



## Efficient self rescue of tunnel users by use of intelligent exit signs.

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### 0. Abstract:

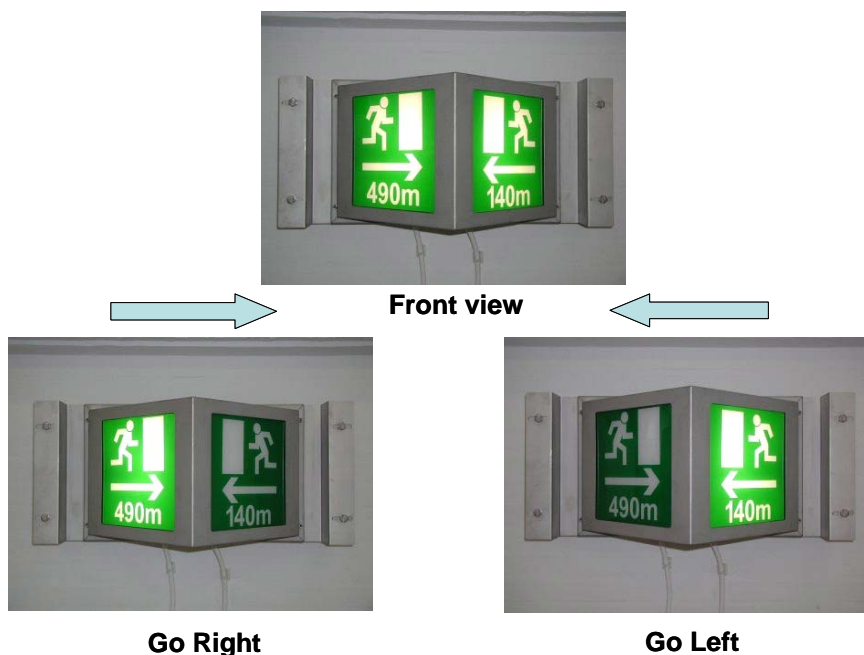
This paper describes the technical functionality of a safety concept for efficient self rescue of tunnel users.

The aim for this paper is to describe the function of a technical concept to improve safety for tunnel users in case of an escape situation in a tunnel.

The concept comprises intelligent escape light fixture in combination with a redundant power supply and cabling system.

In this paper we will try to clarify the thoughts and basic ideas behind a concept where escape signage is an integrated part of the overall safety system in a tunnel.

The technical features described in this paper have been installed and tested in real environments in a 16 km long twin bore Metro tunnel under the city of Copenhagen Denmark.





## **1. Introduction.**

In the last decade a lot of major tunnel complexes around the world have experienced serious accidents. The most serious accidents involve fire and have caused destruction of material and loss of lives.

By monitoring these very unhappy situations it is obvious that one of the most important factors when it come to saving lives is to reduce the time of impact from the unhealthy environment.

The shorter time a person is exposed to high temperatures and toxic gasses the higher the chance is to survive the accident without, or with limited, permanent damages to the health.

Many engineers are doing a great effort to prevent accidents. An increasing number of systems and measures have been taken to mitigate all thinkable accident scenarios.

In the initial minutes of a tunnel accident the tunnel users are alone in the decision making about their own safety and if taken wrong it could be fatal.

It is therefore important to provide the tunnel users with sufficient information about the tunnel and the safety options in order to enable them to make the right decisions about their escape.

In some of the major accident that have occurred lately the tunnel users has been trapped because they were unable to find the exits or the emergency shelters. It is a very unfortunate situation which often could have been prevented with simple means e.g. improved signage.

The signage in tunnels around Europe varies in quality. The visibility is often limited by the size of the sign, dirt and the fact that the signs often are un-illuminated.

In a road tunnel the visibility is often low due to exhaust fumes. In case of a fire smoke will soon reduce the visibility to a minimum. It is therefore important to consider these facts when designing the tunnel user information system.

It is reasonable to assume that the numbers of casualties are in some way proportional with the time spend in the smoke. The latest tunnel accidents in the Alps have shown that suffocation due to smoke are the main cause of death in a tunnel accident. It is therefore of great importance that the tunnel users can get away from the hazardous environment as quick as possible.

