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WHITE PAPER

Aspects of Radiation Safety for Nuclear Power Plant Decommissioning

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Overview

A decommissioning project is a process involving both the administrative and technical steps aimed to clean up a nuclear facility in a safe, secure and environmentally friendly manner. The permanent closure of a nuclear power plant involves therefore its safe removal from service and the dismantlement of the facility to the point that it no longer requires measures for radiation protection; i.e the radioactivity level is residual. A growing number of nuclear power plants are reaching the end of their lifetime[1], therefore their decommission is an increasingly important topic for governments, regulators and industries. Among the main parameters to be considered in nuclear power plants decommissioning are the Cost, timescale, Radiation protection and related services.

General cost aspects

For the industry, assessing the decommissioning cost is an important step to develop a cost-effective strategy which is coherent with national policy and assures personnel, public and environment safety. Recent studies estimate decommissioning cost to be about $500 /kWe for nearly all water reactors but significantly higher for gas-cooled reactors (around $2,500 /kWe) with the labor costs generally representing a significant share of total decommissioning costs ranging from 20 to 40%[2] or even 50%[3]).

The two cost elements representing a major share of total costs are dismantling and waste treatment and disposal, accounting for around 30% each. Three other cost elements represent around 10% each of the total: security, survey and maintenance; site cleanup and landscaping; and project management, engineering and site support. Other cost items generally do not exceed 5% of the total decommissioning cost[2].

An important aspect among the main parameters to be considered in nuclear power plants decommissioning is radiation safety and related services.

During nuclear power plants decommissioning, the sources of radioactivity depend on the NPP type and material types used. Sources of radiation are commonly:

- The nuclear fuel rods material and equipment which are generally equivalent to 99% of the plant radioactivity.
- Surface contamination of the plant; and
- Activated products in steel (pressure vessel) following long neutron irradiation.

The produced dominant isotopes from long term exposure in the latter case are highly radioactive materials such as

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Co-60 (half-life of 5.3 years), Fe-55 (half-life of 2.7 years), Ni-59 (half-life 76k years), Ni-63 (half-life of 100 years), Mo-93 (half-life of 4k years) and Eu-152 (half-life of 13.5 years). Some of the above isotopes are considered leading nuclides as they provide a measurable gamma signal. Co-60 offers highly penetrating Gamma energies of 1.17 and 1.33 MeV. In addition to the isotopes related to stainless steel, Ba-133 (half-life of 10.5 years) can be found in concrete.

The selection of appropriate radiation monitoring instruments measuring to protect workers, the environment and to monitor decommissioning processes is highly important. The sensitivity, response time, connectivity, etc. of these instruments are among the critical parameters to be considered during the selection.

The time scale and scope of the current decommissioning work varies from country to country and even between different decommissioning projects, it was common to take 30 to 40 years from the reactor shutdown date to complete all the decommissioning work. For some countries, a mandatory time scale of 10-15 years is set, including a complete restructuring of the location back to a green field. While for others the recommendation from the Nuclear Safety sub-committee is to finish the decommissioning activities 30 years after commencement. It is worth to mention that a few countries still consider a time scale up to 100 years after shutdown. Nevertheless, it appears that the number of actively performed decommissioning projects with short time scales increases globally.

Reducing the radioactivity to a residual level in a plant during decommissioning is highly critical and radiation monitoring instruments are key indispensable instruments used during this decommissioning process. They measure reliably the radiation dose, activities and isotope compositions from materials and equipment to ensure the protection of workers, the public and the environment. The instruments are therefore designed to provide reliability and fast analysis for gamma-rays and charged particles (alpha, beta). To support the waste processing stream with a timely manner, highly sensitive detectors in excellent measurement geometry offer the low detectable activity requirements for free release or waste categorization steps.

Thermo Fisher Scientific whose mission is to enable its customers to make the world healthier, cleaner and safer is committed to offer products and services required for the nuclear facilities decommissions. Thermo Fisher's offering includes innovative radiation monitoring instruments and comprehensive services (installation, training, documentation, etc.) which met requirements of radioactive waste handling, transportation, storage, and disposal to protect human health and the environment.

