# INTERACTIVE INTEROPERABILITY BETWEEN FIREFIGHTERS AND FIRE PROTECTION EQUIPMENT

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## Abstract

An operation of fire protection equipment may be dangerous for intervening fire-fighters in some cases. Therefore, it is necessary, in addition to the analysis of fire development which includes a description of real fire scenarios, to affect active response of fire safety measures.
In 2009 the complex automatic fire protection equipment of coal handling route was installed into operation in Tušimice power plant. However, after starting the operation it showed that activation of the extinguishing system on the inclined conveyor bridge threatened the health and life of fire-fighters conducting an intervention.
In the paper an interactive algorithm that ensures a flexible cooperation intervening fire-fighters and automatic extinguishing system without a risk of fire-fighters life is investigated. Possible fire scenario is analysed in FDS. By numerical simulation applicability of the algorithm is confirmed. Development of gas temperatures in strong chimney flow gives also a view into part of mechanical response of structure.

**Keywords:** coal handling bridge, fire-fighters intervention, automatic extinguishing system, numerical simulation, fire development

## INTRODUCTION

In 2009 the installation of a complex fire protection equipment of coal handling route was started in Tušimice power plant. Equipment consisted of sensors of temperature above and under belts, coal dust sucking off, alarm system and automatic extinguishing system with sending signals to 3 different surveillance locations. Automatic extinguishing system was set to start in 5 min after fire alarm. However this time limit was insufficient to complete a fire survey by fire-fighters. In case of automatic extinguishing, very dangerous conditions for fire-fighters originated from the water flowing down on inclined coal handling bridge. Moving on inclined greasy floor covered with continuous flush of water (about 6760 l/min) was found as life-threatening. In the first moment there were two solutions. To stop using of automatic start of extinguishing system – the solution could lead to a big fire, or to do not realize fire surveys. The second solution was not acceptable because of high number of false alarms (in last 8 years - 676 false alarms). Extinguishing by false alarm would cause several days of lay-by of power plant and loss of 40.000 Euros per day.
The solution was found as an interactive algorithm of interoperability, which enables both an elimination of false alarms or competent control of fire-fighting and automatic extinguishing and cooling of construction in the shortest possible time in difficult conditions of the inclined coal conveyor bridge.

## 1 DESCRIPTION OF INCLINED COAL HANDLING BRIDGE

Coal handling bridge T12 of Tušimice power plant consists of coated steel truss construction inclined in angle of 16°, see Fig. 1 and Fig. 2. Total length of 170 m reaches the height of 47 m. The bridge is 7 m width and 3,3 m high. Steel structure consisted of trusses with upper and lower stiffening trusses is covered by aluminium sheet, window openings are made of reinforced glass. Massive rigid frames are spaced at 3 m. Bottom deck laying bellow two conveyors with rubber belts is made of reinforced concrete. By the aid of fire protection walls the coal handling bridge is divided into 2 fire compartments of lengths 102 m and 68 m. However, because of conveyors going through there are big holes in the fire partitions.

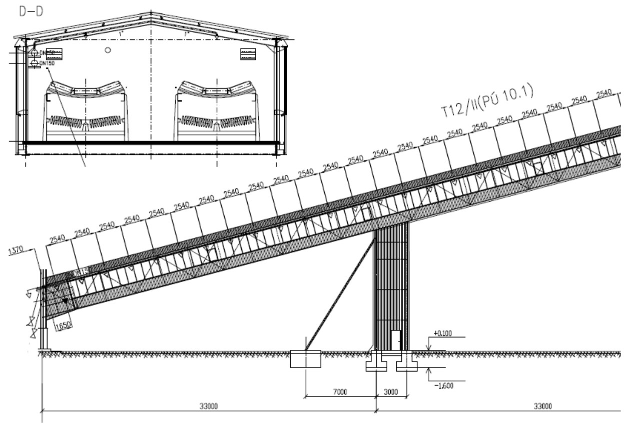


Fig. 1 Construction of coal handling bridge T12

Fig. 2 Tušimice power plant

## 2 DESIGN FIRE SCENARIOS

Four main reasons of the fire on the coal handling bridge can be specified:

