

# **FORConnect Initiation System (FIS) wireless initiation for non-electric shock tube detonators. The solution to the missing link between manual and automation of blasting operation in underground mining, tunneling**

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## **ABSTRACT**

As we know drill & blast method of rock excavation is still considered as most cost-effective way of excavation. The cycle of operation with drill & blast methodology in underground mining or tunneling follows a well-defined pattern i.e., scaling, rock-reinforcement, drilling, charging, blasting, ventilation, loading and haulage of material. Over the years with developments in the mechanization and autonomous technology some of the activities in the above referred cycle of operation has been fully mechanized or automated e.g. drilling, material haulage. Although there has been lot of technological advancements in the industry but dream of having a complete operational autonomous cycle in mining or tunneling is still to be realized. One of the bottlenecks in operation cycle is manual explosive charging, connection of shock-tubes (or bunching) and blasting activities. With recent developments in mechanized, semi-automated explosive charging equipment, it would be possible to remove explosive charging crew from hazardous operation. But still the connection of charged holes, bunching of non-electric shock tubes needed to be performed manually. It exposes the blasting crew to high risks and dangers of rock-fall, rock-burst at unsupported working face in tunnels, mines. FORCIT Explosives realized these challenges faced by blasting crew and with its deep knowledge, understanding of customers' needs in Nordic mining, tunneling operations, it has developed a wireless initiation system for shock-tube detonators, it is called FORConnect Initiation System (FIS)\*. In authors view FIS\* will support mining and tunneling company's vision of complete autonomous operation cycle at working face. In this paper we are presenting the FORConnect Initiation System (FIS)\*, a wireless initiation solution for non-electric shock-tubes. FIS\* will eliminate manual connection or bunching of shock-tubes, it will minimize the risks exposure of the blasting crew members at unsupported hazardous working face in underground mines, tunnels.

## **1 INTRODUCTION**

The cycle of operation with drill & blast methodology in underground mining or tunneling follows a well-defined pattern i.e., scaling, rock-reinforcement, drilling, charging, blasting, ventilation, loading and haulage of material. With recent developments of mechanized, semi-automated explosive charging equipment, it is possible to remove explosive charging crew from hazardous operation but still the connection of charged

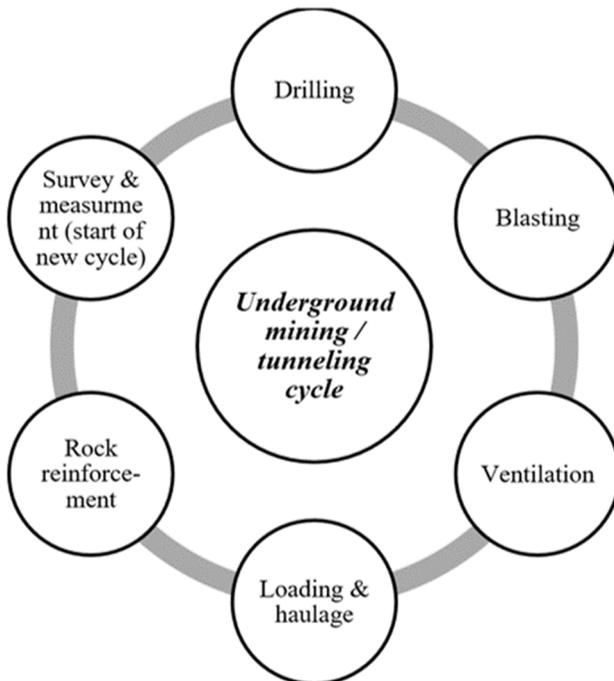
holes, bunching of non-electric shock tubes remains manual and exposes the blasting crew to dangers of rock-fall, rock-burst at working face.

To address the challenge of manual connection of charged holes, FORCIT Explosives has developed FORConnect Initiation System (FIS)\*. In the sections below in this paper we will look at details.

## 2 DRILL AND BLAST CYCLE IN UNDERGROUND MINING AND TUNNELING OPERATION

### 2.1 General overview of drill and blast operation cycle

In underground mining or tunneling, operation cycles follows a well-defined pattern. Figure 1 representing a general overview of underground mining, tunneling operation cycle.



