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Interim Report on Fire Risk Management

April 2013-July 2015

Integrated Group for the Safety Case (IGSC)
Expert Group on Operational Safety (EGOS)

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Radioactive Waste Management Committee

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English - Or. English

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NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Foreword

Geological disposal of high-level waste or spent nuclear fuel is a strategic area in the work program of the OECD Nuclear Energy Agency Radioactive Waste Management Committee (NEA RWMC). In 2012, the Integration Group for the Safety Case (IGSC), under the mandate of the RWMC, created an Expert Group on Operational Safety (EGOS). The key objective of the EGOS is to identify, evaluate and help define international best practice in safely operating geological repository for radioactive waste.

The EGOS recognises fire as one of the major hazards among various operational risk of both nuclear facilities and underground mines. A key focus of the work programme has thus been dedicated to further explore fire safety and fire protection in geological repositories. In 2013, a fire risk sub-group, consisting of implementers from 8 countries, held two meetings to discuss design options, best available technologies, and good practices for fire safety.

Operational experience from existing mines and nuclear facilities has illustrated the potential occurrence of fire accidents in geological facilities. Various fire hazard management strategies and repository design options for preventing and minimising human and environmental damages are evaluated in this interim report. Design basis accidents as well as fire assessment approaches are also discussed. Future work of the EGOS includes the following:

1. Develop an EGOS operational hazard database for safety evaluation and identifying root causes of fire accidents and preventing reoccurrence of similar incidents;

2. Develop technical data on collateral damage caused by fires and operation of fire-fighting measures, e.g. effects of fire-fighting agents, aerosols used in fire brigade actions, damages on waste packages such as corrosion damages caused by sprayed chemicals and smoke, etc.;

3. Improve understanding on scientific issues such as the thermal effects of large fires, heat release rate, smoke production and spread. This will help improve the designs of fire-protection measures (e.g. the provision of refuge stations, escape-ways, etc.).

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1. Introduction

With the limited number of existing geological disposal facilities for radioactive waste, safe operations of disposal repositories is anticipated to be similar to the operations of nuclear facilities. The main aim is to prevent the release of radioactive substances into the environment and to minimise potential human exposure to radiation. During the repository development process, developers and regulators apply experience gained in nuclear power plants, radioactive waste management facilities and underground mines, in addition to the fundamental radiation safety principles of ALARA and defence-in-depth (INSAG10)

Fire is known to be a major hazard contributing to operational risk of both nuclear facilities and underground mines. Under the auspices of the IGSC, the Expert Group on Operational Safety (EGOS) was formed in 2013 with one of its key focuses is to further explore fire safety and fire protection in geological repositories. A fire risk sub-group, consisting of implementers from 8 countries[1], held two meetings since then to discuss design options, best available technologies, and good practices for fire safety. Following the 1st meeting (April 30, 2013), participants provided a brief description of their current disposal programme status in relation to their planned fire management strategies. Collected inputs are provided in Appendix A. This interim report summarises key information exchanges and major findings of the conducted discussions, results of a preliminary analysis undertaken by the Secretariat. Minutes of the meetings are presented in Appendices B and C as supplementary information.

The structure of this report is as follows:

- Chapter 2 provides an overview of the current disposal concept as well as the fire risk management approaches of member countries. Major outcomes of the 1st fire risk meeting are captured in this chapter.
- Chapters 3 and 4 continue the reporting of remarks and observations gathered in the 2nd meeting, with Chapter 3 focuses on the design of ventilation systems and Chapter 4 reveals the formulation of fire scenarios.
- Based on a preliminary analysis of the collected information, Chapter 5 proposes potential future work areas, on a rather broad perspective, in an attempt to induce more in-depth evaluations and investigations.

2. Current disposal concept and fire risk management strategies

Participants attended the 1st EGOS fire risk meeting held in 2013 were requested to provide an overview of their radioactive disposal concept as well as their planned fire risk management strategies. Table 1 summaries the current disposal concept of several radioactive waste management programmes. Meeting minutes of the 1st meeting are provided in Appendix B for additional details.

1. Fire risk sub-group member countries: Belgium, Canada, Finland, France, Germany, Sweden, Switzerland, and the UK

Organisations	**Facilities**	**Disposal method/concept and fire risk management**
Ondraf/Niras, Belgium	Geological repository for long-lived and/or high-level waste	Fire risk management: fire safety to be achieved via: • A layout that guarantees safe evacuation at all times: provision of 2 evacuation routes (advantage of parallel access galleries will be evaluated); maximum length of blind galleries without the need of a refuge chamber will be considered • An adequate ventilation system possibly including HEPA filters; • Minimisation of flammable materials/heat sources in underground facilities – use battery driven locomotive, minimise electrical equipment and provide electric insulation.
NWMO, Canada (as TSO for OPG L&ILW DGR)	Deep geological repository for L&ILW disposal	Fire risk management: • Preliminary fire protection system design, in conformance with applicable legal codes; • Preventative/mitigation measures include: – minimise amount of flammable material in underground facility, – provisions of refuge stations and fire detectors in key locations; – implement emergency procedures and rescue plans • Fire suppression plans: automatic and manual fire suppression systems (foam, dry chemical for underground facility, water for above-ground facilities), ventilation flow changes and fire door closures; • An on-going fire hazard assessment to refine the design.
Posiva, Finland	Geological repository for spent Fuel	Fire risk management: • Provisions of fire compartments, fire suppression systems, automatic fire detection; • Minimise fire load in tunnel, use of fire walls/doors to separate fire compartments, use of fire dampers. • Automatic fire extinguisher in vehicle engine room; • Foam fire plug every 100 meter in tunnel; • Training on operating fire extinguisher; • Vehicle maintenance/inspection procedures; • Ventilation system maintenance/inspection procedures; • Provisions of refuge chamber every 500 m in tunnel
Andra, France	Geological repository for ILW, HLW	Fire risk management: • Prevention: limit heat load, no combustion engine in nuclear areas; • Detection: automatic fire detection, extinguishing systems. • Mitigation: fire barriers, every 800 m in operational area, control smoke by ventilation control; fire-fighting equipment, back up path for evacuation and emergency access; no *cul-de-sac* gallery, 2-tubes design, • Fire barriers to isolate fire. • Maintain safety functions during fire and post-fire incidents
Nagra, Switzerland	Geological repositories for L&ILW, HLW	Fire risk management: • Conceptual fire protection plan exists since 1994; • WAC and disposability certification procedure account for fire safety, flammability, combustion properties.
NDA, UK	Geological repository for all RW	Fire risk management: • Evaluate fire faults, consequences; • Ignition sources and flammable inventories; • Fire suppression systems; • Design/operation of fire compartments, ventilation systems; • Provision of refuge station, evacuation.