- seized rollers under the belt causes ignition of the elastic rubber belt (ignition temperature – 460 °C), after burning the coal on the belt can ignite, the belt may sever, and swirling coal dust can explode (scenario A)
- sparkle from the seized roller can initiate ignition of coal dust – thanks to regular cleaning it is not probable
- transport of fire outbreak from outside – burning of coal followed by burning of belt or reversely (scenario B)
- failure of wiring, human mistake, nature element – burning of coal or coal dust, ignition of belt (with previous reason compiled to scenario B)

### 2.1 Scenario A

Burning of the bottom of belt and its subsequent rupture causes whirling of burning materials and the coal dust. This may exceed the limits of coal dust explosion. Early detection of fire from the bottom of the belt is possible only by monitoring the temperature in the area of rollers. Linear heat detectors are installed in the area of conveyors rollers. When the detected temperature is higher than 80 °C, signal is sent to local fire station. However indication of higher temperature does not start any extinguishing sequence. Starting of automatic extinguishing system is not favourable in this case because of a small effect of extinguishing during burning at the bottom side of the belt and conveyors cannot be stopped, because the belt does not ignite during movement. This fire scenario is not further considered because automatic extinguishing does not start.

### 2.2 Scenario B

In this scenario fire detection is possible by monitoring the temperature above the belt. After detection of the temperature higher than 80 °C belts are stopped and fire intervention is started. The fire development can be determined by calculation of the design fire with following conditions:

- the most conservative case is considered (both belts are full of coal)
- a rupture of the belt is not reached
- an explosion of coal dust is not included

## 3 NUMERICAL SIMULATION

In inclined bridge there is a strong chimney effect, which accelerates the combustion on one side and intensively cools the construction of the bridge on the other side. Cold air is sucked by lower openings and heated by burning of coal on handling bridge. Holes in fire walls allow air flow to upper part of the bridge where the hot air can leave by upper openings. Numerical simulation based on CFD analysis is the most suitable method for solution of this problem. Fire scenario B is studied numerically by FDS 5 (McGrattan, 2010).

### 3.1 Description of model

One of the FDS model of inclined bridge is shown in Fig. 3. The dimension of the computational domain is 165 m by 7 m by 50,5 m. The size of openings for conveyors in the lower, middle and upper fire walls is 2 x 2 m by 1,3 m, middle fire wall is placed in two-thirds of the bridge. In the model there are 6 different materials including steel, concrete, plaster, fire brick, coal and rubber. The detailed properties of these materials are described in (Entler, 2013). Properties of burning materials come from Catalogue of brown coal 2009-2010 of mining company SD a.s. and Czech standard CSN 73 0804. Surface properties of the obstructions in the FDS model include steel sheets, concrete bottom deck, plaster and fire brick walls, coal layer and rubber belts. Nominal movement of the conveyor belt of 2 m/s is simulated by air flow. Heat release rate, air velocity above the centre of fire, the air temperature below the ceiling and the wall temperature of the structure of the bridge are measured in 10 min (time needed for fire-fighters intervention).