Mission requirements of the NPP decommissioning project

The decommissioning of nuclear power plants follows both technical and administrative steps which depend on the country's regulatory bodies. The timelines associated to each step of the decommissioning operations depends also on the country regulations. The objective at the end of the process is to release the site for other purposes without restrictions. Among the decommissioning operations are for example three options that can be used in the decommissioning process and the plant operator can generally use at least one of these options to decommission their facilities:

- **DECON** (Decontamination) is an option which consists of dismantling or removing all radioactive components above acceptable limits. This step reduces the radiation level in the plant and minimizes the potential exposure to workers during subsequent decommissioning operations.

- **SAFSTOR** (Safe Storage) is the second option and it consists of leaving the reactor intact but in a safe state. Highly radioactive components such as the fuels are removed and placed in on-site storage while the surveillance and monitoring continue. This low initial cost process allows time for decay of radioactivity and the plant is dismantled following steps like the DECON ones.

- **ENTOM** (Entombment) is a rarely used option and it necessitates to permanently enclose on site the facility into a condition that will allow the remaining radioactive material to be on-site without ever removing it.

One can make a subdivision of decommissioning activities into tasks that may have to be executed for either immediate decommissioning or safe enclosure:

1- Pre-decommissioning actions;
2- Facility shutdown activities;
3- Procurement of general equipment and material;
4- Dismantling activities;
5- Waste processing, storage and disposal;
6- Site security, surveillance and maintenance;
7- Site restoration, cleanup and landscaping;
8- Project management, engineering and site support;
9- Research and development;
10- Fuel and nuclear material;
11- Other.

It is important to note that not all tasks necessarily need to be performed for all decommissioning projects. The radiation monitoring instruments are included mostly in the:

Task #3 where are needed the general radiological protection and health physics equipment. For these systems, a change in every 10-15 years depending on the instruments type is generally advised due to wear and outdating.

Task #6 where a periodic radiation and environmental survey is needed but the frequency and scope of inspections are currently in most countries not regulated.

Task #9 It is fair to skip the R&D activity since all technologies and equipment that are necessary to decommissioning an NPP are currently available[1], and could be purchased on the market.

The radiological properties of the waste (e.g. activity and composition of radionuclides, dose rates from the waste) are measured using radiation monitoring instruments. These radiation monitoring instruments include personnel and environmental protection dosimeters as well as general-purpose instruments. Their use is highly critical since the decommissioning of facilities is conducted in a safe and environmentally acceptable manner in accordance with regulatory practices.

[1]The need for R&D activiy may depend on changes local and/or international specifications and requirements as well as changes in the isotope composition of materials over time.

Technologies requirements

Protection of workers

The radiation monitoring instruments are a set single or networked device used to monitor radiation exposure to the human body, contamination (e.g. skin, of clothes or surface of the nuclear power plant facility) as well as activities in air, liquid. The following sections below describe the main systems used during the decommissioning phase:

Whole Body Contamination Monitors are commonly designed to measure surface contamination by charged particles (alpha and beta) on personnel feet, hands and body. The available instrument versions offer measurements of alpha, beta, alpha-beta, alpha-beta-gamma.

The detection technologies use generally gas-filled systems or scintillator/PMT sensors followed by a fast shaping time front-end electronics. The HFC back-end electronics generally possesses a user-friendly graphic interface displaying measurements or faults (wrong positioning of foot and hand). Finally, the instrument should provide networking capabilities such as Ethernet connection.

During decommissioning activities, workers leaving controlled areas must exit through whole body monitors checking for the contamination of personal. Similar to what is done in an operational nuclear power plant. They generally monitor the presence of alpha and beta, or only beta emitting isotopes depending on the monitor type and the detector technology being used. The whole-body monitor uses generally gas-filled systems or scintillator/PMT sensors followed by a fast

shaping time front-end electronics. Optionally whole-body monitors can be equipped with highly sensitive large area gamma detectors that are positioned behind the surface contamination detectors. Their purpose is a quick scan for ingested activity. The principle of operation is based on the background radiation level measurement until a person enters with the correct position, afterwards, it measures successively the front and back body and reports measurement results. If they exceed the settings signaling the level of contamination, a visual and acoustic signal is activated. Common additions are integrated special chambers for small articles as well as adjustable detectors for the top of the persons head.