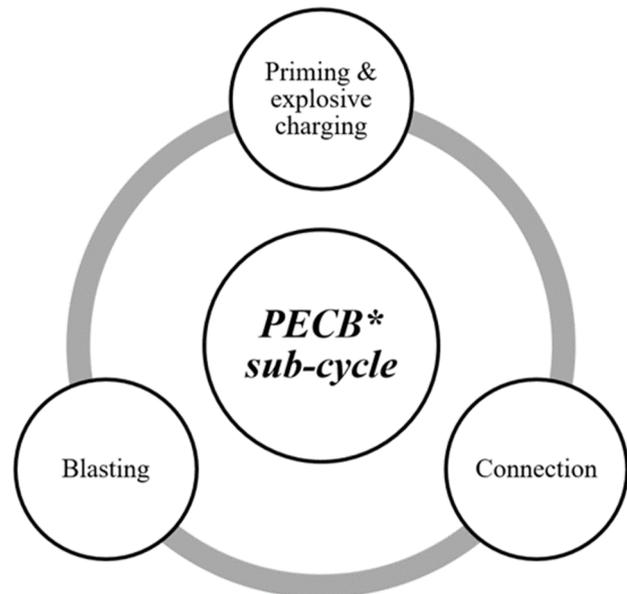
**Figure 1** General overview of underground mining and tunneling operation cycle.

### 2.2 Explosives charging and blasting operation sub-cycle

Generally underground development or production activities start with drilling as the first step and starting point of a new cycle, refer to Figure 1. Next step is blasting, it is considered as one activity but practically it consists of a sub-cycle of three different steps i.e. priming & explosive charging, connection of charged holes, and blasting, shown in Figure 2 below.

Figure 2 below showing sub-cycle **PECB\***, i.e.

- PE-priming & explosive charging,
- C-connection,
- B-blasting.



**Figure 2** Explosives charging and blasting, **PECB\*** sub-cycle.

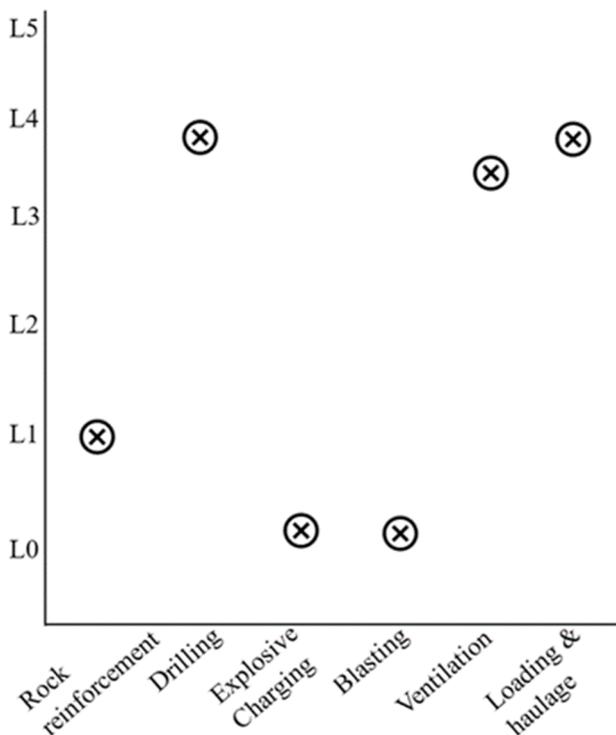
All 3-different activities shown in PECB sub-cycle above, performed at the same working face but it varies from each other in its application. Depending on local practices followed in the mines or tunnels, the same team could be handling all these 3-different tasks or in some places it is divided between PE (priming & explosives charging) team and CB (connection & blasting) team. The explosives charging and blasting team involved with PECB sub-cycle activities should have good application knowledge and are certified to handle explosives and accessories safely. Today almost all the activities or tasks involved in above referred cycle in Figure 2 are either manual or semi-mechanized and it presents safety risk for the personnel working at production or development face in underground tunnel and mines.

An overview, status of mechanization, automation in underground and challenges associated with, described further in section 3 below in the paper.