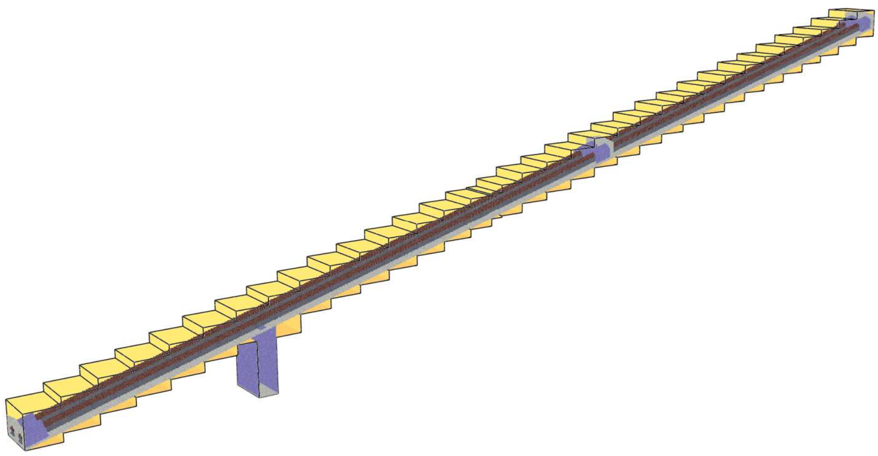

Fig. 3 FDS model of inclined coal handling bridge

Minimum flaming core which causes stopping of belts was found by iteration method. This size depends on parameters of a specific used coal. In this case the minimum flaming core is 40 x 40 x 30 cm. The focus of these dimensions stops the belt after driving of 40m.
During the study two different approaches were analyzed: a model of bridge with inclined construction and ranked grid as stairs (approach A) and a model of bridge with horizontal construction and horizontal cells of grid with inclined vector of gravitational forces (approach B). The final model leading to probable results (approach A) was compiled from a total of 35

computational grids of two sizes of cells. Basic cell size was 6 x 6 x 6 cm, cell size on continuous parts of the bridge was 12 x 24 x 12 cm. The total number of computational grid cells reached 1,8 mil.

### 3.2 Fire development

Based on the above findings, the fire outbreak is placed at 40 m from the beginning of the bridge. After 20 s of moving on the belt, the temperature of 80°C is detected and belt is stopped. Diagram of relative air flow shows fast movement of the flaming core inside the bridge, then stopping of the belts is proved, see Fig. 4. After stabilization of air flow equilibrium the fire starts to burn up and the flow rate gradually increases. From development of rate of heat release shown at Fig. 5, it is obvious that burning the fire up starts after 2 min. The fire spreads upward, in the direction of air flow. Till the 7th min the fire involves only one belt of the bridge. Then it starts to spread to its width - to the second belt. Because of lack of oxygen in upper part of the bridge flames start to spread in the down direction after 7 min.