Individual personal dose monitoring and dose reporting are subject to local regulations and requirements. A combination of passive dosimetry, that is commonly the legally required dose surveillance method, and active dosimetry is often applied. While a passive dosimetry system ensures legal compliance through regular written reports, worn active electronic dosimeters alarm immediately, when a person enters a high dose rate field. In addition, sophisticated electronic dose meters can be managed by data base applications offering quick personalization via ID card data, dose and dose rate threshold setting regarding defined work description for that individual and a function as key to access restricted areas like controlled areas. The networking of active dosimeters can be achieved through reading stations or wirelessly.

Monitoring of the environment

The level of radioactive particles in the air must be monitored for decommissioning works as used material treatment methods for decontamination are often causing dust generation like cutting and grinding. The contamination in air measurement is often separated into a workplace aspect and an environmental aspect for the final air release via a stack. For both, two methods are established: Recurrent sampling and online monitoring. The recurrent sampling process uses a filter that removes particles from a defined volume of air, typically by sucking that volume of air through a filter paper. After this filter loading process over a longer period, the activity is measured with the help of a laboratory radiation analyzer (e.g. alpha/beta, high resolution gamma). Often this method used as the legally required method for official air contamination reporting. In addition, online monitors are operated insuring immediate alarming in case increased air concentrations are measured requiring immediate counter measures. Taking a sample or a representative air sample stream from a large air ductwork like the exhaust air stream of a larger facility requires a high level of expertise as the sample taking must be done in an isokinetic manner. In addition to radioactive particles and depending on further regulation, the sampling and measurement of radioactive Iodine, Tritium and the isotope Carbon-14 can be required.

Wastewater for release is typically pre-collected in tanks and a water sample is taken and analyzed with a laboratory system (e.g. high-resolution gamma spectrometer allowing Marinelli geometry measurements) before the release process starts. In addition, an online monitor (e.g. detector integrated into the pipe works) can be installed acting as secondary measurement, ready to close the release valve in case increased radiation levels are identified originating from diluted activities as well as hot particles causing short peaks of increased radiation signal. A trustful measurement of the water volume released via according flowmeters is mandatory for a later reporting of the released water volume and activity concentrations.

General purpose radiation monitoring

Handheld monitors like dose rate meters or surface meters are required for the daily work of quick contamination scanning and dose rate monitoring. In addition, sample monitors for wipe test analysis in enough quantity shall be considered supporting the daily routines and challenges for the duty of radiation protection.

Process monitors

The actual methods and processes for the decontamination of materials from the dismantling of a nuclear power plant may depend to site requirements. Nevertheless, decontaminated materials require a free release process including low level radiation measurements else measurements for the categorization and documentation of waste for later storage. The free release process for materials into the normal recycling cycle requires a highly sensitive and well shielded measurement chamber to the local size requirements of pre-cut parts. Larger objects are alternatively investigated with a high resolution in-situ gamma measurement and analyzing mobile monitor. Waste categorization can be performed also high-resolution gamma measurement systems (e.g. HPGe Drum Monitor) for high level analysis and documentation. Waste from a well-known, documented origin may be handled and categorized with an alternative highly sensitive chamber system (chamber based on large area plastic scintillation detectors).

Gate monitoring

Gamma radiation monitors are placed at the entry/exit gate of a decommissioning facility preventing orphan sources of radiation are not brought to the facility and on the other hand no radiation is carried out the facility without being recognized. To perform the detection of Gamma rays at moving objects (e.g. trucks) passing a detector, highly sensitive, large area detectors are required to perform this task (i.e. high-volume plastic scintillators). Fast, sophisticated electronics offering background learning[2] and - in case of a vehicle monitor - a shielding compensation method[3] are required to keep the monitors sensitivity to highest levels under all conditions.

[2]Gate monitors are placed at the fence of a facility outdoors and are therefore subject to changing background conditions (e.a. caused by weather changes like beginning rain).

[3]Trucks driving through a gate monitor shield the natural radiation from the ground below from the detector array. As a consequence, the learned background is not the actual during the truck scan. The learned background must be adopted by an algorithm to the actual background with truck in the gate.