## 2. Traditional escape signage in tunnels.

In this clause we will describe some general aspects concerning the traditional method of designing escape light systems.

### *Visibility:*

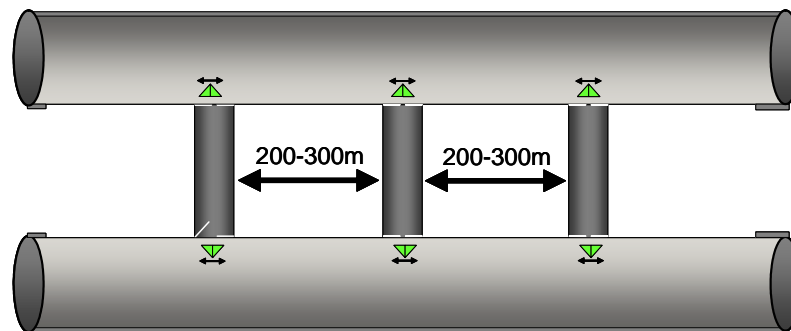
The traditional escape signages in tunnels are often limited to a minimum.

The signs are often small and provided with a reflective surface only functional when illuminated by the headlights from a vehicle. When the accident occur the traffic stops i.e. the illumination of the signs are terminated and the sign is not visible any more.

The distance between the signs are often 200-300m and the signs are placed close to the escape door.

The figure below shows a traditional twin bore tunnel equipped with escape lights for every 200-300 m.

### Traditionel installation of escape signs



Exit signs placed with a mutual distance of 200 – 300 meters are impossible to find in the smoke.

Exit signs showing both escape directions at all times can guide you towards the accident area.

The combination of size, low visibility and no illumination makes it difficult to see the signs find the escape doors.

Other tunnels are fitted with illuminated sign but the distance between them is often too far as mentioned above. Simple tests will show that these signs are equally difficult to see in a fume filled tunnel.

### *Information given by the sign:*

Escape signs are designed to show a pictogram indicating the direction to an escape route. If there are two escape routes, one in each direction the signs are designed to show both directions. However if one of the routes are blocked by a fire the signs still leads in the hazardous direction. This means that the sign can be misleading in some cases. This situation is difficult to avoid with traditional escape signs.



*Temperature:*

The illuminated signs are often of a robust but and simple construction. The key words for the layout of these types of light fixtures are long life time of light sources and easy maintenance and there off cost efficient maintainability.

Considerations about temperature resistance for the complete function and the light sources ability to provide light in case of an emergency are often overlooked. Most florescent light sources have a maximum operational temperature of 70° C. By this temperature the light source will not provide an illumination level sufficient to be visible and useful as an escape light.

This means when the temperature rises due to hot smoke passing through the tunnel the luminance from the light sources are reduced radical. It can therefore be concluded that some of the escape light fixtures are unable to serve their initial purpose to show the escape route.

*Power supply:*

Power supply to the light fixtures is often based on an emergency power supply system to enhance the availability in case of a power failure in the primary power supply system. In case of a physical impact on the cable installation e.g. de-railing or fire a redundant installation must be considered. Often light fixtures are not designed for redundant cabling. Special design considerations have to be taken to enable the light fixture to operate on to separate power circuits.

### **3. Intelligent escape signage in tunnels.**

In this clause we will describe some of the aspects concerning a concept comprising an intelligent escape light systems.

Intelligent escape signs are a concept where the light fixtures are an integrated part of the safety system in the tunnel. The escape sign are controlled by the tunnels SCADA system and interact with the tunnel ventilation scenarios in order to guide the tunnel user away from a fire or accident area.

*Concept:*

One escape light fixture consists of two separate units in one house. Each unit can be operated independent from the other. The sign is divided vertical and can indicate three escape scenarios i.e. both directions in normal operation, go left or go right. This is achieved by switching between the circuits in each side of the housing.

The lighting installation is wired to the SCADA system via contactors in the LV-switch boards. By dividing the light fixtures on different supply circuits and cables redundancy is achieved.

*Visibility:*

The escape sign must have a size that enables the user to locate it easily in the tunnel.