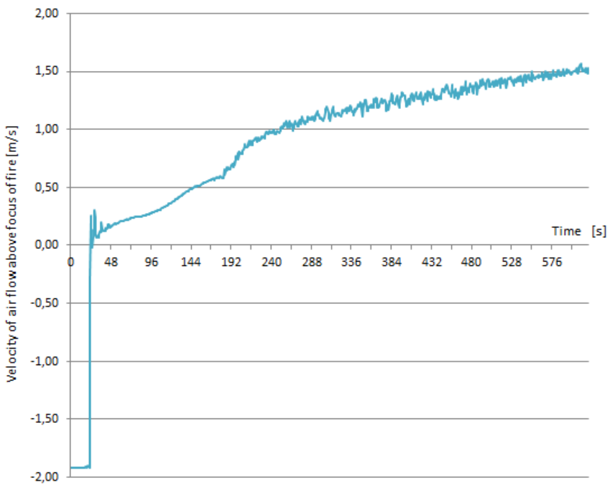


Fig. 4 Air flow above the fire outbreak

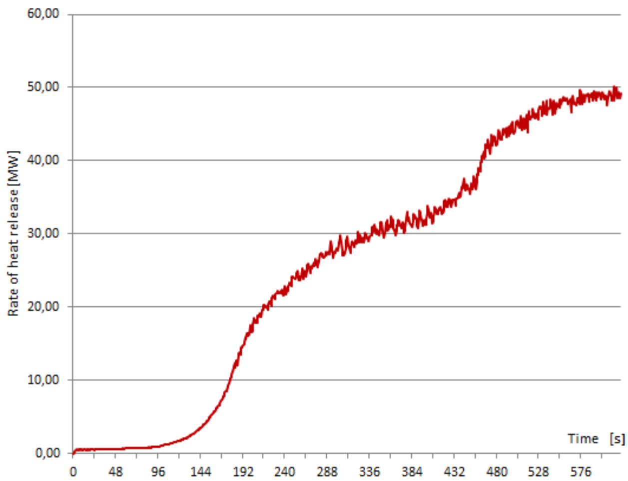


Fig. 5 Rate of heat release

The gas temperature measured below the ceiling, fluctuates significantly. Development of gas temperature in several locations in longitudinal direction of the bridge, below and above the place of ignition is calculated. The trend of the transfer of warm air along the air flow direction is evident. The highest gas temperatures occur between 40 m and 70 m from the beginning of the bridge (450 -950 °C). Maximum temperature of the structure which forms the ceiling reaches more than 800 °C in the most affected part. However the highest temperatures occur only at small areas for short intervals of time. Average temperatures of members of ceiling construction are less than 300 °C.

## 4 INTEROPERABILITY ALGORITHM

The solution of interoperability interactive algorithm is based on an analysis of fire-fighters intervention of fire scenarios. The necessary fire precautions, however, varies according to the fire scenario:

- Detection of elevated temperature in the area of rollers (scenario A) does not start any extinguishing sequence and requires immediate control of coal handling operation by fire-fighters. Until the belts stop, there is sufficient time for the fire survey.
- When a fire on belt is detected (scenario B) automatic extinguishing is started within 2 min from the announcement of a fire to prevent the risk of ignition of a conveyor belt.

- Before the activation of automatic extinguishing the fire-fighters intervention is expected. Within 1 min after fire alarm head of the fire intervention decides. To carry out a comprehensive survey of the conveyor bridge time of 10 min is required. Therefore, the delay of automatic extinguishing for management of fire intervention is allowed to the head of the intervention by technically interactive form, but no longer than 10 min from the fire alarm announcement.
- In order to prevent the spread of fire and prevent rupture of a conveyor belt, fire-fighting must be started manually immediately after the confirmation of a fire by fire-fighters, at latest 7 min after alarm.
- Elimination of risk of breakage of conveyor belt, which is critical for both fire scenarios, can be ensured by excluding stopping of belts. In practice it is still considered to be the only method to prevent the breakage.
- Delay of automatic extinguishing is made by mechanism of interactive algorithm that allows changing of fire safety operations in accordance with the current development of a fire.

Fig. 6 shows 3 phases of the interoperability. The phase 1 describes a situation when the fire-fighters intervention is not realised. The phase 2 shows a fire safety process when the intervention is carried out. In case the fire is not confirmed or cancelled during fire-fighters intervention, the process follows algorithm described in phase 3.