Thermo Fisher products and services in decommissioning projects

Decommissioning projects challenge executing teams with multiple aspects like legal, technical and organizational tasks. Further to that, such aspects are also strongly influenced by local desires, requirements and capabilities Therefore Thermo Fisher offers to team with the project executors for the topic of radiation protection, helping them with tailored packages of locally required project execution as well as hardware, software and service support in regards to related measurement instruments and solutions. Thermo Fisher creates and leads a team of globally experienced and locally knowledgeable decommissioning experts in accordance to the locally given requirements and present capabilities. Further to professional soft skills, Thermo Fisher offers also own produced hard- and software solutions as well as the integration of 3rd party devices into the package, that is based on local preferences and specifications. For example, project executors can make use of a dedicated team of application specialists designing a radiation measurement solution for the protection of workers through contamination control and dose management including job specific dose allowances and access restrictions. Thermo Fisher can support the project with expertise regarding the protection of the environment when it comes to the permanent analysis of the interfaces to the surrounding environment like releases of water, air and radiation.

Utilize Thermo Fisher's application as well as technical expertise to place adequate equipment into the waste handling process, achieving quick and trustworthy radiation level or contamination information for next step decisions.

Relieve their project by getting professionals from Thermo Fisher and its partners involved in crucial service activities like documentation, installation or training of required radiation measurement equipment.

Leveraging the practical experience from the professional partner, Thermo Fisher (for aspects of radiation protection) helps those teams performing in time and scope.
In addition, Thermo Fisher and its partners offer solutions to the nuclear power plant decommissioning projects.
These solutions include:

- Radiation monitoring instruments for personnel, area and environmental protection.
- On-site installation and setup of the complete radiation monitoring instrumentation.
- Formal classroom and hands-on training as method educational systems for radiation measurement equipment
- Variety of other training options such as online self-paced, pre-recorded training, instructor-led live Seminars.

The following sections describe these varieties of radiations monitoring systems and services offered by Thermo Fisher for nuclear power plant decommissioning projects.

Protection of workers

Decommissioning facilities maintain the highest safety standards to assure the health and safety of workers by the use of reliable radiation protection services based on sensitive, real-time monitoring instruments and easy to use procedures supported by professional data management tools.

Professional handling of personal dose: Recording workers dose with TruDose.

The **Thermo Scientific™ EPD TruDose™** delivers unparalleled real-time reliable dose reading of both gamma and beta radiation with a sensitivity as low as 0.005mrem/h. The added warning thresholds enable users to react before an alarm condition arises. It finally offers an integrate Bluetooth Low Energy (BLE) without an additional module.

Stopping displacement of radioactivity: Whole body monitors.

IPM96 Whole Body Personnel Contamination Monitor

The Thermo Scientific IPM96 Whole Body Contamination Monitor enables efficient and accurate scanning for beta/gamma contamination on the entire surface of the body using 96 independent detection zones. Thorough contamination monitoring of the body and clothing is executed with three vertical arrays of six detectors (18 total), with an active area of 600 cm2. Four detectors exclusively monitor the hands. The foot detector has an active area of 570 cm2. The overhead detector comes with an auto retracting overhead pull-down head detector.

iPCM12 Whole Body Personnel Contamination Monitor

The Thermo Scientific iPCM12 personnel contamination monitor takes personnel contamination monitoring to a new level. The unique sculpted geometry utilized in the Thermo Scientific PCM2 is combined with the serviceability of the Thermo Scientific IPM9 and the breakthrough electronics of the Thermo Scientific Series 12 monitors.

The iPCM12 personnel contamination monitor utilizes 21 detectors in monitoring the body, head, hands, and feet. The detectors are split into four detection zones to minimize the background during monitoring, and achieve the best detection limits. Three optional detectors can be mounted to monitor the side of the foot, the shoulder, and the top of the head. The very best geometry is ensured, with sprung detectors making contact with the arm and the top of the shoe. Excellent coverage, with nearly 17,000 cm2 of detection area.

PM12 Gamma Portal Monitor

The Thermo Scientific PM12 gamma portal monitor breaks new ground in personnel monitoring. It provides a major improvement in sensitivity over similar instruments, thus leading to faster monitoring.