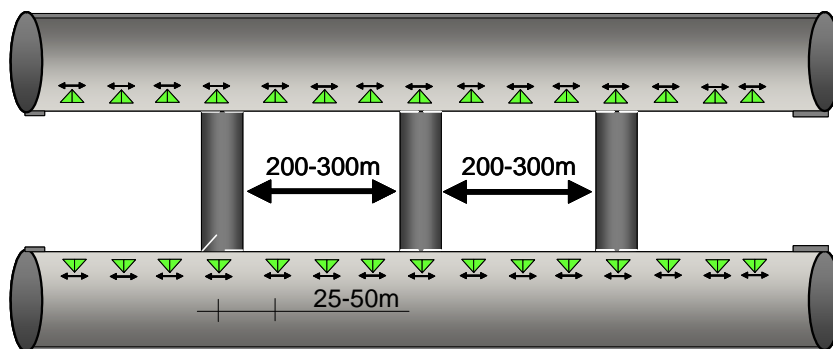
The signs must be illuminated from the back in order to provide a high level of luminance. The distance between the signs must not exceed 50 m as it can be difficult to maintain visibility longer than 25m when there is smoke involved.

The signs must have a geometrical shape that enhance the reading friendliness and removes any doubt of correct information of escape direction.

The signs must show the distance to the nearest exit in both directions.

The figure below shows a traditional twin bore tunnel equipped with escape lights for every 25-50 m.

### Controlled Escape direction



**Fast and accurate information is minimising the time for the people to find the shelters.**

**Automatic selection of escape direction avoids wrong decision making.**

The combination of size, geometrical shape, high luminance and uniform indication of distances makes it easy to locate the signs and find the escape doors.

When switching of the one side of the sign that indicates the direction towards the accident tunnel users will then be guided in the safe direction.

#### *Variable indication of escape direction:*

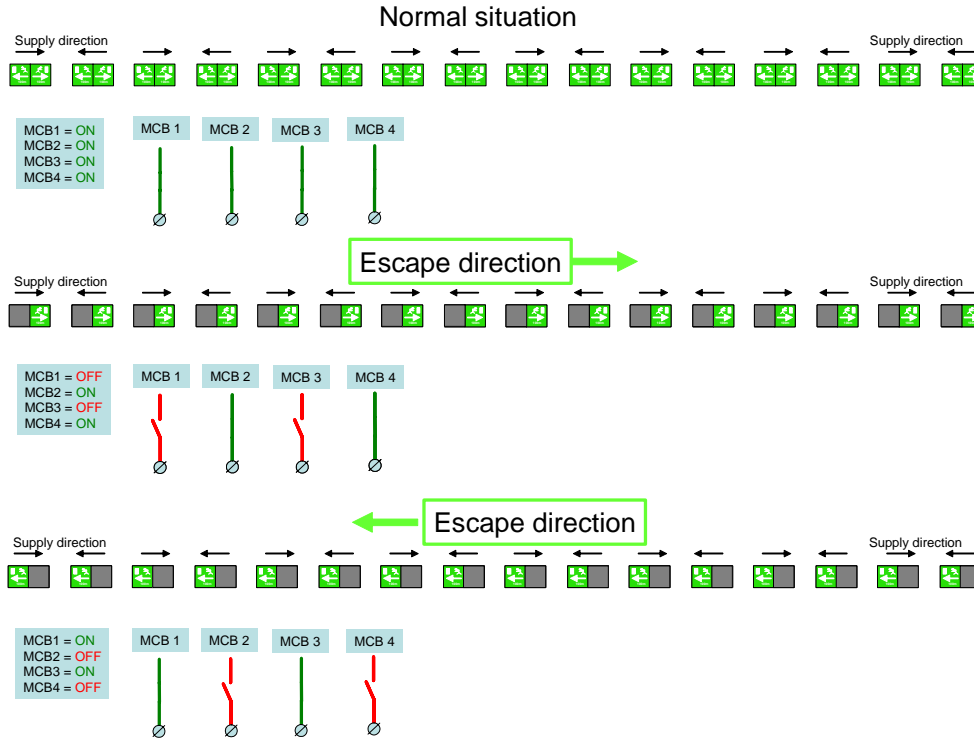
Intelligent Escape signs are designed to show a pictogram indicating the direction to an escape route. If there are two escape routes, one in each direction, the signs are designed to show both directions in normal operation. However if one of the routes are blocked by a fire the signs can be controlled by the SCADA system and lead the tunnel users away from the hazardous area.