National waste management programmes are at different stages in their geological disposal development. Regarding their fire risk management, some have more developed fire protection plans (e.g. Posiva, Konrad, SKB and Andra) or have identified fire mitigation measures (e.g. NWMO), while others remain at conceptual stage (e.g. Ondraf/Niras, NDA and Nagra). In general, most programmes designed their accidental fire scenarios under certain assumptions on fire initiation, evolution and development mechanisms. Almost all programmes based their fire hazard analysis on the hypothesis of the presence of controlled combustible materials in the facilities and limited number of simultaneous sources of ignition. Consistent with conventional fire safety assessment, all programmes reported in Table 1 rely upon mitigation measures and fire related operational procedures.

Relevant experience is documented in an IAEA report that evaluated the lessons learned from fires in nuclear power plants (IAEA-TECDOC-1421). The report showed that large fires could be induced from external sources and/or ignited inside the facilities by fire loads transferred from the outside. This suggests consideration of large external fire scenario, i.e. involvement of large areas with fire induced from outside.

In the 2013 meeting, safety assessment practices in relation to fire safety were reviewed, and may be concluded that they are based on three (3) main layers of defence in depth, complemented by appropriate operational procedures to manage possible fire-induced-losses:

i. Prevent fires from starting:

   Fire prevention is achieved by minimising fire loads through appropriate design and material choices, good housekeeping to minimise transient fire loads, and minimising ignition sources through regular maintenance as well as appropriate work procedures and permits.

ii. Early detect and extinguish any occurring fires to limit damage:

   Active fire protection measures such as detection and suppression systems serve the purpose of rapidly controlling the damage caused by any fires. The design of the fire protection system should be balanced to achieve rapid detection and suppression. For example, the use of automatic systems may avoid false or spurious alarms but may release suppression agents which may subsequently cause damage to equipment.

iii. Prevent spreading of fires (if fires cannot be extinguished readily) to minimise potential fire effects on key systems and components:

   Passive fire protection measures serve the purpose of preventing fire spreading and minimising the impact on important systems and components. Many programmes establish fire compartments and distance to physically separate safety systems from each other. These measures comprise of fire rated walls, ceilings, doors, penetrations, fire dampers, and local insulations, etc.

2.1 Fire safety management strategies

In addition to the above defence-in-depth principles, the meeting deemed that effective fire safety management can be enhanced by other complementary measures:

- Policies and procedures:
  - Emergency procedures that clearly define the responsibility and actions of responders in responding to a fire event, giving clear instructions to set out the role of operating personnel in relation to fire rescue/fire brigade team and external emergency services, as well as how they should interface with each other will allow efficient and successful fire-fighting activities.
  - Annual fire protection inspection of all underground machinery/vehicles must be carried out by trained staff. Emergency preparedness training for both the

construction and operations phases must be given to all workers and regular practices through fire drills should be performed.

- House-keeping procedures to continually ensure minimal amounts of combustible materials/ignition sources will reduce the risk of exposure to fire. Other procedures for inspection, maintenance and testing to be implemented throughout the lifetime of the repository/facility will ensure the reliability of the installed fire protection features to be maintained.
- A quality assurance programme with its fire protection policies and criteria clearly stated will ensure the fire protection systems to be properly maintained throughout the life cycle of the repository. Further to this quality assurance program, a database to record all fire and other operational events could be useful in tracking or providing traceable reference to root cause(s) of accidents. Information on the involved equipment, its operational history and experience, inspection, test and repair records, and operating statistics may be helpful in preventing reoccurrence of similar accidents.

  Note: The EGOS operational hazard database, currently being evaluated and to be developed in near future, is therefore suggested to include data on plant fire protection features.

- Engineering design and planning:
  - Construction methods and building materials of underground repositories may greatly influence fire prevention and protection. For instance, the modernisation of the mining industries in many countries has minimised wood structures in underground facilities to reduce fire risk. Whenever possible, non-flammable building materials should be used (e.g. stairs, head frame, shafts, transport conveyors, etc.) in order to reduce the risks of fire. Materials that may disintegrate into dangerous substances which are injurious to health or may explode should be avoided in constructions underground;
  - Electrical installations may lead to extensive damage of system(s) in the event of a fire, i.e. their location as well as the material of electrical equipment must be chosen with care. Whenever possible, only fireproof material should be used, electrical cables should be installed in non-conductive environment, away from flammable materials and/or fuel, and preference should be given to the highest fire prevention category (e.g. cables with aluminium strips instead of PEX or PVC insulated cables). Electrical cables and wires necessary for the control of the ventilation system and for the rescue equipment must be installed in such a way that no damages will result in case of a fire.
  - Explosives used in repository excavations, during the construction phase, must be handled with extreme care. No open flames should be in places where explosive and detonators are handled, stored or conveyed. All works should be carried out at a safe distance from any explosive storage/usage location. Dust control during construction is equally important as dust explosions can be triggered by dense dust clouds which will ignite if a certain concentration is reached in the air. Precautionary measures such as frequent cleaning to prevent dust accumulation, limit of oxygen content of the air in closed areas, and forbidden lighting sources are common practices in preventing dust explosions.
  - Fire compartments, separated by fire gate(s), minimise the spread of fire/smoke. Doors installed underground should be made of fire resistant material, self-closing, and can be secured in an open position when not normally kept closed. As air pressure increases in a fire, it is particularly important to ensure the hermetical seals of the fire gates are maintained at all times, and the functions of the fire gates and dampers are not jeopardised.

- Regular monitoring, air sampling and maintenance are also crucial in safeguarding workers underground.
- Alternative escape options should be considered in the design. This may be accomplished through alternative escape routes, or through rescue chambers or refuge stations in areas that are difficult to evacuate within a short period of time. Escape routes should directly lead workers into the open or to another safe area. In cases where lifts are used for rescue purposes, an independent means of ensuring its power supply should be provided.
- Ventilation systems are particularly important to prevent noxious fumes from spreading. The design of the ventilation system must ensure that ventilating air is provided in sufficient volume, velocity and quality to remove harmful contaminants. In designing the ventilation system, the location of sensitive installations such as workshops, fuel tanks, storage facilities, must be carefully planned for to warrant the supplies of fresh air. Similar to the fire gates, the ventilation system must be regularly tested to ensure its effective removal of fumes in case of a fire.
- Fire alarm and fire suppression systems should be installed in areas where the risk of fire is high, with regular testing and maintenance routines planned for. The selection as well as the positioning of monitor(s) / detector(s) should be based on the fire hazard analyses specific to each facility and environment.