The PM12 gamma portal monitor utilizes eight identical large gamma-sensitive plastic scintillation detectors to monitor personnel passing through the portal. Traffic flow can be either direction. Three detector assemblies are located in each side of the portal, with additional detectors to monitor the head and feet. The PM12 gamma portal monitor offers simplified operation. In its basic form no keypads or complicated displays are necessary. The only user control is an alarm acknowledge switch, which is used to silence the audible alarm after contamination has been detected. The operational status of the portal is clearly indicated by a set of vertical system indicator lights located on both sides of the portal frame.

SAM12 Small Article Monitor

The Thermo Scientific SAM12 small article monitor is used to measure tools and other hand carried objects for gamma contamination before leaving a radiological controlled area. The SAM12 small article monitor readily measures down to clearance levels less than 80 Bq (5,000 DPM), but adds sophisticated new electronics allowing dynamic discrimination between natural and man-made radiations, as well as a unique feature for Co-60 monitoring. Measurement of fixed, smearable, internal and external gamma contamination is done simultaneously. It features excellent uniformity of response across the chamber. It is fast, easy and thorough with no special training or supervision required. It is equally effective for single particles or distributed contamination.

HFM11-SC Hand and Foot Monitor

The Thermo Scientific HFM11-SC hand and foot monitor provides the proven class leading reliability and ease of use associated with gas-flow systems, but with the added benefit of not requiring counting gas.

The HFM11-SC hand and foot monitor uses an established technique for monitoring alpha and beta radiation simultaneously. Sprung detectors clamp both sides of the hand monitor and monitor them simultaneously.

The vertically mounted detectors minimize the risk of detector contamination, and the top-mounted occupancy sensors avoid blockages. Each foot detector utilizes two photomultiplier tubes in order to minimize the variation in efficiency across the area of the foot.

FHT65QC Quick Internal Gamma Counter

A recurrent, quick, but sensitive scan of a worker's chest helps radiation protection officers to detect internal activity so that next step safety measures can be applied in a timely manner. The Thermo Scientific Quick Counter supports this control task with a height adjustable, highly sensitive detector array and a user-friendly interface. Using a network connected to the Thermo Scientific Dose Management System, the worker's scan data can be added to his personal file for storage and quality control.

Monitoring the environment

The public, environmental agencies and related bodies need to be insured that radioactive contamination of the air and water as well as the irradiation of the environment is well recorded, traceable and below the given acceptable limits. In case of an accidental release, Thermo Fisher environmental systems respond fast and accurate providing the needed, reliable data for counter measures. Customized systems for monitoring water, air, and ambient dose rates are offered. Additionally, software for real-time monitoring of these systems is also available.

Radiation awareness during waste treatment operation

Checking surfaces for adhesive activity

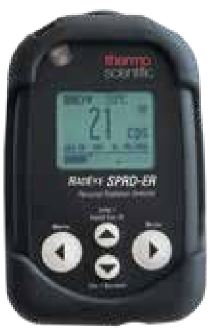
RadEye-X

The Thermo Scientific ™ RadEye™ X Series Survey Meters comprise three different types of compact, multi-purpose survey meters suited for a wide range of applications including waste characterization, clearance surveys or personnel exposure to radiation RadEye X Series Survey Meters can operate with virtually any manufacturer's Geiger-Mueller, scintillation or proportional detectors to perform general count rate, surface contamination and dose rate measurements.

RadEye G/G10

The Thermo Scientific RadEye G/G10 survey meter is a light-weight and very rugged instrument designed for quick and reliable measurement of gamma dose rates. Modern electronic circuitry guarantees excellent linearity over 6 decades of radiation intensity: from background level to 1 Sv/h (10 R/h) - with over-range indication up to 1000 R/h. The RadEye G-10 version incorporates a different energy filter in order to achieve a Sievert response curve according to ambient equivalent dose rate H*(10).

The high-quality counter tube in conjunction with the non-metal instrument housing allows detection and reliable measurements down to very low gamma energies such as Am-241. The intelligent rate meter algorithm (ADF mode) guarantees that even the smallest change in radiation rates will be displayed immediately, while coincidentally occurring fluctuations will be effectively suppressed.