In case of a fire the tunnel operators initiates an emergency scenario where tunnel ventilation are started and the direction of exhaust is chosen. In the same scenarios the configuration of the escape signs can be pre-set. This feature is implemented in the Copenhagen Metro as a part of the overall safety concept for the tunnel.

The figure below shows in a simple form the status of the contactors in the three basic operation modes. If more scenarios are necessary the installation can be subdivided into additional zones.



Above each row of light fixtures the direction of supply are shown. This is a part of the philosophy concerning redundancy of the supply cabling. This will be described later in this paper.

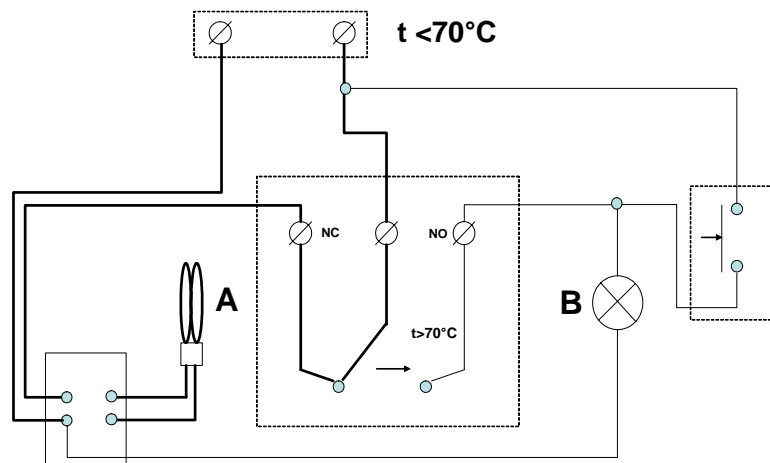


**Temperature:**

In order to mitigate the lifetime requirements of light sources and temperature resistance a special patent pending circuit has been developed. This circuit comprises again two circuits, one for normal operation temperature up to 70°C and one for temperatures above 70°C. The circuit for temp. < 70°C is for normal operation and consists of a 13W PLC fluorescent light source (A) with more than 8000 operation hours.

The circuit for temp. > 70°C is for emergency operation and consist of a 60W Halogen light source (B) that can withstand high temperatures. A thermal devise switches between the circuits in case of temperature rise in the surroundings.