### 3 STATUS OF MECHANIZATION AND AUTOMATION IN UNDERGROUND OPERATION AND CHALLENGES

#### 3.1 Status of mechanization, automation in underground mining and tunneling operation

Figure 3 is modified version from original Singh & Lundhede 2023, showing an overview of mechanization and automation in underground mining, tunneling operation.



**Figure 3 Mechanization and automation level in underground mining & tunnel operation cycle.**

The horizontal scale of the Figure 3 above, showing a general operation cycle of underground mining, tunnels around the world and the vertical scale showing mechanization and automation level from L0 to L5, as defined by GMG (Global Mining Guidelines Group).

As described in referred GMG guidelines and authors interpretation with reference to Figure 3 above are,

- Level 0 (L0) – No automation / entirely manual
- Level 1 (L1) – Assistance / some features in the system assists operator

- Level 2 (L2) – Semi- autonomous / some portion of tasks in the system performed in autonomous mode
- Level 3 (L3) – Conditionally autonomous / system can complete designated tasks in autonomous mode
- Level 4 (L4) – Highly autonomous / system can operate in autonomous mode and minimize the risks
- Level 5 (L5) – Fully autonomous / system can operate without inference of operator

The existing level of mechanization and automation in underground operations varies a lot, referring to Figure 3 above, explosive charging and blasting operation is at L0 i.e. it is performed manually, whereas material haulage has almost reached at L4 – highly autonomous. The goal in the mining and tunneling industry is to move working personnel from hazardous manual operation to safe place and let the machines performed repetitive tasks. Latest technological developments in explosive charging for underground mining, tunnel operations are covered in following sections of this paper.

#### 3.2 Recent developments in automation and mechanization in underground explosives charging

Across the globe different companies have taken many initiatives and working on projects to automate explosive charging operation. With reference to shock-tube initiation technology and FORConnect Initiation System (FIS\*), the authors noted following two recent product development –

- Charmec Revo – developed by Normet, Finland.
- ABB Robot Charger – developed in a technology development project led by Swedish mining companies Boliden, LKAB, together with explosive manufacturer LKAB Kimit and FORCIT Sweden AB.



**Figure 4a** Normet Charmec Revo working prototype.



**Figure 4b** ABB Robot Charger working prototype.

More information about these products and projects could be found on respective websites of the companies.

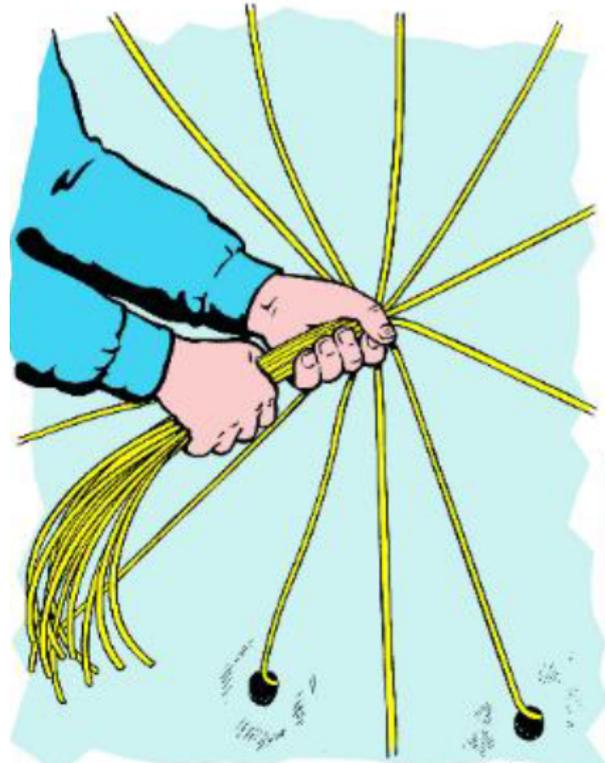
Normet's Charmec Revo and ABB Robot Charger, both uses robotic arm for explosives charging i.e. it eliminates human exposure in front of working face. With this development authors view is the PE (i.e. priming and explosives charging) operation as shown in Figure 2 above could be considered as reaching level L3 in mechanization and automation scale, refer to Figure 3. Robotic arms of these machines are developed to work with shock-tube initiation system, detonators, and primers.