- Training:
  - Plant personnel who engaged in activities relating to fire safety will establish efficient co-ordination with the plant operation and fire-fighting efforts with proper qualifications and training. Periodic fire exercises will ensure staff to be aware of their immediate actions and responsibilities in a fire. Training records and documentation including lessons learned will reduce previous errors to be recommitted. Not discussed in the meeting but more of a general observation of human behaviours is that an individual with a clear understanding of the potential consequences of errors tends to appreciate their contribution and take their responsibilities more earnestly. A questioning attitude also was noted to foster continual improvement in their task performance which may subsequently prevent an accident recurrence.
  - A designated emergency coordinator whose main responsibility is to guide the local rescue services in an emergency event can efficiently coordinate a rescue. Such personnel shall be knowledgeable in the usage, control and maintenance of emergency equipment, basic first-aid, life-saving, and rescue techniques, general fire safety matters, and other practical aspects of the underground facility.
- Fire hazard analysis:
  - A comprehensive fire hazard analysis determining the consequences of potential fire hazards will allow fire protection systems and features to be properly designed. Typical fire hazard analyses (FHA) for nuclear or industrial facilities involve the following:
    - An evaluation of the physical layout of the facility – the facility is often divided into fire cells/fire compartments in order to illustrate the separate equipment belonging to redundant safety trains;
    - An evaluation of safety systems and equipment, i.e. their identification and location; related to safe shutdown;
    - An inventory of combustibles, including maximum transient combustibles, potential ignition sources, calculation of fire development, probable duration, etc within each fire compartment/cell;

  - A description of fire protection equipment, including detection systems, manual/automatic extinguishing systems in each fire cell, taking into account of characteristics of facility that influence fire growth, e.g. ventilation system, air flow, fire detection, suppression system, etc.;
  - An analysis of irradiated material storage areas.
- The resulted fire hazard analysis provides a conclusive basis for identifying a design basis fire.

2.2 Fire assessment approaches

Two (2) complementary approaches namely (i) deterministic fire safety assessment and (ii) probabilistic fire safety assessments have been considered. While these approaches used in managing fire risk among the various programmes were not revealed in details, they can be broadly differentiated as follows: the deterministic approach evaluates events that are completely determined by cause and effect, i.e. the deterministic approach analyses the effects of assumed causes whereas the probabilistic approach evaluates events that can be identified by the probability of occurrence. More details on the methodologies, suitability as well as the parameters required for the 2 approaches may be further evaluated, pending decisions and priorities of other EGOS initiatives.

3. Ventilation system

Designs of ventilation systems adopted in different national programmes were discussed in the 2nd fire risk meeting, held in February 2014. Details of four (4) ventilation systems were presented and summarised in Table 2. Further specifics discussed in this 2nd meeting can be found in the meeting minutes in Appendix C.

Table 2: Current ventilation system plans in Canada, Belgium, France and the UK

Canada – Proposed deep geological repository for L&ILW

- A "once-through" ventilation scheme with main fans located underground;
- HEPA filter (outlet) is not used in the ventilation system as only gases contaminated mainly of tritium and C-14 are expected. Low dosage of other radionuclides are anticipated;
- Ventilation is maintained through filled emplacement rooms until the series of rooms within a panel are sealed off;
- Surface intake fan will provide the required air flow to compensate the pressure drop in surface inlet facility. Underground exhaust fans are used to create a "suction-type" ventilation system;
- Air flow modelling and heat/humidity are based on VNetPC and CLIMSIM software;
- Inlet air heaters will be used to ensure inlet air is >5°C for both worker comfort and infrastructure integrity;
- Plan to have 3 refuge stations in underground facility, i.e. 1 permanent and 2 portable stations;
- The underground repository will be equipped with various control system such as both audio and visual fire alarms, heat and smoke detectors, gas monitors, portable and fixed suppression system.

Belgium – Long-lived and/or High-level waste

- 3 shafts of which 1 (the waste shaft) will be used for transporting radioactive waste packages to underground ; the other 2 shafts are for transporting personnel and materials and providing ventilation inlet;
- A "once-through" ventilation scheme with exhaust fans located on top of the waste shaft is currently being considered; also considering an auxiliary ventilation system with duct system for ventilating the dead-end disposal galleries;
- No carbon dioxide is expected as combustible engines are not used in the repository;

- Air flow modelling (performed by DBE) : NetzCad;
- To protect workers, air flow in the repository will always be upstream of the waste packages;
- No significant dust source is anticipated in the operational period;
- Regarding fire emergency equipment; the plasticity of the Boom Clay may create potential problems with the construction of possible refuge stations; currently no legislation on the use of such stations exist in Belgium; German requirements require refuge stations every 400 m in blind or dead-end galleries;
- Other outstanding issues (i) to determine a suitable mode of the ventilation, i.e. air suction or air blow; (ii) further evaluate the potential release of radionuclides from LILW waste.

France

- Two separate ventilation systems will be provided: one for the construction area and the other for the operation area;
- HEPA filters will be used in the exhaust air of the ILW cells. HEPA is not required in the HLW due to the air-tight packages ;
- Ventilation system is a "once-through" type with ground facility situated near to heads of shafts and ramps;
- Different pressures in galleries and cells are used to reduce probability of radionuclide particles transfer into galleries;
- Disposal cells are separated with fire doors, parallel inter-connected galleries are provided for rescue operations;
- In case of a fire, air shutters at the inlets and outlets of the disposal cell (in-fire) will isolate the cell and ventilation in the neighbouring disposal cells will stop;
- The current ventilation design does not account for radionuclide release. Air suction is provided from down to top of ramp in a fire;
- Various one-dimensional and 3-dimensional fire modelling codes (e.g. ventsim, simevent, simsmart, etc.) are used to estimate the potential fire impact.

United Kingdom

- Three shafts are being planned for in the current generic design, each with a diameter of 8 m;
- Two separate ventilation systems for the construction and operational areas – in the construction zone, slightly (+)ve pressure with respect to atmospheric pressure will be maintained while the disposal area will have slightly (-)ve pressure; in the operating area exhaust fans are located at the top of shaft 3 in order to provide a (-)ve pressure (relative to atmosphere pressure);
- Air flow is always maintained to be from low to high concentration (of contamination) areas;
- Intake air will be pre-filtered to remove chloride and the relative humidity of air entering the vault is controlled as stainless steel packages are used in the repository;
- Preliminary studies indicated the repository will reach the 5% limit of CH_4 in 4 days and 5 months to reach 4% LEL limit for H_2. NDA uses 2% H_2 in their design requirements;

In their ventilation system planning, repository developers often considered the repository layout, locations of potential hazards and impacts of potential ventilation system failures. Design details presented also suggest that most programmes use controls such as (i) prevention/elimination of hazards, (ii) isolation, and (iii) minimisation to manage air quality hazards in underground facilities. The provision of differential pressure settings to prevent contamination and/or potential radionuclide transfers is also considered in some programmes.

To isolate potential airborne hazards, repositories are commonly divided into zones where hazards are confined (e.g. seal off filled emplacement chambers or zones) and worker exposures are minimised (e.g. a "once through" ventilation scheme, keep air flow upstream of waste packages, minimal air velocities, etc.). All programmes aimed at arranging their ventilation systems to maintain sufficient oxygen, dilute and render harmless noxious and flammable gases, and minimise airborne contaminants, while maintaining a suitable heat/cold and humidity levels in the workspace. Various means have been employed to achieve these goals in their designs which include (i) continuous monitoring of air quality, (ii) place intake airways as far as reasonably practicable from potentially contaminated air; or away from activities generating harmful levels of dust and fumes; (iii) equip installations that are near the primary intake airway with automatic fire suppression system(s); (iv) select ventilation fans with characteristics matching the required ventilation duties and (v) place combustibles/flammable materials in areas where no adverse effect on the intake air should they be involved in a fire.

