

Tujuan konsep defence-in-depth adalah:

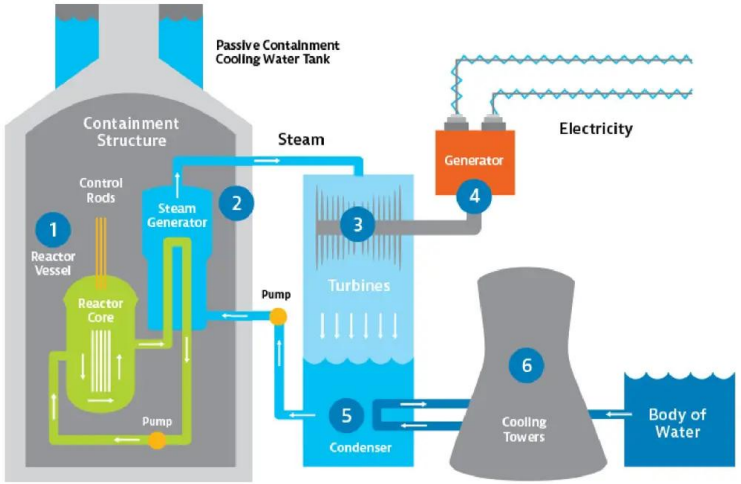
- mengantisipasi potensi kegagalan manusia dan komponen.
- menjaga keefektifan penghalang ganda dengan mencegah kerusakan terhadap instalasi dan terhadap penghalang itu sendiri.
- melindungi publik dan lingkungan pada kondisi dimana penghalang berlapis tidak efektif secara penuh.

The levels of Defense in Depth

Levels of defence in depth	Objectives	Essential means
Level 1	Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation
Level 2	Control of abnormal operation and detection of failures	Control, limiting and protection systems and other surveillance features
Level 3	Control of accidents within the design basis	Engineered safety features and accident procedures
Level 4	Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Complementary measures and accident management
Level 5	Mitigation of radiological consequences of significant releases of radioactive materials	Off-site emergency response

Level 1: Prevention of Abnormal Operation and Failures

- Mencegah Terjadinya Gangguan atau Kegagalan
- Memastikan Kualitas Desain dan Konstruksi
- Operasi yang Aman dan Terkendali
- Pemeliharaan dan Inspeksi Rutin
- Mengurangi Kemungkinan Kesalahan Manusia



- Desain Reaktor yang Aman
- Quality Assurance (QA)
- Prosedur Operasi Standar (SOP)
- Pelatihan Operator

Level 2: Control of Abnormal Operation and Detection of Failures

Mengendalikan operasi yang abnormal dan mendeteksi kegagalan

berfokus pada pengawasan, deteksi, dan respons cepat

- Reactor Protection System (RPS)
- Sistem Alarm dan Instrumentasi
- Prosedur Operasi Standar (SOP)
- in-service inspection and periodic testing of systems and plant components

Technical Safety Features

- Redundancy
- Diversity
- Physical separation
- Fail Safe Principle

- To ensure high reliability

Redundancy

a function performed by more than one subsystem or equipment;
jika satu komponen atau sistem gagal, komponen atau sistem lainnya dapat mengambil alih

a reactor protection system consists of 4 channels, it is necessary to have at least two operating channels so that the protection system can successfully shut down the reactor.

Diversity

a function performed by more than one subsystem with different designs;

- control of the reactor via control rods and boric acid injection;
- Menggunakan metode yang berbeda untuk sistem pendingin darurat – ECCS (active/passive).
- Sumber Daya Listrik: Grid Utama / Diesel / Baterai

Physical separation;

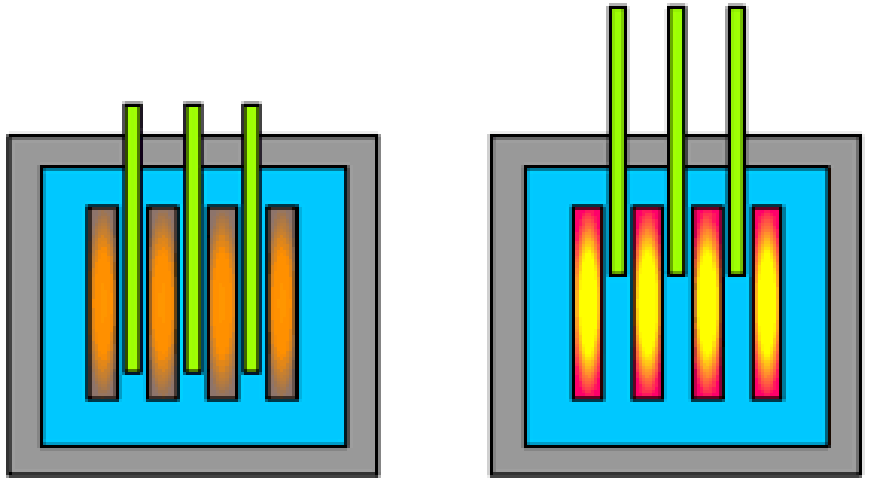
components or systems designed to perform the same function are physically separated to protect against concurrent failure due to floods, fires etc.