RadEye SPRD-ER

The Thermo Scientific RadEye SPRD-ER spectroscopic personal radiation detector is a high-performance radiation detection and radionuclide analyzer designed to detect, locate and identify radioactive gamma nuclides such as those found at nuclear sites. Fast, accurate and reliable dose rate measurements due to highly sensitive detector extended by a high dose rate detector in the ER Version. Scan surfaces faster due to high sensitivity

The RadEye SPRD-ER spectroscopic personal radiation detector provides nuclear workers with high performance detection and gamma radionuclide analysis for any scenario. The ability to perform spectroscopic extended range nuclide identification in a pager sized Personal Radiation Detector (SPRD-ER) offers advantages over current market options; including, compact size, low weight, long battery life time and low cost. This combination makes the RadEye SPRD-ER spectroscopic personal radiation detector a perfect tool for users detecting, locating and identifying sources of radiation.

RadEye HEC+

The Thermo Scientific RadEye HEC+ sample counter is a light weight portable sample counter for swipes and air filters up to 60 mm diameter. It incorporates a 2-inch windowless, low noise dual phosphor scintillator detector that that is sensitive for beta emitters from 10 keV, low energy X-ray emitters from app 3 keV and alpha emitters.

Depending on the expected nuclides of interest, dual channel measurements can be performed in 2 different operating modes. In addition to the mandatory measurement of medium and high energy beta radioactivity the other measuring channel covers:

• Alpha radioactivity
  or
• Low energy beta emitters (in particular C-14, Ni-63 and H-3) and electron capture nuclides (Fe-55, Mn-54, Cr-51).

The RadEye HEC+ sample counter enclosure is made of durable plastic that can withstand rough handling. Its built-in handle, in combination with the battery option, allows up to 800 hours of field use between charges.

FHT770 Family of Sample Changers

Thermo Fisher offers a variety of automatic and manual sample changers with the Thermo Scientific FHT770 family of sample changers. These products can be used for analysis of aerosol samples, swipe samples and verification of real time aerosol monitor measurements.

The FHT770G series of sample changers is available in configurations for measurement of filters up to 60mm and 200mm. Planchets carrying the filters are moved into the measuring position by an electric-motor-driven transport system.

Applying the ABPD (alpha beta pseudo coincidence discrimination) detection principle, the activity sampled on the filters is discriminated as alpha and beta activity of natural and artificial origin. Depending on their sampling process, the measured values can be obtained in units of Bq, Bq/m^3 or Bq/cm^2.

The FHT 770 K-L manual α/β sample changer is typically used for performing smear test in conjunction with the release of working tools, measuring devices or other parts, which have to be released from control areas. In addition the sample changer can be used to evaluate filter samples from an aerosol sampler. Two different sizes are suitable for the sample drawer: Ø 60 mm, 8 mm height and Ø 104 mm, 3 mm height. A sensor will discriminate between the two different diameters. The FHT 770 K-L sample counter utilizes is a single board computer with a touchscreen-display. The FHT 770 software offers a user-friendly interface with a simple menu structure and allows the configuration and parameter settings of the main functions and measuring tasks.

Assessing repackaged active waste in Drums and Boxes

FHT 3040 CCM monitor

The Thermo Scientific FHT 3040 CCM grid box monitor is designed for the clearance measurement of grid boxes filled with machine components, demolition materials etc.. The monitor is based on the CCM method which is Co-60 nuclide specific, spatially focusing and even has no cross-sensitivity against interference from ambient dose rate.

The grid boxes to be measured can simply be put onto the carriage by a forklift truck. The carriage itself is seated on bearings so that the grid boxes can easily be moved into and out of the cavity. Costly door mechanics and floor reinforcement usually necessary to cope with the heavy loads of the lead shielding can simply be omitted.