The expert group noted the significant relationship between monitoring and operations of the ventilation system and agreed to consider a future meeting to further discuss the various monitoring aspects.

Also unanimously agreed in this meeting is the important role played by the ventilation system in case of a fire in a repository. In such incident, the group discussed the widely used concept in mines of running the ventilation system without changes during evacuation in order to avoid any flow direction changes, and the potential changes of the operation of the ventilation system after evacuation so as to improve the environment for fire extinguishing and/or rescue attempts from refuge stations. Not explicitly stated but well understood in this meeting is the importance of a hazard management and ventilation control plan. The ventilation plan is a crucial tool when using the ventilation system and its fans to control the smoke spread in an underground facility. The main purpose of a ventilation plan is to clearly document the ventilation requirements, in order to establish and maintain a safe level of air supply within an operating underground environment. Similar to the remarks noted in the 1st fire meeting (see Section 2.1), experience gained from existing nuclear facilities and underground mining operations has suggested the following matters must be addressed in a ventilation plan:

i. Detailed description of system components shall cover, but not limited to, the locations, designs and performance of the key system components (e.g. main/auxiliary fans, the provision of supporting devices (e.g. monitoring), the installation of ventilation control devices to control the supply of ventilation to the underground facility, the means used to ensure that ventilation control devices will not be interfered with, etc.).

ii. Well written and communicated procedures shall include, but not limited to, the procedures for construction, installation, use and maintenance of the ventilation systems during operation, the procedures for hazard reporting relating to ventilation; measures to be taken if the prescribed ventilation limits protection is breached, the evacuation procedure or immediate actions to be taken in the event of a failed ventilation system; the procedures for maintaining escape-ways, return airways for access to emergency personnel.

iii. Management of records and plans shall comprise operational and maintenance records of the ventilation system, air monitoring plans and data, incident reports and subsequent corrective actions, training records of relevant personnel, etc.

Lastly in the discussion of ventilation systems, some programmes have mentioned their ventilation simulation modelling which was conducted to confirm their ventilation design and to assess the impacts of potential hazards (Canada, Belgium and France). Despite various software were used, common parameters such as the locations of ventilation/auxiliary fans, air egress, flammable gases, blasting fumes, dust particles, underground equipment/vehicles, anticipated waste volume etc., are often input into these simulations.

4. Design basis accidents on fire

Design basis fire accidents and more generally, fire safety assessments were discussed in the latter part of the 2nd fire risk meeting. In the discussion, approaches used to assess fire hazards, types of fire scenarios evaluated in fire assessments, as well as the overall management of fire risks were evaluated. More details of how various programmes assess their fire scenarios and/or manage their fire risks can be found in the meeting minutes in Appendix C. Due to the limited discussion time and information presented, no major commonalities, findings or guidance can be concluded at present. However, the discussion nevertheless revealed the temporal evolution of a design fire to include the following phases: (i) incipient phase, (ii) growth phase, (iii) fully developed phase, (iv) decay phase, and (v) extinction.

In identifying possible fire scenarios, the group continued to consider historical fire incident/statistical data at nuclear facilities and underground mines applicable and useful but also noted the growth of a fire is highly dependent on the arrangement/placement of the fire loads (or combustibles) and the availability of oxygen. Specifically, in the case of unlimited access of oxygen, the duration of the fire will be determined by the fire load whilst if oxygen is limited or ventilation controlled, the mass flow of air will have a major impact on the duration of the fire. To minimise fire risks, many programmes attempt to minimise the amount of combustibles/flammable materials in underground installations and equipment (e.g. transfer vehicles, hydraulic fluid, cables, waste packages design etc.). In particular, fire spreading on large areas, along with other potential hazards (e.g. mechanical impacts, explosions, failure of fire barriers) remains a challenging threat to repository safety. Further to the available mining experience, a major risk to people in an underground fire is poor visibility and smoke inhalation. In establishing design fire scenarios as well as in optimising rescue operations, it is therefore important to consider factors such as the relationship of fire duration and smoke generation, smoke spread, the effect of heat release rate on smoke temperature, and visibility.

Some programmes (e.g. Andra) have noted the lack of documented fire experiments in various areas and have plans to perform fire tests in improving understanding of various fire protection measures. Other have considered working areas with mobile equipment (e.g. drilling rigs, service vehicle) as high risk areas of fire, therefore design fire curves, fire data of underground vehicle/mobile equipment are essential knowledge in designing new mine sections.

5. Lessons learnt from the 2014 fire incident at the WIPP

The WIPP facility is a geologic repository mined within a bedded salt formation located in Carlsbad, New Mexico; designed to isolate the nation's defence transuranic (TRU) waste from the environment. By February 2014, the facility, has removed approximately 90,800 cubic meters of TRU waste from 22 generator sites throughout the country. On February 5, 2014, the facility suspended operations due to a fire involving an underground salt haul vehicle. The direct cause of this accident, according to the investigation, is contact between flammable fluids (e.g. hydraulic fluid or diesel fuel) and hot surfaces on the salt haul truck. The fire burned the engine compartment and consumed the front tires which contributed significantly to the amount of smoke and soot in the underground facility. The vehicle operator attempted to extinguish the fire with a portable fire extinguisher stored on the truck and then by activating the truck's fire suppression system. Both attempts to extinguish the fire were unsuccessful due to the deactivation of the automatic on-board fire suppression system. A detailed chronology of the fire events is documented in the WIPP Investigation Report (http://www.wipp.energy.gov/Special/AIB%20Report.pdf).

The root cause of the incident has been identified as the breach of at least one TRU waste container which resulted in airborne radioactivity escaping to the environment. The Accident Investigation Board further concluded the accident was caused by the failure of management and operations contractor to adequately recognise and mitigate the fire hazards in the facility, i.e. failed to remove the build-up of combustible through inspections and periodic preventative maintenance. Ten (10) contributing causes were also identified in which many of them were found to be related to inadequate fire protection procedures and management processes. Contributing causes are defined as events or conditions that collectively with other causes increased the likelihood or severity of an accident but that individually did not cause the accident. Among the ten contributing causes, the investigation specifically noted the NWP and CBFO management did not adequately consider overall facility impact with regard to operations, emergency response, and maintenance, which in due course affected the safety posture of the WIPP. Such deficiency has resulted with less than acceptable rigor in the performance of equipment inspections and maintenance, causing unacceptable operation of underground equipment and fire protection gear. The subsequent fire incident was a combined consequence of several shortcomings including combustible build-up on truck, conversion of the automatic fire suppression system to manual, removal of the automatic fire detection capability, avoid usage of fire resistant hydraulic fluid, discontinued use of the vehicle wash station, chained open ventilation doors and an out-of –service regulator and fans and inoperable mine phones. More details of the conclusions drawn in the investigation can be found in their investigation report.