Generator diesel darurat ditempatkan di lokasi yang berbeda

Fail-Safe Principle

components or systems are designed to bring to a safe condition (safe) when experiencing failure or loss of electrical power,

the control rod will suddenly fall in free when it loses power.



Level 3: Control of Accidents Within the Design Basis

- Memastikan bahwa kecelakaan dapat dikendalikan dengan sistem keselamatan yang ada
- Mencegah kecelakaan kecil berkembang menjadi situasi yang lebih serius
- Melindungi Integritas Sistem dan Komponen
- Mempertahankan Integritas Containment

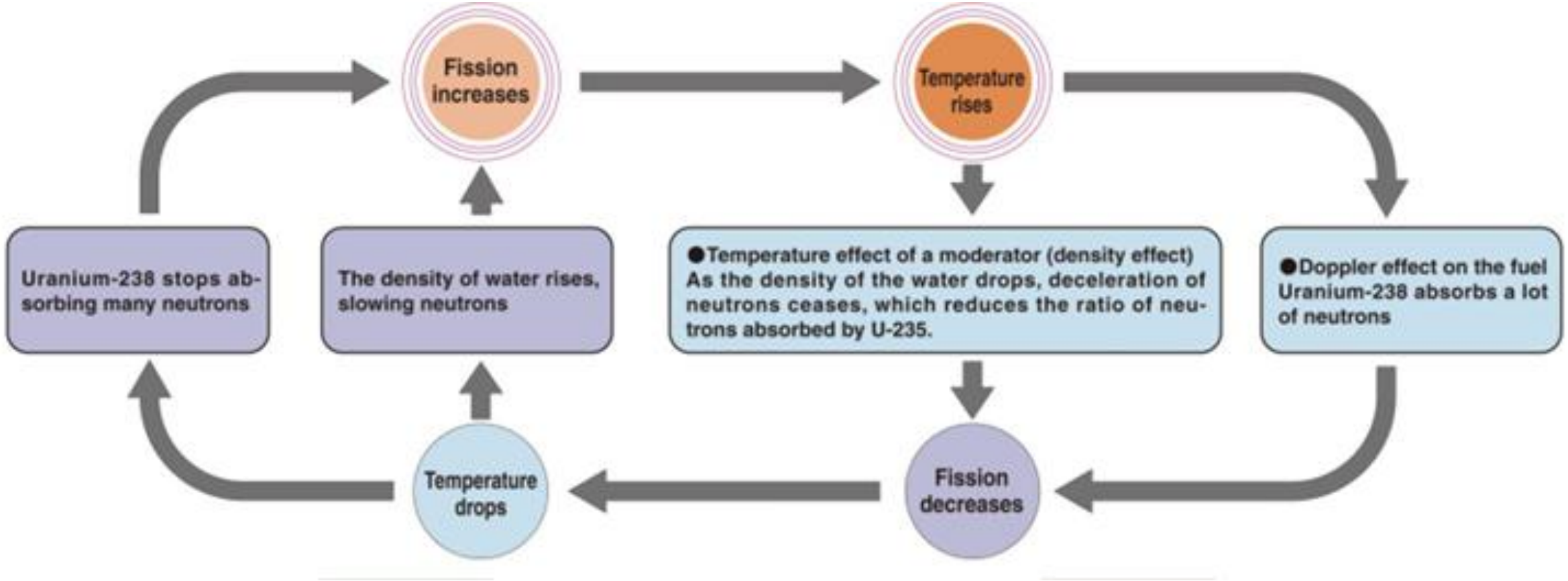
- Emergency Core Cooling System (ECCS)
- Reactor Protection System (RPS)
- Containment Structure
- Containment Spray System