### 3.3 Challenges and bottlenecks

Even with development of robotic solutions for charging of explosives, as described in section 3.2 above, there are still some parts of operation in PECB cycle, refer Figure 2, in underground mine or tunnel face where personnel need to

enter in the hazardous working environment and perform the tasks manually.

The challenging task of connection or bunching of non-electric shock-tubes at the working face as shown in Figure 5 below, is to be performed manually today.



**Figure 5** Example of manual connection or bunching of shock-tubes.

The task of manual connection or bunching of shock-tubes, are one of major bottleneck in achieving the goal full autonomous cycle in underground mining face or tunnel. Depending on the working conditions, size of blasts, local practices and processes followed by mining and tunneling companies, the connection or bunching time of shock-tubes at the blasting face varies from 5 minutes to >20 minutes. Authors experience from Scandinavian mines and tunnels shows that on an average, shock-tube connection or bunching time takes around 5 to 10 minutes per blast rounds. Considering normal mine development or tunnel operation cycles. To perform this task of manual connection or bunching, the explosives charging and blasting team needed to re-enter in the hazardous, unsupported working environment. In this

period, they are constantly exposed following risks and danger –

- Injury to personnel from rock fall from roof or side wall. It could cause damage to assets and infrastructure.
- Risk of exposure to rock-bursts or seismic activities in deeper underground mines could create catastrophic danger for personnel working there.

FORCIT Explosives realizes this challenge and to address it developed an initiation system for shock-tubes which works on wireless principles. In section 4, it is described in detail.

#### 4 INTRODUCTION TO WIRELESS FORConnect INITIATION SYSTEM (FIS\*) FOR NON-ELECTRIC SHOCK-TUBE DETONATORS

##### 4.1 Introduction

FORCIT Explosives with its long history of developing innovative products and deep understanding of its customer need in Nordics, started an internal project to develop a wireless solution to initiate shock-tubes detonators and primers. The R&D (research and development) team of FORCIT Explosives together with its technology development partners and customers actively worked on this project for last 4 years and successfully demonstrated this technology in real application environment in underground mine development blasting face in Q1-2024.

Considering fundamental need and value of safety for personnel working with explosives & blasting in underground mines, tunnel FORCIT Explosive's main objective with development of FORConnect initiation System (FIS) was to provide wireless initiation solution to non-electric shock-tubes detonators, primers, so that blasting team do not need to enter in the danger zone for connection or bunching of shock-tubes at unsupported mine or tunnel face.

In general mechanization and automation improves safety, productivity in mining and tunneling operations, FORCIT Explosives' vision with FORConnect Initiation System (FIS) project was to enable robotic, mechanized explosives charging and blasting. The mission of

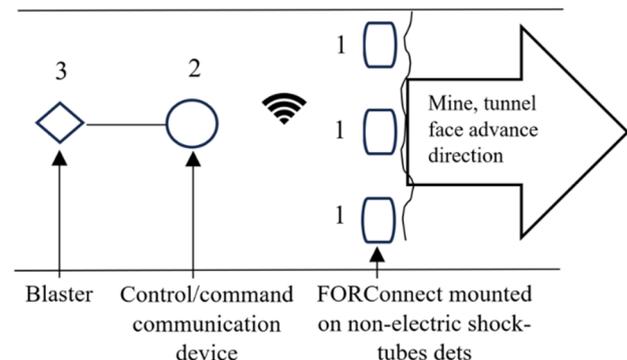
the project was to develop a safe, reliable, and cost-effective wireless initiation solution capable of initiating non-electric shock-tube detonators. The authors believe FORConnect Initiation System (FIS) is first of its kind product in the industry for initiating non-electric shock tube detonators in wireless mode.

##### 4.2 Description and working principle of FORConnect Initiation System (FIS)

The FORConnect Initiation System (FIS), consists of 3 components i.e.,

1. FORConnect
2. Communication/control device for ignition
3. Blasting interface /device

Figure 6 shown below showing working principle of FORConnect Initiation System (FIS).