Then nine days later, on February 14, 2014, a radiological event occurred at the site which released a small amount of americium and plutonium from its transuranic (TRU) waste container(s) into the environment. The Accident Investigation Board (AIB) identified the root cause of the release to be NWP's and CBFO's management failure to fully understand, characterise, and control the radiological hazard. While no personnel were determined to have received external contamination; the post-accident investigation indicates that a thorough hazard analysis, coupled with a robust/well maintained ventilation system could have prevented the above-ground offsite release. The investigation also found significant degradation in the material condition of several ventilation system components partially due to the fact that the HEPA ventilation system was not considered a credited safety system after the system upgrade. Overall weaknesses in oversight by management, ineffective nuclear safety/radiation protection programs, in addition to incompliant operations program are all contributors to this radiological event. More thorough findings of the incident are described in the investigation report (http://www.wipp.energy.gov/Special/AIB_Final_WIPP_Rad_Release_Phase1_04_22_2014.pdf).

6. Concluding remarks

This interim report summarised the key information exchanges in the area of managing fire risks in underground repositories. Operational experience from existing mines and nuclear facilities has shown the occurrence of fire accidents, and that with greater attention to address the potential fire hazards, human and environmental risks may be reduced.

In reviewing the designs and fire hazard analyses of geological repositories, many programmes have significantly improved their fire scenarios and models over the past years. However, further work is planned.

In carrying out this preliminary analysis of the available meeting outcomes, the Secretariat is therefore proposing the following future work activities:

1. In developing the EGOS operational hazard database, include generic operational, maintenance, failure details of fire protection equipment (e.g. detectors, suppression systems and fire barriers), specifically in terms of their reliability and effectiveness in response to events. This will provide traceable reference information which can be useful in identifying root causes of fire accidents and preventing reoccurrence of similar incidents;

2. Develop technical data on collateral damage caused by fires and operation of fire-fighting measures, e.g. effects of fire-fighting agents, aerosols used in fire brigade actions, damages on waste packages such as corrosion damages caused by sprayed chemicals and smoke, etc.;

3. Improve understanding on scientific issues such as the thermal effects of large fires, heat release rate, smoke production and spread. This will help improve the designs of fire-protection measures (e.g. the provision of refuge stations, escape-ways, etc.).

7. Reference

IAEA, Experience gained from fires in nuclear power plants: lessons learned, IAEA-TECDOC-1421, IAEA, Vienna, Nov 2004.

Appendix A – Current disposal concepts of national programmes and their planned fire management strategies

Belgium

Integrating fire safety in the Belgian geological disposal design is done by:

1. developing a repository layout that guarantees a safe evacuation route at all times.
2. developing an adequate ventilation system.
3. minimising flammable materials and heat sources.

Repository layout

The current repository layout considered in the Belgian R&D program on geological disposal offers 2 evacuation routes at all times. Nevertheless it will be examined whether a layout consisting of parallel access galleries could offer a more robust design in terms of fire safety as such a layout will create an additional evacuation path. Further research on the construction feasibility of this layout is however necessary.

The blind galleries in the layout constitute a safety risk. The construction of rescue chambers is not envisaged as gallery excavation is foreseen to be done by the use of an open-face tunnelling machine and this technique does not allow alternating the excavation diameter. The question therefore remains what the maximal allowable length is for the blind (dead-end) disposal galleries without the need to construct a rescue chamber. The use of survival shelters can avoid the potential necessity of having to construct a rescue chamber.

Figure 1: Survival shelter

Ventilation system

A ventilation system is considered consisting of a primary ventilation system generating a continuous airflow in the access gallery and shafts and an auxiliary ventilation system ventilating the disposal galleries. In case nuclear ventilation is required for the repository, HEPA filters can be included at the ventilation outlet at the top of the waste shaft.

Minimise flammable materials and heat sources

When developing the design, flammable materials or equipment and heat sources are minimised. The main fire risks are the transport system and the electrical equipment. The transport system envisaged in the Belgian geological disposal design is a battery driven locomotive. No vehicles on fuel will be used. Furthermore all electrical equipment will be adequately insulated and if possible, placed on surface outside the repository.

Canada

Ontario Power Generation (OPG) is proposing to build a Deep Geologic Repository (DGR) for Low and Intermediate Level Waste (L&ILW) near the existing Western Waste Management Facility at the Bruce nuclear site. The Nuclear Waste Management Organisation (NWMO) has been tasked by OPG with managing the DGR Project and conducting all technical and support activities for environmental impact assessment, site preparation and construction licensing approvals.

The preliminary design for fire suppression and detection system follows the National Building Code of Canada and the National Fire Code of Canada for surface structures, and Occupational Health and Safety Act (Ontario) – Mines and Mining Plants Regulations R.R.O. 1990 (Reg. 854) for underground facilities. Design will minimise risk and spread of fire through e.g. reduction of flammable material. Fire detectors will be placed in key locations in the facility to quickly detect a fire. In the event of fire, personnel underground will move to refuge stations for protection. Plans for addressing the fire and for emergency rescue will be implemented. The fire suppression plans include automatic and manual fire suppression systems, and fire door closures. Underground fire suppression systems will include foam, clean agents and dry chemical. Fire suppression with water is unsuitable for this underground nuclear waste repository facility due to the large quantities of water involved which can get contaminated with tritium and other radionuclides.

Topics of interest for next meeting:

i. Fire consequence analysis (fire characterisation, and consequence analysis to workers and public).
ii. Design basis and beyond design basis accidents, and their characterisation (not limited to fires).
iii. Ventilation system design, and flow control in case of a fire and in case of other accidents.
iv. Flood accidents, design basis provisions and consequence analysis.
v. Safety of personnel – notification, refuge station provision and evacuation plans.

Finland

Topics of interest:

Participants then agree to provide 5 topics of interest to the Secretariat by May 10. The Secretariat will summarise key common topics and arrange for future meetings/workshops:

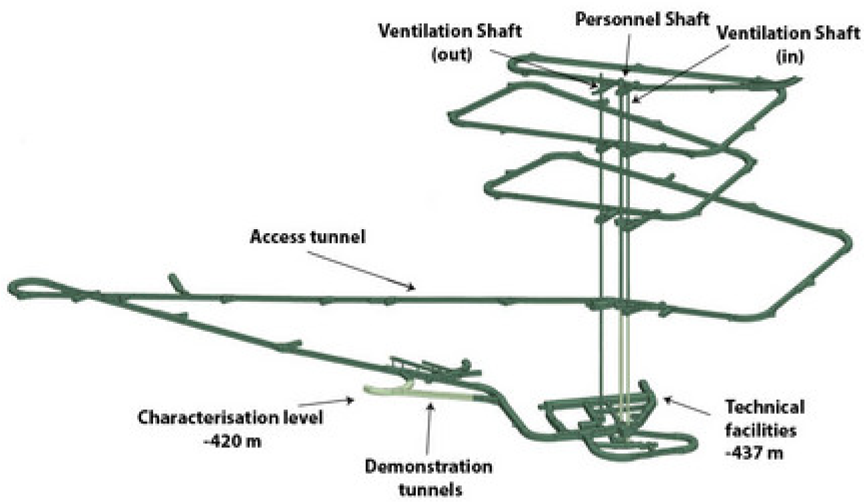
- How to operate the ventilation effectively in case of fire
- How to reduce the fire load in the vehicles (tyre's material, oil less fluids etc.)
- Profiling basic accidents
- Experiences of water mist Fire suppression systems
- Compare fire models used in different countries
- Approval of the large fire doors

