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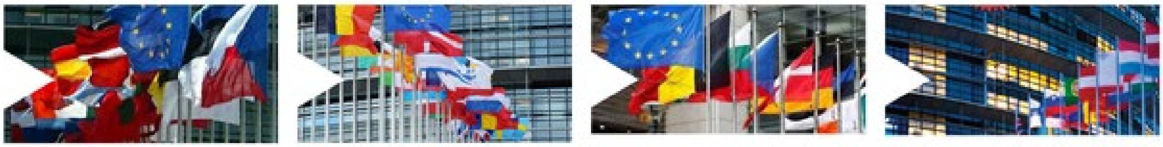

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Fire Protection Design in Underground Mines – A Brief Introduction to the Challenges and Considerations

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Underground mining operations are an important part of the modern mining supply chain, and modern society relies heavily on the products from these operations. However, these operations have some unique and challenging fire risks. Designing for these risks require an understanding of the dangers inherent to working underground, the interactions between various systems, people, and equipment, as well as a proper understanding of various fire protection standards. In many cases, a healthy dose of engineering judgement and common sense is necessary to find practicable solutions to challenging problems. This paper gives an overview of challenges and considerations when developing underground fire safety solutions.

Typical Fire Hazards in Underground Mines

Underground mines have a variety of dangerous equipment and operations. Many of these have fire hazards associated with them. Because of the nature of these operations, many of these can be classified as "Special Risk", for which specific fire protection procedures are not clearly defined, but rather approached in a more general fashion in various currently used fire protection standards. Typical fire hazards in these operations are summarized below:

Fixed Equipment Hazards
Typical underground fixed equipment and machines that have associated fire hazards include the following:

Conveyor Belts: These are very common in underground mines, especially where the mine makes use of decline and strike tunnels. These tunnels are very often long and narrow, with very low roofs, making the use of conveyors ideal to transfer Run-Of-Mine (ROM) ore to the transfer or receiving areas, as shown in Figure 1. As these belts are often in unmonitored and hard to reach locations, possible damage to the belts and insufficient maintenance can lead to conveyor fires developing in places where they can escalate very quickly and result in partial or complete equipment loss, production loss and possibly even in injury and death of people in the area.

Figure 1: Typical conveyor in an underground mining tunnel [Adobe Stock Photo]

Electrical Rooms: A typical underground mine might have multiple electrical installations spread throughout various sections. These can range from Substations and Motor Control Centres (MCCs) to transformers of various sizes. As the underground mining tunnels are often vary narrow with low roofs, the spacing option for electrical equipment is limited, causing this equipment to be installed in small openings in the tunnel walls called “cubbies”. The normal hazards associated with electrical equipment are present with these installations, but the geometry of the tunnels might have a significant impact on how the fire behaves in these spaces. Manual fire-fighting methods are also difficult in these areas, and they are often in far-off corners of the mine, resulting in increased response time by any fire-fighting team which might be available to fight such fires. This will likely result in significant damage to the equipment involved.

Workshops: Many mines may have multiple underground workshops. These workshops are typically used to service a variety of light and heavy vehicles which are used in mining operations. It is also possible that a mine might have a general engineering workshop underground to support the operations. Typical fire hazards in these workshops are the following: Vehicle fires, fuel and oil storage, spillage of flammable liquids, and hot work (grinding, welding, and cutting). Fires in these workshops can happen in any area, depending on the type of work performed in each section. As these workshops are typically built inside ventilated tunnels, an uncontrolled fire can quickly get out of control, resulting in equipment damage and possible injury or even death.

Mobile Equipment Hazards: In addition to the fire hazards posed to vehicles in the underground workshops, it is also possible that a vehicle might catch fire in any part of the underground operational area. This can be for several reasons. Depending on where a vehicle catches fire, it can possibly block off a mining tunnel, which can result in a disruption of production and possibly limiting the escape routes from the tunnel location for any people in the area. An example of a typical mining vehicle in a narrow route is shown in Figure 2.

Figure 2: Underground mining vehicles operate in remote locations with limited escape routes [Adobe stock photo]

Flammable Gasses, Dust and Liquids: Depending on the type of commodity mined, underground mines can have a variety of flammable gases, dust, and liquids throughout the mining sections. The most typical flammable gases are those used in maintenance work, which is typically stored in pressurized cylinders which may be moved throughout the area for various uses. In addition to these, natural methane gas might also be present in substantial quantities in underground coal mines for example. Flammable dust is also found in underground coal mines. In these mines, the mining tunnels are often constructed directly in the coal seam, resulting in the floor, walls, and roof of the tunnels being made from coal. Mining operations can result in fine coal dust, which, when combined with the right concentrations of methane gas and an ignition source, can result in very dangerous coal dust explosions which often cover vast areas underground, causing significant damage and injuries.