Basic Safety Features

Basic Safety Features in Nuclear Reactors:

- ❑Inherent Characteristics
- ❑Active Safety System
- ❑Passive Safety System

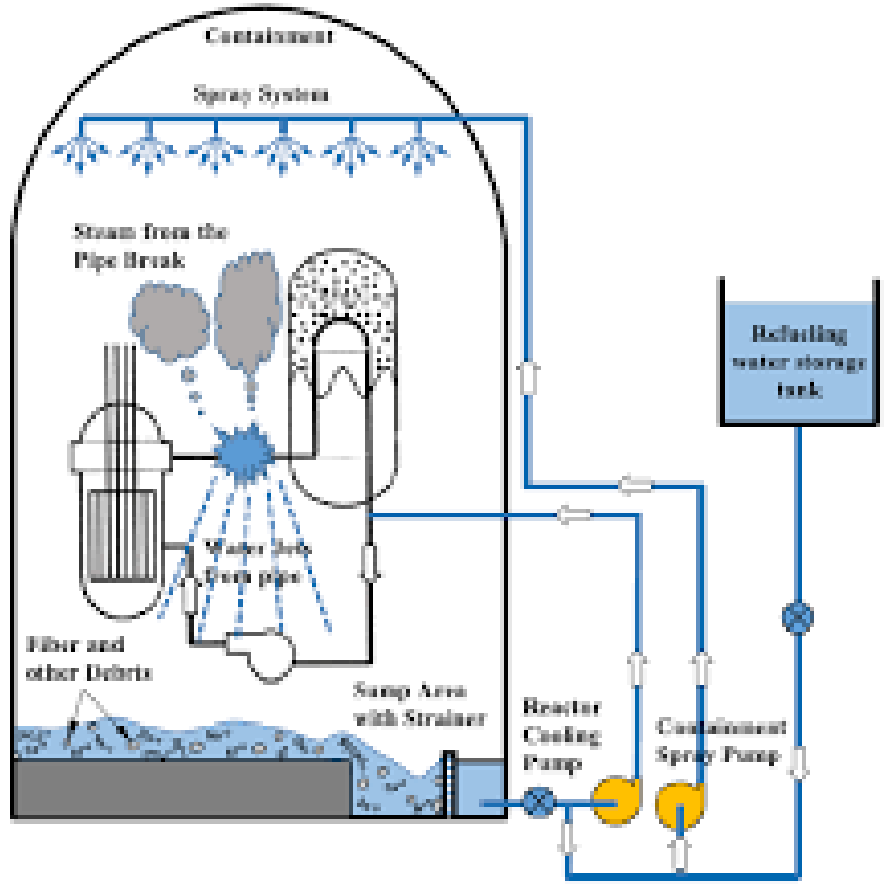
Inherent safety



Level 4: Control of Severe Plant Conditions

- BDBA
- Mengendalikan Kecelakaan Parah
- Mencegah Pelepasan Material Radioaktif ke lingkungan