Posiva's key messages:

As for reporting the results of this meeting to the EGOS working group, participants also agree to provide a short summary (1-2 paragraphs) of key messages of their programmes (also by May 10). Key messages shall (very) briefly describe the programme status, any foreseeable challenges, and/or planned activities/actions to resolve the expected challenges.

Posiva have nearly finished the excavations of the ONKALO, the underground rock characterisation facility for the final disposal of spent nuclear fuel. The excavation started in 2004 so we have been dealing with the fire safety cases in the underground rooms under construction since that.

Figure 1: ONKALO (http://www.posiva.fi/en/)



Constructions fire safety principles based on national legislation and regulations and also conventional and nuclear specifics regulations.

Also the normal ventilation and the smoke ventilation based on regulations and also on the fire simulations (FDS). We have made multiple simulations to find out what is the best and safest way to proceed with planning and construction.

Because of the multistage construction we will have rooms finished and accepted and the same time we have the rooms under construction. To handle the fire safety and ventilation in the both kind of rooms is the real challenge. For that we have or will have among other things the fire compartments, fire suppression systems in the technical rooms and automatic fire detection systems.

A great challenge is also the time that takes for the fire brigade reaching the site and especially the tunnels. It takes at least half an hour. Because of that we have made a several actions to assure we can reduce the risk of the fire as low as possible:

- Minimising the fire load in the tunnel.
- Divide the tunnels for the separate fire compartments with the fire walls and doors with the fire penetrations and the fire dampers.
- Fitting all the vehicles engine room with the automatic fire extinguisher system.
- In the tunnel we have on every 100 meter the fire plug (with foam).
- Technical rooms will be equipped with the fire suppression systems.
- Rooms are and will be equipped with the fire detection systems.
- Every workers have got the introductory briefing including the learning how to use the fire extinguisher.
- Every vehicles are under regularity maintenance and inspection.
- The ventilation fans and smoke fans and fire dampers are under regularity maintenance and inspection.
- In the access tunnel we have on every 500 meters we have a refuge chamber or a transferable rescue container. Elsewhere in the tunnel we have adequately amount of the refuge chamber or a transferable rescue container depending on actions.

Even we have made a lot to prevent the fire and we have been successful so far we have to make a lot of work also in the future.

Switzerland

Nagra's topics of interest:

1. Developing common approaches among programmes in managing fire risks, understand differences (if they exist) in the management of fire risks (e.g. the use of diesel powered machinery).
2. Comparing design basis accidents and their justification.
3. Comparing fire models used in different countries (e.g. effectiveness of counter measures).
4. Comparing quantitative methodologies to calculate consequences and to estimate probabilities (refers to simulation, tests and research work related to fire risk).
5. Assessing the impact of waste properties (→ waste acceptance criteria) on design measures (wrt fire risk).

Nagra's key messages:

The current site selection procedure for a L/ILW repository and a HLW repository underway in Switzerland focuses on long-term safety for discussing the suitability of regional and local geological conditions. The planning for operational safety including fire protection and fire defence is conceptual, based on established standards of civil and nuclear engineering. The roots of Nagra's work on operational safety go back to a study on operational safety performed for project Wellenberg in 1994 (positively reviewed general application licence for a L/ILW repository) and on the feasibility study for the disposal of SF/HLW and ILW "project Opalinus Clay" in 2002.

Waste acceptance criteria take into account Nagra's concept and activities for operational safety also wrt fire risk. Each waste package type has already today to be submitted to a disposability certification procedure (based on preliminary waste acceptance criteria), in which Nagra reviews qualitatively and quantitatively properties of the waste wrt to long-term and operational safety (including inflammability and combustion properties). The MIRAM database of waste sorts to be disposed of contains in addition to nuclear inventories the inventory of materials from which possible fire risks can be assessed.

Locating possible sites for the installation of the surface facility is part of the site selection procedure, which requires the consideration of possible external hazards to the facility including fire risks. Requested by the Swiss Federal Office of Energy a generic investigation on how to ensure safety during construction and operation of the surface facility is in preparation.

United Kingdom

Topics of interest:

- Fire protection standards for fire doors.
- Ventilation design and operating mode in fire conditions – smoke dissipation versus oxygen starvation.
- Features of refuge stations and evacuation protocols.
- Fire suppression systems.
- Comparison of design basis accidents.
- Design and use of HEPA filters in fire conditions (this may actually be a subset of bullet 2).

Challenges and planned activities in respect of fire protection:

During the period 2009-10 the NDA's RWMD produced the generic Disposal System Safety Case. This is a suite of safety case and design documents, supporting research Status Reports setting out the scientific evidence base for geological disposal and other reports underpinning the generic case. The generic DSSC was subject to independent peer review and launched in 2011.

The generic DSSC covers:

- Transport of waste from the site of interim storage to the GDF – the Transport Safety Case.
- Safety of construction, commissioning, operation, decommissioning and closure – the Operational Safety Case.
- Performance of the disposal system in the long-term post-closure – the Environmental Safety Case.

The generic DSSC has proved to be a very useful tool to demonstrate RWMD's confidence in the safety of geological disposal and has been discussed with regulators, the independent Committee on Radioactive Waste Management and with stakeholders particularly those in Cumbria that have been involved via the MRWS process.

The Operational Safety Case and associated Design is at an early generic stage and RWMD is careful not to assume that the design is fixed and therefore the technical programme includes consideration of some faults which in the event may be able to be designed out. This seems to be the appropriate way forward for this early stage. The following topics are identified for further development in relation to fire performance:

- Reduction in pessimism in DBA analysis – fire duration and intensity.
- Design improvements to reduce potential dose pathway to operators.
- Research to define improved thermal release fractions from key radionuclides.
- Development of thermal modelling capability for the range of waste packages likely to be handled and emplaced.

We recognise that as our programme progresses and we have a defined site we will need to refine the design to better address fire scenarios. This will require us to consider in more detail:

- Fire faults and consequences.

- Ignition sources and flammable inventories.
- Fire suppression systems.
- Design of underground areas for fire conditions – design and operation of fire compartments and ventilation systems.
- Safety of personnel – refuge provision and evacuation.