**Figure 6 FORConnect Initiation System (FIS) working principal sketch.**

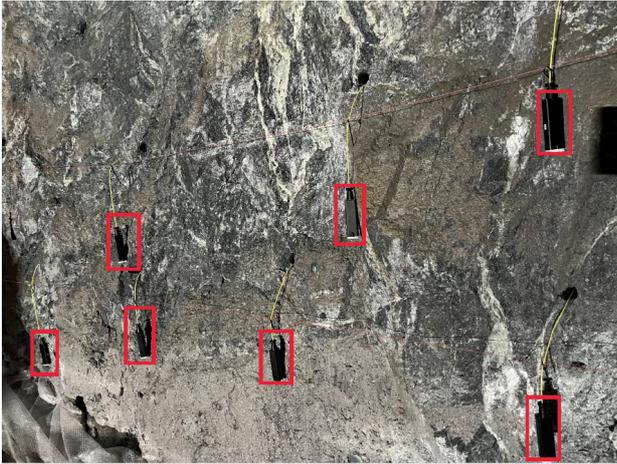
The FIS working principal is represented in Figure 6 and it follows following process:

- i. FORConnect attached to non-electric shock-tubes at site workshop or site magazine before taking it at working face.
- ii. Priming and charging of holes as per local practices followed in mines, tunnels.
- iii. Setting up two-way wireless communication between control/command device and each charged hole with non-electric shock-tube detonator attached with FORConnect.
- iv. Blast interface /blaster communicate with control/ command communication to check all FORConnects are connected and

match to the planned number of charged holes.

- v. Blast interface / blaster sends the final ignition command wirelessly to FORConnects which initiate the attached non-electric shock-tubes detonators.

Pictures from technology demonstration in underground mine are shown below in Figure 7(a) and 7(b).



**Figure 7a** Prototype FORConnects module marked with red color are tested in underground mine.



**Figure 7b** Prototype FORConnect control/command wireless communication device and blast interface/ blaster.

#### 4.3 Results and next steps

- FORConnect Initiation System (FIS) successfully able to ignite non-electric shock-tubes detonators on wireless command.

- Non-electric shock-tube detonators from different manufacturers are tested and all ignited with 100% reliability in wireless mode with FORConnect Initiation System (FIS).
- Next phase of the project is industrialization of the FORConnect Initiation System (FIS) together with FORCIT Explosive customers and development partners.

#### 4.4 Benefits with FORConnect Initiation System (FIS)

- Improve safety for personnel working in underground working face. With wireless initiation of shock-tubes FORConnect Initiation System (FIS) eliminates need of manual connection or bunching of non-electric shock-tubes.
- Enable mining companies' vision of complete mechanization, automation of underground mining cycle by provide wireless solution to manual connection or bunching of shock-tubes.
- Improves sustainability, potential for reducing standard length of shock-tubes used in the market today.

## 5 CONCLUSION

FORConnect Initiation System (FIS) successfully demonstrated wireless ignition solution for non-electric shock-tube detonators. In authors view its first initiative taken in the world to initiate non-electric shock-tubes wirelessly. Next phase of the project will be crucial where new user interface and products for mass production will be developed.

## REFERENCES

- ABB, (2024). ABB Robot Charger, picture source – <https://www.new.abb.com/>, retrieved on dtd. 20240313.
- Atlas Copco, (2015). The sequential operations performed at the face in mine drifting. Atlas Copco Underground Mining – Talking technically (pp 71 -72).
- Global Mining Guidelines Group (GMG) website <https://gmgroup.org/>, retrieved on dtd. 20240312.
- Normet, (2024). Normet Charmec Revo, picture source – <https://www.normet.com/>, retrieved on dtd. 20240313.

Orica, (2018). Exel Non-Electric Initiation System, picture source – Instruction manual, retrieved on dtd. 20240313.

Sandvik Tamrock, (1999). Drill and blast cycle. Rock Excavation Handbook, (pp 214 -215).

Singh, N. & Lundhede, O. (2023). The autonomous system cycle approach in off-road industrial applications – a holistic view. Published in proceedings of the 15<sup>th</sup> International ISRM Congress 2023 & 72<sup>nd</sup> Geomechanics Colloquium (pp 715-720), 9 -14 October 2023, Salzburg, Austria.