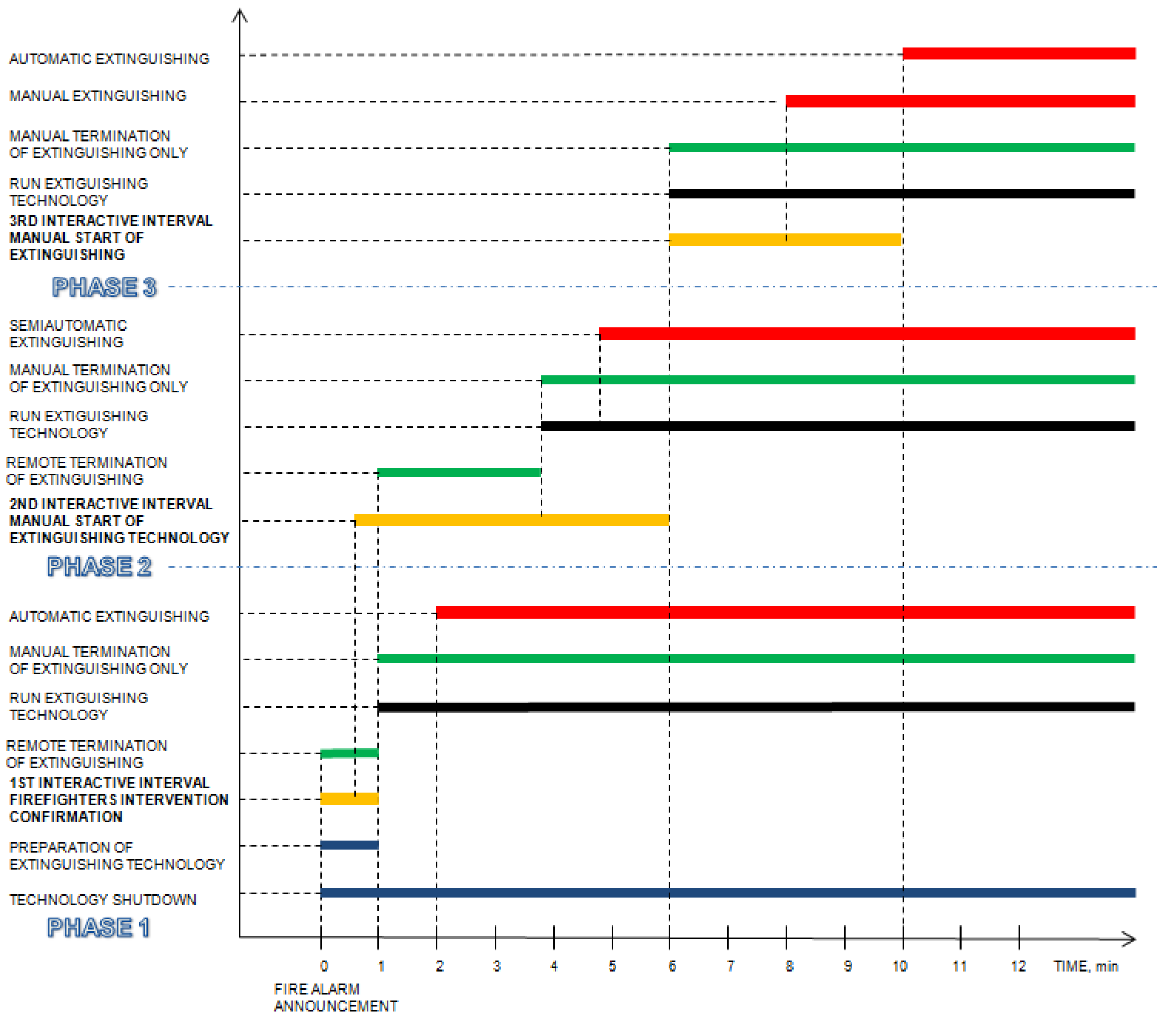


Fig. 6 Interoperability interactive algorithm

## 5 SUMMARY AND ACKNOWLEDGMENT

Based on the requirements for the interaction of fire safety equipment and fire-rescue units new interactive algorithm was developed. This algorithm has been successfully operated since 2010 in power plant Tušimice II. Number of tests was performed to confirm its functionality. The algorithm has been further improved and has already been installed on another power plant Tisová.

Numerical simulation proved that the evolution of the fire is based on flammability of coal and rubber conveyer belts. Brown coal burned in the power plant is less flammable compared to the material of belts. In case the coal is ignited, fire development is very slow and due to the high speed of conveyors transporting the coal it is unlikely probable that the fire occurs on the coal handling bridge. The development of the fire, therefore, depends on the ignition of the conveyor belt, because the fire will spread rapidly at the moment of ignition of a rubber belt. Analysis of all forms of design fire scenarios and CFD models proved that rubber-textile conveyor belts are critical site of fire safety on coal handling bridge. To avoid the risk of fire, regardless its place of origin it is therefore necessary to use a self-extinguishing (fire and flame resistant) conveyor belts.

Analysis of the main design fire scenario in FDS which shows probable fire development confirmed the applicability of the algorithm. By calculation of gas temperature and average temperature of the structure at the most affected part of the bridge in 10 min (time needed for fire-fighters intervention), it is proved that upper construction of the bridge should in the worst case of fire survive only with local damages.

Work on the research presented in this paper is supported by project grant LD11039 and SGS12/122/OHK1/2T/11.

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