Appendix B – Meeting minutes of the 1st fire risk meeting

30 April 2013
NEA Offices, Issy les Moulineaux, France

Key Observations

Participants:

Philippe Van Marcke	Ondraf/Niras	BE	Wilhelm Bollingerfehr	DBE Tech	DE
Kelly Liberda	NWMO	CA	Johan Sydqvist	SKB	SE
Pasi Makela	Posiva	FI	Sven Keesmann	Nagra	CH
Fabrice Boissier	Andra	FR	Steve Barlow	NDA	GB
David Claudel	Andra	FR	Mark Johnson	NDA	GB
Myriam Rabardy	Andra	FR	Hiroomi Aoki	NEA	N/A
Yannick Severe	Andra	FR	Gloria Kwong	NEA	N/A
Sylvie Voinis (Chair)	Andra	FR	Vladimir Lebedev	NEA	N/A

Key observations/conclusions drawn from the presentations given by the participants include the following:

1. National waste management programmes are at different stages in their geological disposal development. In regard to fire risk management, some have relatively developed fire protection plan (e.g. Posiva, Konrad and SKB), other may be at conceptual stage only (e.g. Ondraf/Niras, NDA and NAGRA). More specifically, Andra and NWMO identified their fire mitigation measures and indicated to finalise/revise their fire protection details in the next stage of their programmes.

2. Many national waste management programmes developed their fire protection programmes using similar defense-in-depth principles; i.e. (i) prevent abnormal situations – prevent fires from starting by limiting flammable materials/gases, ignition sources in underground facilities); (ii) prevent degradation – early detection and system readiness to allow firefighting measures to be initiated as soon as possible; and (iii) minimise damage – prevent the spread of fire (if fire cannot be extinguished immediately) to minimise damages on essential systems. Similar firefighting methods/solutions are also noted in different programmes. E.g. the use of fire compartments for containment; use of fire doors to separate compartments. Many programmes consider resolving fire issues and/or exchanging experience with others essential and advantageous.

3. Many national programmes also use similar approach to demonstrate safety, i.e. establish a “reference fire scenario”; identify related hazards and safety objectives, consider other potential scenarios. Some countries further apply bounding conditions in order to focus on more realistic assessments (e.g. Canada, UK).

4. All participants agree that operation experience from the mining industries is applicable and valuable in developing a fire protection system for a disposal repository. They also

expect their final regulatory framework will compose of mining regulations, existing nuclear laws and “new” regulations to be specifically developed for underground disposal facilities.

5. Different design methods and details of the fire protection systems are noted in different countries. For instance, Canada only uses water to fight fire in above-ground facilities and water will not be applied in their underground DGR. Whereas other programmes are considering the use of water in their underground facilities (e.g. SKB plans to install water sprinklers in their central area and on ramps). Different equipment/machinery to be used in the disposal facilities are also noted. E.g. France, Germany use only electric motored vehicles, battery driven locomotives or cable engine (no diesel engine) while other programmes are considering the use of diesel forklift or diesel fuelled transport vehicles.

6. With respect to the meeting, participants consider having separate meetings among implementers allow them to exchange knowledge and experience openly and effectively, particularly in developing the aims and goals of various fire prevention measures. It was then agreed that such format will be maintained and future dialogues with regulators will be held on a separate platform. Meeting outcomes will be communicated with the EGOS working group by the Chair and the NEA Secretariat.

7. In concluding the meeting, participants have also identified their topics of interest. These include, but not limited to (i) ventilation system design and their functions in case of a fire ; (ii) develop common fire protection standards/approaches among programmes which will allow design/research efforts to be combined; (iii) compare fire models used in different countries so as to improve the evaluation of fire hazards; (iv) compare design basis accidents; (v) essential features of refuge stations and evacuation protocols; (vi) other simulations, tests, and research work related to fire risk, etc.

8. **Action 1**: Participants then agree to provide 5 topics of interest to the Secretariat by May 10. The Secretariat will summarise key common topics and arrange for future meetings/workshops.

9. **Action 2**: As for reporting the results of this meeting to the EGOS working group, participants also agree to provide a short summary (1-2 paragraphs) of key messages of their programmes (also by May 10). Key messages shall (very) briefly describe the programme status, any foreseeable challenges, and/or planned activities/actions to resolve the expected challenges.

Appendix C – Meeting minutes of the 2nd fire risk meeting

11 February 2014
NEA Offices, Issy les Moulineaux, France

Objectives of the workshop

The presentations are organised according to achieving the following objectives:

1. Develop technical solutions for fire prevention.
2. Develop technical solutions for mitigation of fire.
3. Develop technical solutions for emergency situations.
4. Design basics accidents.
5. Evaluate various monitoring aspects (if time allows) of underground facilities.

Key messages (* the following key points are supplementary to the presentation slides, refer to the presentation slides for additional details)

	Opening Remarks
1.0	Welcome Note
1.1	Context and Objectives of Meeting *Sylvie VOINIS (Andra, France)* • Sylvie Voinis recapped the key objectives (above) of this project with the key questions that were sent in advance to the meeting. A short review of project was presented regarding the level of fire safety in various national waste management programmes.
	Topic 1: Ventilation system
2.1	Current ventilation system plans in the context of the OPG's proposed DGR for L&ILW *Kelly LIBERDA (NWMO, Canada)* • The reference design has a "once-through" ventilation scheme with main fans located underground; • HEPA filters are not used in the ventilation system as only gases mainly of tritium and C-14 are expected. Low dosage of other radionuclides are anticipated; • The OPG DGR does not plan for concurrent activities, i.e. operation of the repository will not start until the construction of the repository is complete; • Ventilation is maintained through filled emplacement rooms until the series of rooms within a panel are sealed off; • Surface intake fan will provide the required air flow to compensate the pressure drop in surface inlet facility. Underground exhaust fans are used to create a "suction-type" ventilation system; • Air flow and heat/humidity modelling are based on VNetPC and CLIMSIM software;

- Inlet air heaters will be used to ensure inlet air is >5°C for both worker comfort and infrastructure integrity);
- Current plan is to have 3 refuge stations in underground facility, i.e. 1 permanent and 2 portable stations;
- The underground repository will be equipped with various control system such as both audio and visual fire alarms, heat and smoke detectors, gas monitors, portable and fixed suppression system.