**Normal operation**



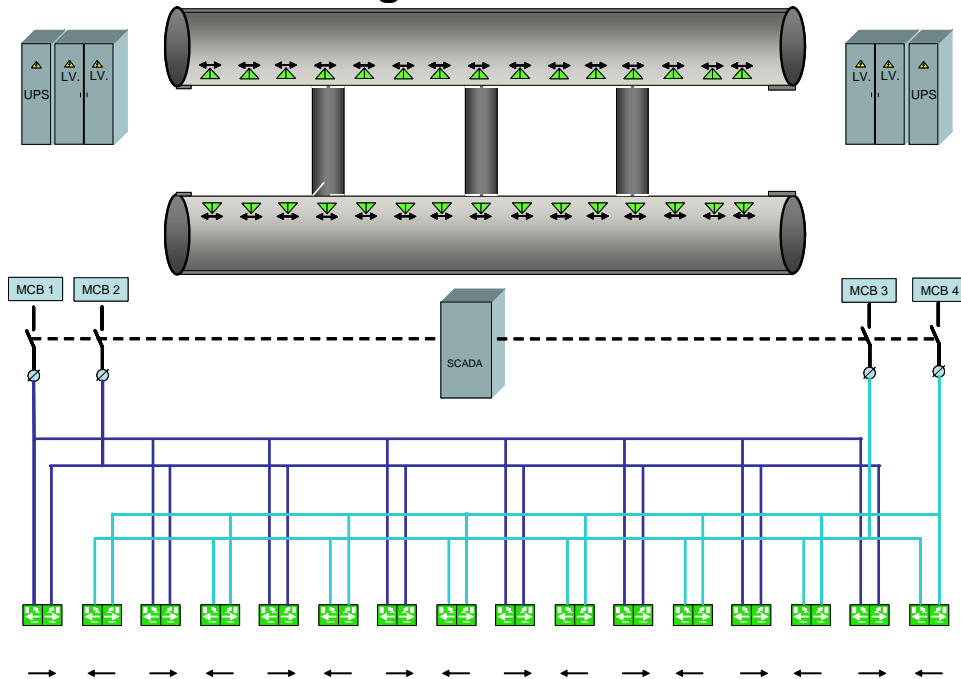


The light fixture is fitted with two circuits as shown above (one for each side).

**Power supply:**

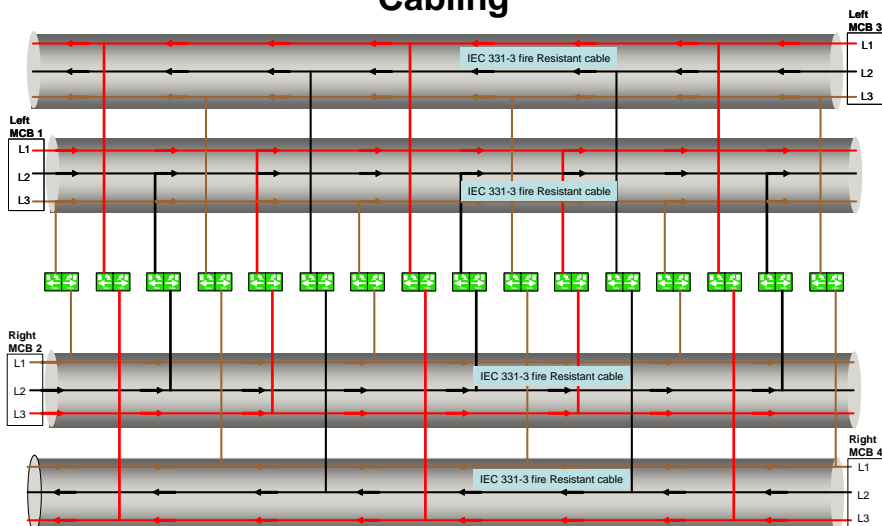
In order to achieve a high level of safety and reliability in the system the power supply to the light fixtures must be based on an emergency power supply system. Redundant cabling must be provided to prevent malfunction in case of a physical impact on the cable installation like de-railing or fire. The intelligent light fixtures are prepared for redundant cabling with full isolation between the two different power sources.

**Cabling and installation**



The figure above shows in principle the low voltage and SCADA installation. Each contactor controlled by the SCADA is placed under the MCB for each circuit. From each supply direction there are two MCB's for each group of light fixture. The cables are interconnected to every second light fixture from each side of the supply directions. The figure below shows the combination of different supply directions and the double cabling that provides a very high level of safety based on redundancy.

**Cabling**

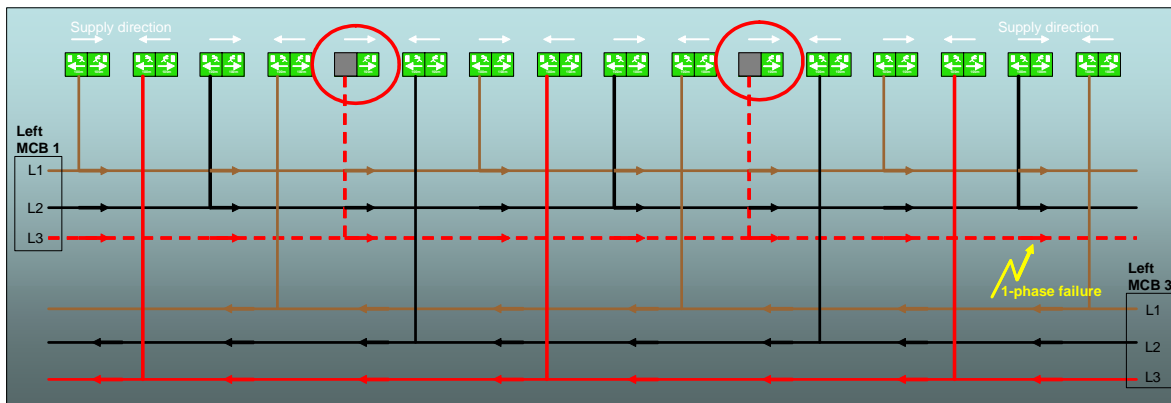




### 1-phase failure:

In case of a simple failure, like a 1-phase failure in the supply from the switchboard in one direction, only every fifth light fixture in a row is out of operation in one side. This means that in normal operation all light fixtures will be illuminated however some only partly. This means that the failure is not so critical that it requires immediately attention.