Flammable liquids are often found in the workshops, where these liquids are commonly stored and dispensed. Hydraulic fluid is also present in hydraulic powerpacks which service various machines throughout the mine. These present the hazard of hydrocarbon pool or high-pressure oil mist fires.

Ventilation Hazards: A very important part of underground mining operations is the ventilation air, with an example being shown in Figure 3. This not only provides fresh air, but also cooling and removal of hazardous gasses and particles from the production areas. In some instances, ventilation air can increase the danger from a fire in an underground mine, depending on the location of the fire. The ventilation system provides the fire with oxygen it needs to survive and depending on the velocity and direction can spread the flames, smoke, and other products of combustion to areas of the mine which may be occupied by people. If the ventilation controls are not adequate, this might result in injury or death.

Figure 3: Typical primary ventilation fans for un underground mine [Adobe stock photo]

Current methods of Mitigation

Over the years, various mining groups have developed various mitigation measures and approaches to reducing the risks posed by fires in their underground operations. Most mines have Standard Operating Procedures (SOPs) for disaster management, which include responses to fires in the mine.

From a legislative side, a mining country such as South Africa has the South African Mine Health and Safety Act [1] that compels mine management to put in place sufficient measures to protect their operations against fire. Government bodies that are responsible for the investigation of accidents and incidents in mines also publish updated directives and COPs from time to time to improve fire safety in mines. Individual mines or mining groups often choose to use their own fire protection standards, which often consider the recommendations from these COPs.

In recent years, some mining groups have endeavored to standardize fire protection standards throughout the group, with various levels of success. As the fire risks in underground mines are varied, as indicated on a high level earlier in this article, the typical mining house fire protection standards make use of a combination of various international and local fire protection standards which may apply to the various fire hazards that they might have on their facilities.

They often make use of tools such as flowcharts, risk assessment matrices and decision trees, to determine the appropriate responses to fire hazards in their facilities, which include underground mining and operational areas. An example of such a decision tree for determining the need for automatic sprinkler detection on conveyors is shown in Figure 4 [2].

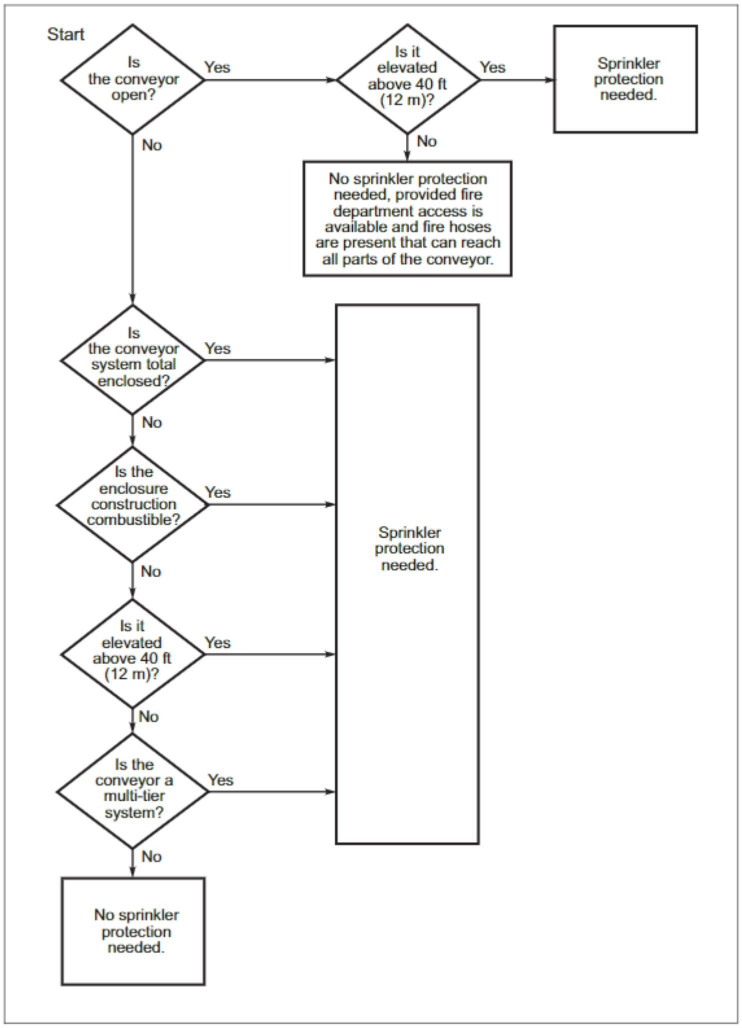

Figure 4: Decision tree for determining the need for automatic sprinklers on conveyors [2]

This is just a single example, but the tools used will depend on a review of the fire hazards present, and the applicable standards and guidelines included in the specification, standards, and COPs of the specific client.

Challenges to Fire Protection Design for this Environment

Using the various available fire protection standards to design for the fire hazards on underground mines might look like a straightforward exercise. However, these standards often provide only general information on the approach to follow when designing fire protection, to make it applicable to general situations. However, in an underground mining environment, there are often unplanned challenges which require ingenuity and common sense to find a practicable solution that strikes a balance between what is practicable and what is required or recommended by the applicable design standards.