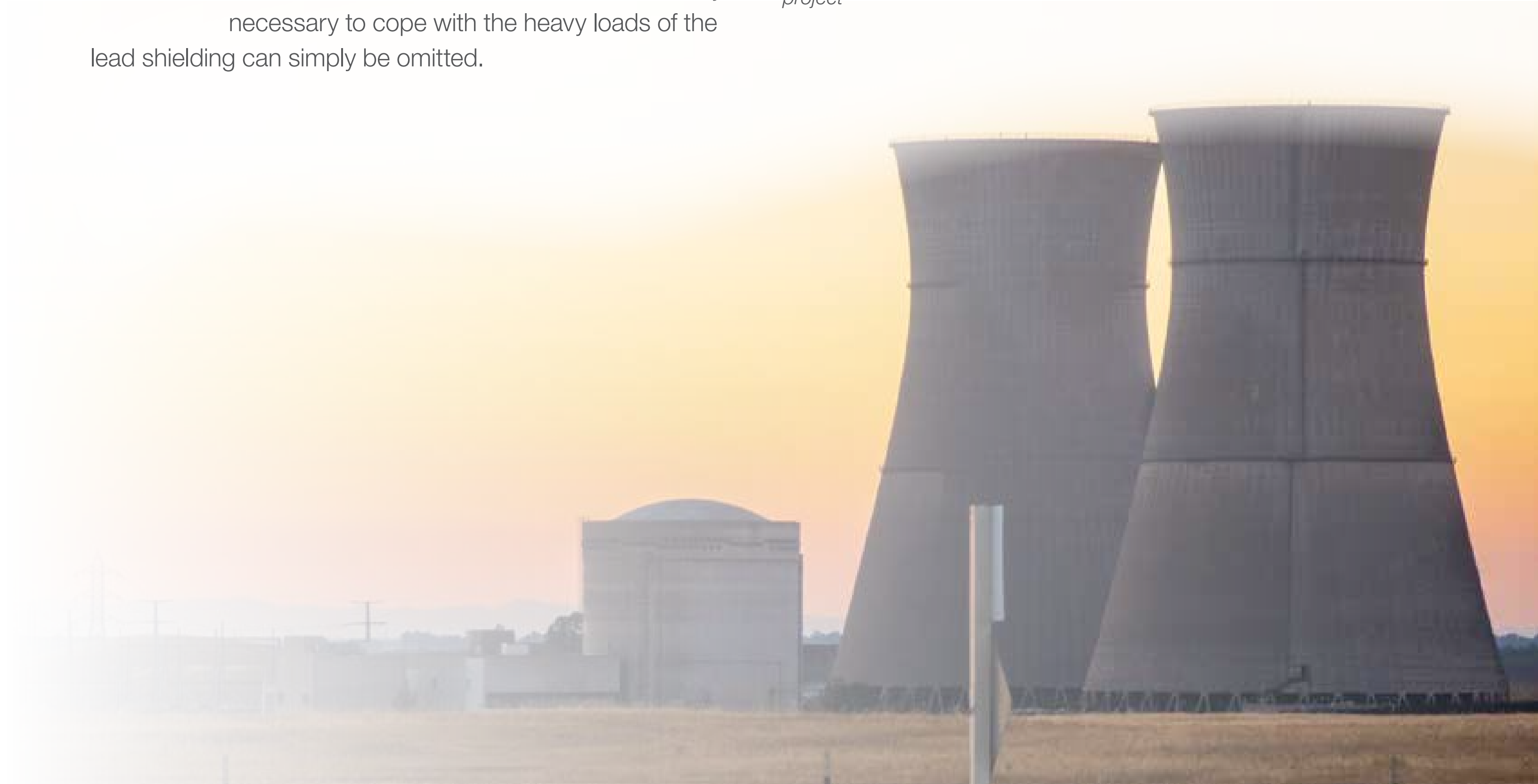
Conclusions

This report describes an overview of the nuclear power plants decommission projects and the solutions offered by Thermo Fisher Scientific[4] to meet their requirements. It summarizes and provides a basis for understanding decommissioning process and the various decommissioning strategies which affect greatly their timescales, scopes and costs. The large difference in these three factors is mainly due to country and site-specific conditions which are major aspects of national policy and industrial strategy that affect the decommissioning.