## 1- phase failure

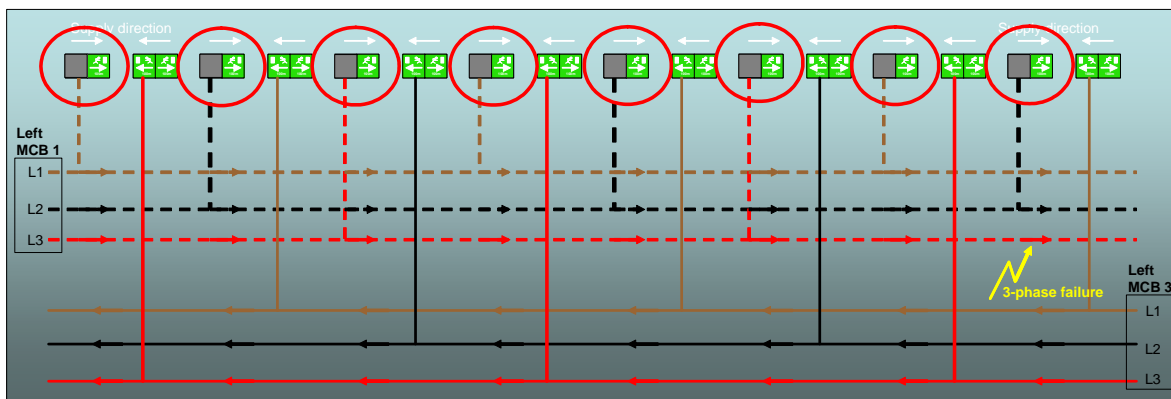


Only 15% of the exit signs are partly out of operation.

### 3-phase failure:

In case of a simple failure, like a 3-phase failure in the supply from the switchboard in one direction, only every second light fixture in a row is out of operation in one side. This means that in normal operation all light fixtures will be illuminated however some only partly. This failure is however critical and requires immediately attention.

## 3- phase failure



Only 50% of the exit signs are partly out of operation.



#### **4. Technical considerations.**

When designing an intelligent escape light installation it is important to consider the complete safety concept for the tunnel.

The overall SCADA system must be the platform for all operations as it is impossible for any tunnel operator to remember how to operate all the different safety systems in the tunnel when an accident occurs.

When planning the safety philosophy in a tunnel various accident scenarios can be identified and the criteria's for tunnel ventilation and escape signage can be preset in the SCADA computer.

The safety philosophy in the installation must be well prepared and comprise as many systems as possible and must be based on pre defined scenarios. In case of special situations an override facility must be implemented.

The operation of tunnel fans and dampers is a subject which many designers are familiar with. Many of the considerations made on the ventilation philosophy can easily be transferred to other systems. The escape direction is almost always based on the direction of the air flow in the tunnel. By integrating the escape light installation in the tunnel ventilation control system tunnel users are always guided in the safe direction.

#### **5. Conclusions:**

For rescue operations in tunnels it is essential to enhance the safety for all people involved, especially for the tunnel users.

When minimising the time of exposure to hazardous environment by improving the tunnel users chance of finding the exits and shelters, the chance of saving lives are far greater than the current situation in most tunnels around Europe.

By uniforming the layout of the safety equipment and signage the chance of survival of untrained tunnel user are improved.

By implementing an intelligent escape sign system the tunnel users can be rescued faster and the chance of saving lives are greater.

Tunnel accident will always be a part of the risk scenario however if more life's are saved the accidents can be reduced to only comprising material damage which will be an improvement of the situations we have experienced in the last decade.