An example of this would be the application of FM 7-11 [2] for the protection of an underground conveyor. Now apart from general advice, this document provides a simple diagram on the installation of sprinklers in various environments, including underground. This figure is shown in Figure 5.

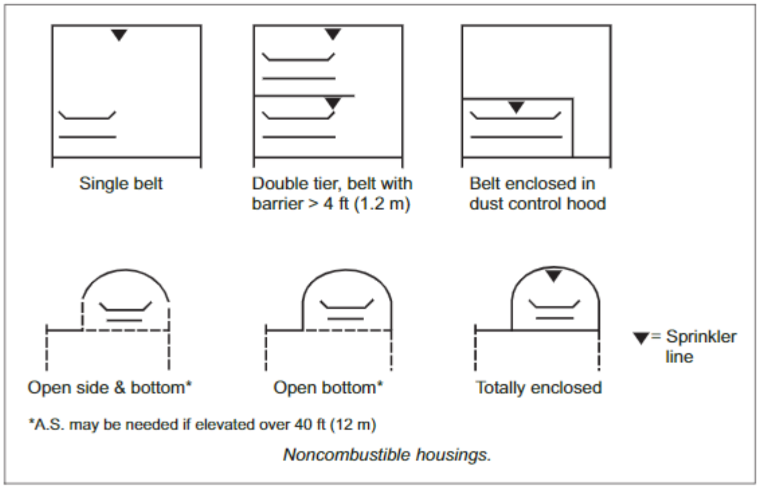

Figure 5: Suggested locations for automatic sprinklers in various conveyor configurations [FM 7-11]

When reviewing the diagram, this might look simple enough, but when working in an underground environment, the fire protection engineer needs to consider various challenges unique to that environment and find ways to overcome them. Examples of typical questions the designer for an underground application should ask are the following:

- How will the uneven mining tunnel affect the flow of hot air and the activation of the sprinklers?
- How fast does this conveyor move, and will the sprinklers have enough time to react to a fire which may only be localized on the belt?
- How fast, and in which direction is the ventilation air in this tunnel, and will the airflow possibly trap people in locations without escape?
- Are there adequate escape routes from the conveyor tunnel?
- How will a sprinkler on the roof protect against a fire that might form between the carry and return sides of the belts, or even below that and the level of the idlers?
- How will loading chutes and other platework on the conveyors affect the operation of the sprinklers?
- Could a fire spread to flammable spilled material next to the conveyor, and will sprinklers provide adequate protection from this?

Now even though this FM datasheet might be adequate for many conveyor applications, the unique challenges of an underground mining environment, might require that other standards such as water deluge [3] or even foam deluge [4][5], be considered for this application, even though this might not be the current standard of the specific mine or mining group. In such a case, it would be prudent of the design engineer to discuss this with client to find the optimal solution.

Even though the example above is only for conveyor belts, this, often iterative approach, needs to be followed for all the fire hazards for which protection design are undertaken. As the fire hazards to people and equipment are often magnified and compounded in an underground mining environment, this places a large responsibility on the shoulders of fire protection design engineers.

Other General Safety Concerns that Impact Fire Protection Design for this Environment

Apart from the fire protection system design considerations, it is also the responsibility of communicating with and assisting the management of underground mines to put in place, or to improve measures that might improve the general fire safety of such a mine. This can take many forms and will be highly dependent on the specific mine. Examples of such measures can include the following:

- Evaluation of escape routes form underground sections, and the effect of possible fires on these.
- Evaluating the adequacy of the entire fire water reticulation system to identify its capabilities and weak spots.
- Evaluation of adequacy of fresh air supply and filtration to underground rescue chambers.
- Review of the spread of smoke in various underground sections due to the ventilation system design. This should be undertaken in conjunction with the ventilation officers of the mine, who are highly qualified and experienced, and have a very important position at a mine with underground sections.

Closing

In closing, developing procedures and fire protection systems for underground mines require extensive knowledge of not only fire science and protection methods, but also of the unique challenges present in this environment. Even though there are multiple international, local and client specific standards available, fire protection engineers should not just accept these as the final word but should always endeavor to review and challenges the current standards. For in doing so, improvements are made, progress is made, and the safety of future generations of underground mineworkers are improved towards the goal of zero harm.

References

[1] South African Mine Health and Safety Act 29 of 1996

[2] DS 7-11 Belt Conveyors (Datasheet) – FM Global

[3] National Fire Protection Association. (2022). *NFPA 15: Standard for Water Spray Fixed Systems for Fire Protection*: NFPA.

[4] National Fire Protection Association. (2019). *NFPA 16: Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*: NFPA.

[5] National Fire Protection Association. (2021). *NFPA 11: Standard for Low-, Medium- and High-Expansion Foam*: NFPA.