Globally, there are 454 operable nuclear reactors. As of 2016, almost 80 operating reactors around the world have been running for 40 years or even longer. New reactors will therefore be required. The instrument upgrade opportunity is estimated to be eight 15-year old reactors per year. The cumulative shutdown profile for these reactors predicts a steady increase in the number of reactors being shut down between now and about 2030 when most will be shutdown. Continued international co-operation, together with exchange of experience and lessons learned, is helping to ensure that the current generation of nuclear power plants world-wide is decommissioned safely and cost-effectively.

Because of its expertise in analytical instrumentation for dose rate measurement and its excellent service to customers, Thermo Fisher Scientific products and services for the nuclear power plants decommissioning are presented. They exhibit some unique features is committed to serve the nuclear power plants decommissioning projects.

[4] Thermo Fisher and it's partners depending on location and scope of the project



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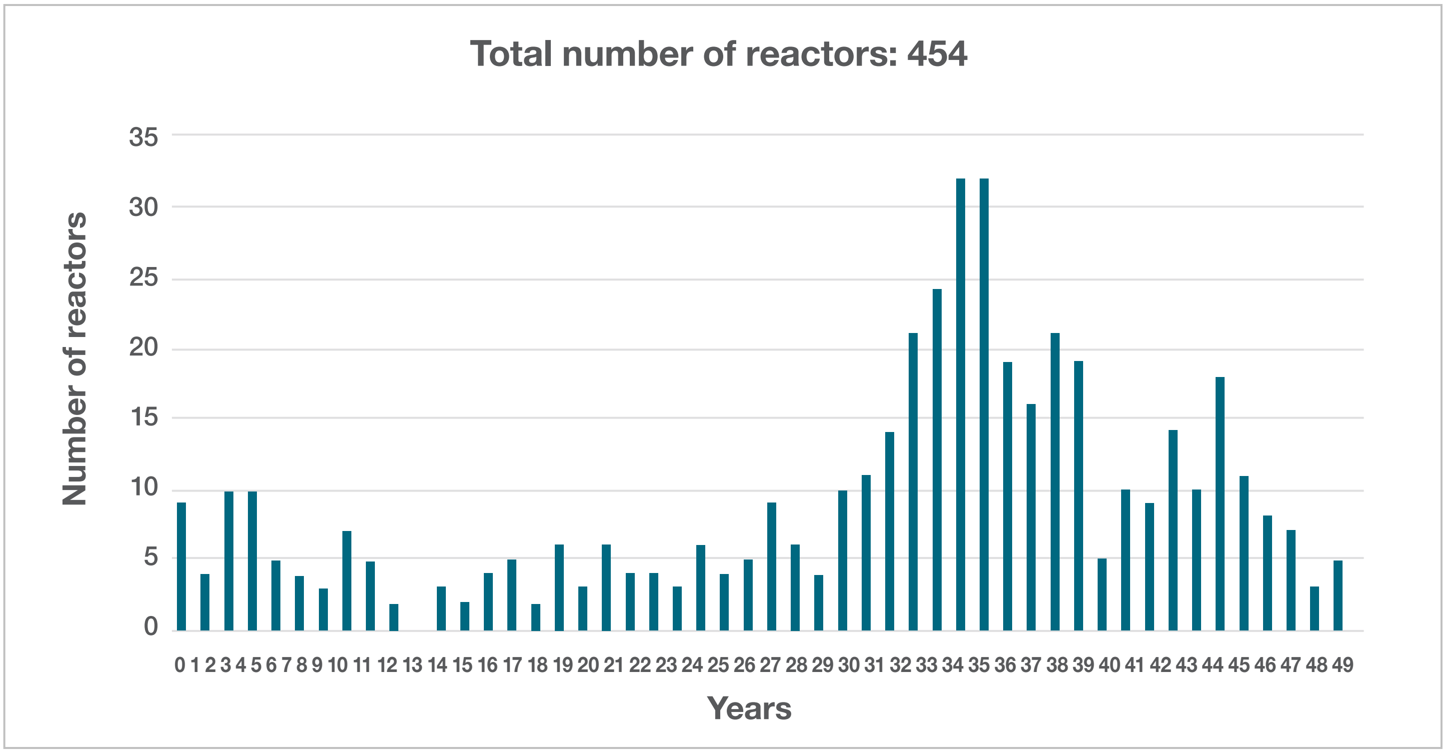

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