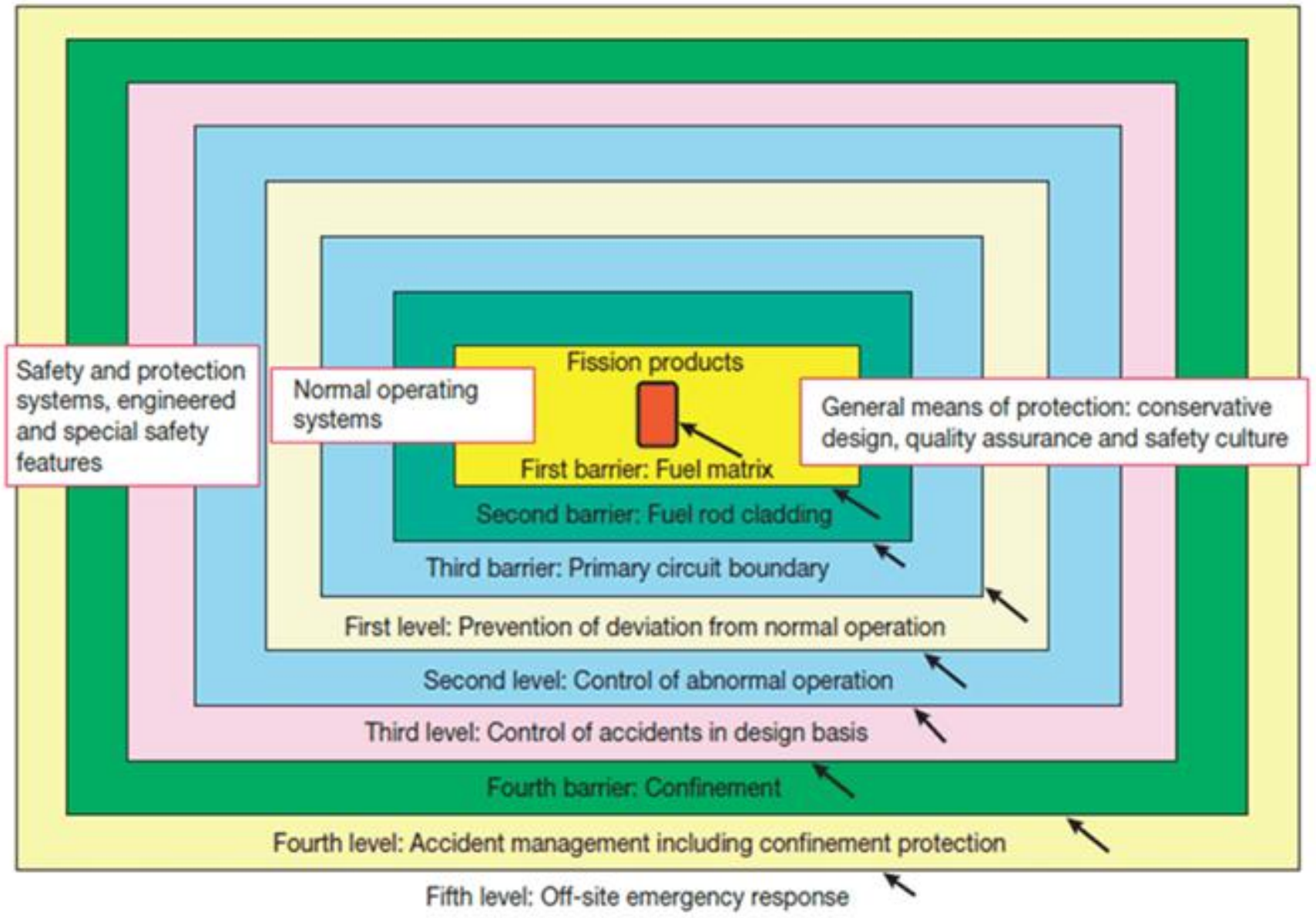
  - Core Catcher
  - Filtered Containment Venting
  - Hydrogen Mitigation Systems
  - Containment spray system



Level 5: Mitigation of Radiological Consequences

- Perlindungan masyarakat dan lingkungan
- Mengurangi Dampak Radiologis
- Menyediakan Respons Darurat yang Efektif
- Memberikan Informasi dan Komunikasi yang Jelas
- Pemulihan Jangka Panjang

- Rencana Tanggap Darurat
- Sistem Peringatan Dini
- Pemantauan Lingkungan
- Decontaminasi
- Pelatihan dan Simulasi


Safety and protection systems, engineered and special safety features
Normal operating systems
Fission products
First barrier: Fuel matrix
General means of protection: conservative design, quality assurance and safety culture
Second barrier: Fuel rod cladding
Third barrier: Primary circuit boundary
First level: Prevention of deviation from normal operation
Second level: Control of abnormal operation
Third level: Control of accidents in design basis
Fourth barrier: Confinement
Fourth level: Accident management including confinement protection
Fifth level: Off-site emergency response

Question?

Kesimpulan

Multiple Barriers dan Defence in Depth menciptakan sistem proteksi yang kuat, berlapis, komprehensif dan andal untuk memastikan bahwa reaktor nuklir dapat beroperasi dengan aman dan mengurangi risiko kecelakaan serta dampaknya terhadap manusia dan lingkungan.

Dengan menerapkan konsep ini, industri nuklir dapat memastikan keselamatan yang optimal dan keberlanjutan operasional.

Referensi:

- IAEA's INSAG-10 - Defence in Depth in Nuclear Safety
- IAEA's "Safety of Nuclear Power Plants: Design", Safety Standard, Specific Safety Requirements, SSR-2/1
- IAEA, "Basic Safety Principles for Nuclear Power Plants", 75-INSAG-3 Rev. 1, INSAG-12