2.2 Belgian experiences on ventilation system

Philippe VAN MARCKE (Ondraf/Niras, Belgium)

- The current design plans for 3 shafts including the centre shaft are used for transporting radioactive waste packages to underground;
- Separate sections for categories intermediate and high level wastes;
- A "once-through" ventilation scheme with exhaust fans located on top of the waste shaft is currently being considered;
- The auxiliary ventilation system with relevant duct system is being considered in their conceptual design of DGR;
- No carbon dioxide is expected as combustible engines are not used in the repository;
- Similar to Canada, no co-activities are expected in the plan, i.e. construction of repository, then followed by operation;
- With no existing applicable Belgian regulations directly, the current design of the repository is based on relevant German law since DBE is the actual designer of the facility;
- Air flow modelling: NetzCad;
- General considerations :
  - The Belgian programme is to further evaluate a suitable backfill material, i.e. mortar, bentonite or cementitious concrete;
  - The repository may be considered as a nuclear controlled zone;
- To protect workers, air flow in the repository will always be upstream of the waste packages ;
- No significant dust source is anticipated in the operational period;
- Regarding fire emergency equipment; the plasticity of the Boom Clay may create potential problems with the construction of possible refuge stations; currently no legislation on the use of such stations exist in Belgium; German requirements require refuge stations every 400 m in blind or dead-end galleries.
- Other outstanding issues (i) to determine a suitable mode of the ventilation, i.e. air suction or air blow; (ii) further evaluate the potential release of radionuclides from ILW waste.

2.3 Fire risk management and ventilation system, based on the preliminary design

Abdelkader AMEUR (Andra, France)

- In the underground facility, during the operational phase, there will be operation and emplacement activities simultaneously;
- L&ILW-LL (long-lived) and HLW will be emplaced in separate sections with separate power and access;
- Two separate ventilation systems will be provided to the construction area and operation area;
- HEPA filters will be used in the exhaust air of the ILW cells. HEPA is not required in the HLW due to the air-tight packages;
- Ventilation system is a "once-through" type with ground facility situated near to heads of shafts and ramps;
- Different pressure in galleries and cells is used to reduce probability of radionuclide particles transfer into galleries;
- Disposal cells are separated with fire doors, parallel inter-connected galleries are provided for rescue operations;
- In case of a fire, air shutters at the inlets and outlets of the disposal cell (in-fire) will isolate the cell and ventilation in the neighbouring disposal cells will stop;
- The current ventilation design does not account for radionuclide release. Air suction is provided from down to top of ramp in a fire;
- Various one-dimensional and 3-dimensional fire modelling codes (e.g. ventsim, simevent, simsmart, etc) are used to estimate the potential fire impact.

2.4 GDF ventilation system design

Mark JOHNSON (NDA, UK)

- The UK programme remains on a generic level, i.e. no site has been selected at present; detailed calculations are still to be conducted in future;
- Three shafts are being planned for in the current generic design, each with a diameter of 8 m;
- Current design assumes the repository to stay open for 500 years and the emplacement vault to be opened for a 100 years; any site containing shale gas will not be considered in the design;
- The current design concept uses two separate ventilation systems for the construction and operational areas. In the construction zone, slightly (+) ve pressure with respect to atmospheric pressure will be maintained while the disposal area will have slightly (-) ve pressure;
- In the operating area exhaust fans are located at the top of shaft 3 in order to provide a (-)ve pressure (relative to atmosphere pressure);
- Concurrent activities are anticipated;
- Emplacement rooms will be backfilled with cementitious material once filled;
- ILW will be separately placed in unshielded ILW vaults and shielded L&ILW vaults;
- Air flow is always maintained to be from low to high concentration (of contamination) areas;
- Intake air will be pre-filtered to remove chloride and the relative humidity of air entering the vault is controlled as stainless steel packages are used in the repository;
- Preliminary studies indicated the repository will reach the 5% limit of CH_4 in 4 days and 5 months to reach 4% LEL limit for H_2. NDA uses 2% H_2 in their design requirements.

Topic 2: Design basis accidents on fire

3.1 Fire safety assessment in the context of the OPG DGR

Kelly LIBERDA (NWMO, Canada)

- The NWMO uses a conservative approach in assessing their fire scenarios. E.g. the current safety case considered a worker is located downstream of the air flow whereas in reality, the ventilation system is designed to provide an air flow that is always at an upstream direction;
- The ventilation flow will not change until all personnel are accounted for;
- 4 fire scenarios are assessed (see the presentation slides for the 4 scenarios description and results). These scenarios target the exposure of workers and public.
- The dose limits under an emergency situation are respectively 1mSv for the public and 50 mSv for workers;
- Self-ignite scenario is considered non-credible.

3.2 Fire risk management

Francois Laumann / David CLAUDEL (Andra, France)

- Andra established the fire guidance by consulting various stakeholders, i.e. nuclear operators, research institutes and the fire department;
- The principle of defence-in-depth is applied in the Andra's fire guidance. (See presentation slides for further details of with three lines of defence;
- The design of the ventilation system of Andra is based in consistency with the fire guidance on 4 key objectives, namely (i) protection of workers' lives; (ii) protect the environment and the public; (iii) maintain safety functions of the repository components; and (iv) maintain all underground activities and installations;
- Current design accounts for co-activity of operation and construction simultaneously; construction zone will be physically separated from the operation area. The design plans fire doors to isolate fire. Two parallel interconnected passageways are provided for worker evacuation in case of emergency. The underground repository is also equipped with fire-fighting equipment and two accesses for fire-fighting;
- Various design features relevant to fire safety are listed for various equipment and systems (see presentation slides for further details);
- Various fire tests are scheduled in the future (some are planned in 2014) to improve understanding of different fire protection measures. Specifically, Andra will evaluate a suitable composition of concrete and designs of the waste packages in near future.

3.3 Design basis accidents for fire situations – UK experience

John MALGET (NDA, UK)

- With the UK potential repository remains on a generic level, the design of the repository considered all fault consequences to the basic safety level in accordance to the highest frequency bands;
- Details of the safety functions of the various repository components are not specified at present but will be defined when the programme reaches the stage of preparing a preliminary safety case;
- The generic operational safety case assumes a fire scenario at 1000°C for a duration of 1 hr;
- In the fire model, actual burning of a package was used to obtain realistic performance data. Preliminary data indicates that packages can tolerate a fire duration of ~24 minutes.

3.4 Key decisions and observations

- The working group agreed to develop a summary summarising key findings gathered in the 2 fire risk meetings;
- Both Andra and NDA have indicated release fraction databases available;
- Various fire modelling softwares are used in different countries. G. Kwong suggested in future comparing fire models used in the different organisations so as to improve the evaluation of fire hazards;
- The number of efficient technical approaches was demonstrated during presentations;
- The task group members agreed to draft a summary report summarising key outcomes of the fire-risk project meetings, in the format of an NEA R-type report;
- The Secretariat has agreed to prepare a draft Table of Contents by mid – late March, 2014;
- Mark Johnson (NDA) will provide, to the Secretariat, links of certain UK reports which may be useful in developing the table of content of the summary report;
- The working group agreed to consider a separate meeting to discuss various monitoring aspects, if required;
- The Secretariat agreed to post all presentations on a NEA protected fire-risk webpage;
- The Secretariat considers the provision of general guidance on how to devise future procedures for engineering systems mode changes (e.g. from operational mode to emergency situation) an essential element in ensuring repository safety. The Secretariat suggests that procedures for mode changes shall base on scenario analysis and existing technological features of the system(s). Such topic may be covered in future technical workshop(s).

Meeting Adjourn